Estimating Returns to Education Using a New Sample of UK Twins*

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Abstract

We use a new sample of UK female identical twins to estimate economic returns to education. We use identical twins to control for family effects and ability bias (due to genes) and the education reported by the other twin to control for schooling measurement error. We also investigate the within-twin pair and within family correlations with observable correlates of ability. Our estimates suggest a return to schooling for females of about 7.7%.

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1. Introduction

A particularly robust correlation in economics is that more educated people have higher earnings. Does this mean that a randomly selected person who invests in more education will earn higher wages? If the earnings/schooling relation is causal the answer is yes: education raises productivity and higher productivity raises wages. If the relation is spurious then no: more able people (better ability, family background) are more productive and get a higher wage, but such people acquire more education to signal their high ability. It is therefore not clear whether a simple relation between earnings and education can be interpreted as a return to education for a randomly selected person. To make such an interpretation, one must convincingly control for factors such as ability and family background that might both affect the choice of education and the wage.

The present paper attempts to do this by using a new data set of identical UK twins.[1] We administered a questionnaire to around 6,600 individuals (3,300 female-female twin pairs) in June 1999, all of whom are on the St. Thomas' UK Adult Twin Registry, based at the Twins Research and Genetic Epidemiology Unit, St. Thomas' Hospital, London, England. As well as the detailed medical information on the questionnaire, which covers sex, age, childbearing etc. we asked the twins additional socio-economic questions on earnings, occupation and schooling. We also asked each twin to report on the schooling of the other. At time of writing we have available data on 1,698 identical twins, of whom 428 comprise 214 identical twin pairs with complete wage and schooling information.

We believe our study is of interest for four main reasons. First, identical twins have the great advantage, relative to other siblings, of being genetically identical.[2] Given the recent prominence of the argument that genetics determines economic success (see e.g. Herrnstein and Murray's, 1994, *The Bell Curve*) twins data are an obvious test. Second, there are comparatively few earnings/education studies based on identical twins.[3] Thus we add to this literature. Third, our study is the first for the UK to present within-twin pair[4] estimates using identical twins. Blanchflower and Elias (1999) used a sample of 23 identical twin pairs from the UK National Child Development Study, but there was insufficient variation of education within each twin pair in their small sample to perform any within pair regressions. Fourth, we

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[1] Other methods attempt to measure ability and background, using for example IQ tests and detailed data sets (e.g. Deardon, 1999), or to find an instrument, e.g. such as the raising of the school leaving age, proximity to college, or birth quarter, that is correlated with schooling but uncorrelated with earnings (see e.g. Harmon and Walker, 1998, Angrist and Krueger, 1991, Card, 1993). See Card (1999) for a survey.

[2] See e.g. Ashenfelter and Zimmerman (1997) for a study based on brothers and father - son pairs.

[3] The other economic studies are: for the US on the Twinsburg sample (Ashenfelter and Krueger, 1994, Ashenfelter and Rouse, 1998, Rouse, 1999), the NAS study (Taubman, 1976) and the Minnesota studies (Berhman et al, 1999), and for Sweden (Issacson, 1999) and Australia (Miller et al, 1995).

have followed Ashenfelter and Krueger's (1994) innovation of asking one twin to report on the schooling of the other, in order to examine possible measurement error.

There are of course a number of potential problems with our work. First, Bound and Solon (1999) and Neumark (1999), building on earlier work by Griliches (1979), have criticised within-twin pair estimates. They argue that whilst within pair differencing removes genetic variation, differences might still reflect ability bias to the extent that ability is affected by more than just genes. To examine this, we follow Ashenfelter and Rouse (1998). We calculate the correlation of average family education and average family characteristics that might plausibly be correlated with ability or discount rates (e.g. birthweight, partner's occupation and smoking). This gives an indication of the expected ability bias in the pooled regression as such correlations are typically very high. We than calculate the correlation of within pair differences in education with within pair differences in characteristics. We find no significant correlation. Thus we expect that the ability bias from pooled regressions is likely to be higher than that from within pair regressions.

Second, our sample of twins might be regarded as selected for a number of reasons. First, they chose to respond to questionnaires. We therefore compare our sample with the LFS and find that in fact the samples are fairly similar and argue that the selection problem is not too severe. Second, to have wage information we restrict our sample to working women. We hope to develop sample selection corrections in future work. Third, in order to implement our correction for reporting error, we rely on data with complete information by each twin. We are as yet uncertain about how much selection effect this might induce.

The plan of this paper is as follows. In the next section we set out some simple theory. In section 3 we describe the data and first results. Section 4 describes our plans for future work.

2. Method

Following Bound and Solon (1999), consider the following choice of schooling model. The wage of twin *i* in family *f* is determined by

$$\log w_{if} = \beta S_{if} + A_{if} + \varepsilon_{if} \qquad i = 1,2;\ f = 1 \ldots F \qquad \textbf{(1)}$$

where S_{if} is schooling and A_{if} is ability, broadly defined, i.e. all the other effects on wages outside those of schooling (intelligence, motivation, access to educational funds etc.) and ε_{if} is

[4] We use the term "within-twin pair", or "within pair" to describe estimates using differences between twins of the same pair. These are variously referred to in the literature as between-twins estimates, within-family estimates, first-difference estimates or within-twins estimates.

an iid error (capturing measurement error in wages say).[5] The central problem is that A_{if} is typically poorly measured and hence the usual estimate of (1) omits it (or includes some correlates that may not measure it fully). This gives rise to the standard omitted variable bias result that the estimated β from (1) excluding A_{if} is given by

$$\hat{\beta}_{OLS} = \beta + \frac{\text{cov}(S_{if} A_{if})}{\text{var}(S_{if})} \quad \textbf{(2)}$$

which simply says that if schooling and ability are positively correlated then β_{OLS} is upward biased. Assume now we can write A_{if} as

$$A_{if} = \alpha_f + g_{if} + u_{if} \quad \textbf{(3)}$$

where A_{if} is due to family effects (e.g. access to funds) denoted as α_f, genetic effects (e.g. the part of intelligence due to genes), denoted g_{if} and the rest is captured by u_{if} , which includes luck, optimisation error etc. Then earnings are given by

$$\log w_{if} = \beta S_{if} + \alpha_f + g_{if} + v_{if} \quad \textbf{(4)}$$

where v_{if} is a composite error term. Consider now the wage equations for twins 1 and 2 in family f

$$\begin{aligned} \log w_{1f} &= \beta S_{1f} + \alpha_f + g_{1f} + v_{1f} \\ \log w_{2f} &= \beta S_{2f} + \alpha_f + g_{2f} + v_{2f} \end{aligned} \quad \textbf{(5)}$$

A within-twin pair estimator is of the form

$$\log w_{1f} - \log w_{2f} = \beta(S_{1f} - S_{2f}) + (g_{1f} - g_{2f}) + (v_{1f} - v_{2f}) \quad \textbf{(6)}$$

where the family effect α_f has been differenced out. Furthermore, if the twins are identical then g_{1f} - g_{2f} = 0 and so the genetic effect can also be differenced out. Thus the basic idea of the within-twin pair method is that returns to education can be estimated controlling for the part of

[5] i takes the numbers 1 and 2. We have one set of triplets on our data which we dropped.

ability due to family background and genetic factors. This method is exactly what we implement below.

There are two issues that arise. First, Rouse (1999) estimates that 10% of variation in schooling is due to measurement error. Since measurement error in schooling will be exacerbated by the differencing, estimates of (6) will be downward biased due to the attenuation bias arising from measurement error (Griliches, 1979, Neumark, 1999). We therefore follow Ashenfelter and Krueger (1994) in instrumenting the reported schooling differences with reported differences based on reports from the other twin.[6]

The second question is what causes the differences in schooling between identical twins? Ashenfelter and Rouse (1998), Bound and Solon (1999) and Neumark (1999, following earlier arguments due to Griliches, 1979) debate this at length in recent papers. As Bound and Solon (1999) point out, conventional OLS ability bias depends on the fraction of variance in schooling that is accounted for by variance in unobserved abilities that might also affect wages. Similarly, within pair ability bias depends on the fraction of within pair variance in schooling that is accounted for by within pair variance in unobserved abilities that also affect wages. Thus the within pair bias will be smaller if the endogenous variation within families is smaller than the endogenous variation between families. Bound and Solon (1999) argue that there is no reason to suppose this is the case.

Ultimately the matter is of course an empirical one. Ashenfelter and Rouse (1998) present evidence that differences in schooling within-twin pairs are uncorrelated with birth order and a range of characteristics such as union status, self-employment, tenure and spouse's education. They therefore argue that within pair education differences are primarily due to random factors (luck, optimisation error) and not ability. But, they find significant correlations between average levels of family education and characteristics. To the extent that these correlations capture differences in ability they therefore argue that most of the variation in ability is between families and not between twins within a family. We present some similar investigations below and find similar results to Ashenfelter and Rouse (1998). If this is right, then the twins estimates have less ability bias than the conventional estimates, if in addition, more able people will go to school longer and earn higher wages (so ability biases are positive) the twins estimates have tightened the upper bound to the returns to education.

[6] Ashenfelter and Rouse (1998) and Rouse (1999) experiment with a number of different instrumentation methods using combinations of own and other twins reporting. Here we instrument using the report of one twin on the education of another. Other instrument configurations gave similar magnitudes to those reported below.

3. Data and Preliminary results

a. Data set

The Twins Research Unit, St. Thomas' Hospital, London, has built up a list of around 4,500 pairs (mainly female) of identical and non-identical twins. The data we have used in this paper is derived from a mailing list to about 6,600 individuals. They are mailed questionnaires on mostly medical information (including birth weight, birth order, gestation period) plus socio-economic questions on sex, age, presence of children, age of mother etc. We added more detailed socio-economic questions to the most recent questionnaire which went out in June 1999. We asked the twins to report their qualifications, their twin's qualifications, the age they finished full-time education, their occupation, their spouse's occupation, their employment status, earnings and household income (see Data Appendix for more details). We should note that response rates are very high (above 80%) on these questionnaires, kept up by remailing and telephoning non-respondents.

Full details of our various measures are set out in the data appendix. To calculate wages we asked twins to report normal earnings before taxes and deductions and then asked whether this was hourly, daily, weekly, monthly or yearly. We also asked how many hours were usually worked (excluding meals and paid overtime). From these questions we converted the wage data into an hourly rate. To measure schooling, we asked each twin to report their qualification and their twin's qualification. Qualifications were split into 12 groups (e.g. University, A levels, 5+ O levels, 1-4 O levels etc. see data appendix). We then assigned years of education to each qualification.[7]

How does our data compare with Blanchflower and Elias (1999) (the only other UK twins study we are aware of)? They identify 267 (individual) twins from the National Child Development Study (a panel study of all UK births between 3rd-9th March 1958). This is a potentially very rich data set since it contains detailed information about, for example, test scores. There are however two difficulties with the study. First, due to high twin infant mortality and subsequent panel attrition, only 59 pairs have complete wage and education information and, of these, 23 pairs are classified as identical twins (see their figures 1 and 2). They therefore have too little variance among their 23 identical pairs to estimate within pair equations. Second, the twins were identified as identical at birth, but ..."from the documentation we have available to us we are unclear how such designations were made in practice" (their footnote 6). The usual method at birth is to see if there were one or two placenta present and identify identicals as coming from one placenta. Unfortunately recent research indicates that as

[7] This measure of education is referred to as estimated years of schooling.

much as one third of identicals can come from double placentas (Bryan, 1992). Thus it seems likely that their sample of identicals is identified with substantial error.[8]

b. Descriptive statistics and comparisons with other work

Table 1 sets out the numbers of twins currently available. We have 1,698 individual twins, all of whom are women. These consist of 1,480 individuals who are one of identical twins and 420 individuals who are one of fraternal twins (the greater number of identicals is due to our processing their data first since that is our primary focus). Due to use of postal questionnaires, we do not necessarily have replies from both members of a twin pair. Of the identicals therefore we have 621 complete pairs i.e. 1242 individuals. Of these, 214 pairs (428 individuals) provided complete wage information.

How does our sample compare with other twins data sets? Table 2 sets out some comparable details. Looking at sample size, our sample is between the usable data in the Ashenfelter and Krueger (1994) and Ashenfelter and Rouse (1998) studies. Our study is somewhat special as we only have data on female twins. Most of the other studies have both male and female twin pairs, although they do not attempt to estimate wage equations separately for men and women. Our sample size is less than Taubman (1976), Behrman and Rosenweig (1999) Miller et al (1995) and Isacsson (1999). However Taubman (1976) had no measurement error correction and Behrman and Rosenzweig (1999) and Miller et al (1995) had no direct wage information. Miller et al (1995) impute earnings from two-digit occupations and Behrman and Rosenzweig (1999) impute earnings for non-working women.

An important innovation of the Ashenfelter and Krueger (1994) study is to ask each twin his/her own and the other twin's education. If self-reported education is measured with error this provides a potential instrument since the report of the other twin should be correlated with the self-reported education level but uncorrelated with the equation regressand. This strategy was adopted in the subsequent Twinsburg studies, the Miller et al (1995) study and ours. Isacsson (1999) uses the comparison of reported education and registry information to control for measurement error.

The rest of the table reports the estimated returns to education. The table sets out the results from pooled OLS (treating twins as independent observations), pooled IV (instrumenting for measurement error in schooling in the pooled regression), within-twin pair OLS and within-twin pair IV. With the exception of Ashenfelter and Krueger (1994), all studies find that pooled OLS estimates are higher than within pair OLS estimates.[9] The lower magnitude of within pair

[8] Note in passing they also find the sample of identicals have no significant within-twin pair differences for maths and reading scores, see their Table 8.

[9] Rouse (1999) shows that the increase of the returns from OLS to first difference estimation in Ashenfelter and Krueger (1994) was due to sampling error.

OLS can be caused by ability bias and the increased effect of measurement error. From the studies reviewed here there is no clear evidence whether the ability bias or the bias due to measurement error dominates.[10]

Table 3 sets out some descriptive statistics for our data along with comparative data from the Labour Force Survey as a check on the representativeness of our sample. Table 3 contains two measures of schooling, reported and estimated years. Reported years are derived from reported age when finished full-time education and estimated years are based on imputed years to obtain highest qualification (see data appendix). In our regressions we use estimated years. Regressions with reported years gave similar magnitude but were less precisely determined (likely due to recall error). We tried different imputations for estimated years and found similar results. Column 1 shows data from the 1999 LFS for all women and all women who report a wage. Looking at all women, on average they have 12.1 years of schooling, are aged 39 and 59.5% are married. Column 3 sets out data for all our twins. They have 12.6 years of schooling, are aged 44.0 and 64.6% are married. So our twins are slightly more educated and slightly older, but our data do not seem to be too far from the average for women. Column 4 shows the data for our working twins, who earn, on average, £10.07 per hour, have worked in the present job for 11.5 years and 57.5% are part time. Comparing this to column 2, which shows the LFS data for working women, wages and tenure are slightly lower. These lower LFS figures presumably reflect the somewhat more educated twins sample. The rest of the table sets out data on our sample of identicals and non-identicals; there are no particular differences across the samples.

Table 3 shows that our twins are older and better educated on average. This is not surprising as the twins volunteer to join the register so there is some selection into the sample. Table 4 shows the age distribution of the working identical pairs and the working females from the LFS. We have 428 working identical twins, of whom 0% are 16-19. The comparable LFS figure for this age group is 3%. As the table shows our twins over-represent the age groups 40-49 and 50-59.

It might be felt therefore that the higher wages, education and tenure in our twins sample reflect the fact that the are, on average, older. Table 5 therefore presents descriptive statistics for the 40-59 year olds and the 16-39 year olds separately. There are three main points to note. First, even 40-59 year old twins are better educated and more highly paid than the LFS sample. Thus the higher wage and education level of our twin sample is not just a composition effect. Second, younger twins appear to earn more than older twins. Note however that there are many fewer part timers among younger twins and differences in hourly wage rates might

[10] All studies that compare estimates for identical and fraternal twins find that the ability bias is larger for identical than for fraternal twins.

reflect this (we control for part-time status below). Third, it is of interest to note that for the younger group their reported years of schooling and estimated years of schooling are closer on average than for the older group for both the twins and the LFS. Looking at the twins, for the older group their reported years of schooling is 12.7 and the estimated years of schooling is 13.8. For the younger group the figures are 14.1 and 14.7 years respectively. This could be because the estimated years of schooling is a more reliable estimate for the young group, as it is based on time taken to complete each qualification now, or that the younger group recall better when they left school.

c. Estimation Results

Table 6 sets out our estimation results. In column 1, we set out a simple regression using all working women from the LFS, entering schooling, age and age^2. The return to education is quite precisely estimated at 7.8%. The rest of the columns show data for the twins. Column 2 is a simple OLS pooled regression of (5) using all identicals for whom we have complete wage information, comprising of 428 individuals. This gives a return to education of 7.7%, similar to the LFS pooled figure. Deardon's (1998) equivalent results on the NCDS are about 12.2% (see her table 4.3, column 1, no control for ability or family background). Column 3 maintains a pooled specification, but instruments education with reported level of the other twin. This should control for measurement error in reported education which would bias down the returns estimate. As column 3 shows, returns rise to 8.5% when this is done.

Column 4 estimates the within pair equation (6). Figure 1 illustrates data in this case. The cluster around zero is due to the fact that 55% of the twin pairs have the same education years. Since the pooled estimates do not control for ability bias we would expect the within pair estimates to be less.[11] As column 4 of Table 6 shows, the return is indeed less, at 3.9%, but is poorly determined. This figure might however reflect downward bias due to measurement error and to check this column 5 instruments reported schooling. As expected the point estimate rises to 7.7%, with a standard error of 0.033. Comparison of the IV and the first difference IV estimates therefore provide an estimate of the magnitude of ability bias as both control for measurement error.

The right hand panel of the table repeats the exercise controlling for marriage, current job tenure and part-time status. Interestingly, the pattern of estimates on the regressors is exactly the same. The pooled OLS estimates (7.2%) are lower than the pooled IV estimates (7.9%) that control for measurement error. The within pair estimate (3.8%) is less than the

[11] If the variation within-twin pairs is uncorrelated with ability, or if there is more between family ability bias than within-family bias.

pooled estimate, whilst the within pair estimate controlling for measurement error (7.9%) is more than the simple within pair estimate.

Thus we can conclude the following. First, ability bias does appear to bias the pooled estimates upwards. Second, measurement error does appear to bias all estimates downwards especially in the case of the within estimate as expected. Third, female returns to education appear to be about 7.7%. Fourth, Deardon (1998) obtains returns of 8.3% after controlling for ability and family background (see her Table 4.3, column 4). Thus our results are similar to hers.

As mentioned above, a key question is why identical twins acquire different schooling. If it is merely due to luck, optimisation error and the like, then such differences are random and uncorrelated with potential unobservable differences that might drive wages. The Bound and Solon (1999) criticism of the twins results is that within pair differences in schooling are correlated with within pair differences in ability. We do not of course observe ability but, as Ashenfelter and Rouse (1998) point out, we do observe a number of other observable characteristics of the twins, such as, marriage, self-employment, part-time incidence, spousal occupation, spousal tenure and birthweight. Thus we can calculate whether within pair differences in schooling are correlated with within pair differences in these characteristics. We can also construct the average family measures of education and average family measures of these characteristics and calculate their correlation. To the extent that such characteristics are correlated with ability then a significant correlation of the average family measures with average family education suggests that ability significantly differs across families. A significant correlation of the within pair measures with the within pair schooling differences would also suggest that ability differences are correlated with within pair educational differences. If however there were no significant correlation then this suggests the educational differences are not being driven by ability differences, which would mean our within pair estimates are unbiased.

A strength of our data is that we have information on the smoking behaviour of the twins at the age of 16 and 18. Smoking has been suggested as an instrument for education, since it might proxy discount rates (Fuchs, 1982). This was criticised by Hamermesh (1999) who suggests it is a measure of family background. A correlation analysis of average family smoking with average family education and within pair differences of smoking with education can shed some light on the above views.

Table 7 shows the results of this exercise. Consider the first column, first row. This shows that families with low average birthweight have low average schooling. This is consistent with ability and family background affecting schooling choice since low birth weight is typically correlated with poor maternal health and low subsequent child IQ. The second column shows an insignificant correlation between differences in education within-twin pairs and differences in birthweight within-twin pairs. This shows that education differences are random with respect to birthweight differences, or at least that within-twin pair education differences are less affected by birth weight than between family education differences.

The rest of the first column shows the cross-family correlations based on average family characteristics. This shows strong correlations between average family education and average family marriage status, self-employment part-time status, partner's tenure and partner's occupation. The second column shows the correlations between within pair differences in education and within pair differences in characteristics. None of them are significant. In sum, within pair education differences are uncorrelated with any other within-twin difference in observables. To the extent these measure ability this suggests that within pair education differences are not due to within pair ability differences. At the very least, it suggests that the between family differences in education are more affected by ability bias than the within pair education differences, which means that the within pair estimator is less likely to be affected by ability bias than OLS estimates. Of course, these characteristics are incomplete measures of ability, but the evidence is suggestive, especially as it mirrors that found by the Ashenfelter and Rouse (1998).

The two final rows show the smoking results. The significant negative correlation between family smoking and family education is consistent with either view - smoking reflecting discount rates or family background - since it could indicate high family discount rates and/or family background effects. There is however no significant correlation between within-twin pair smoking and within-twin pair education suggesting that smoking is more likely to reflect family background than discount rates. Therefore we do not use smoking as an instrument for educational differences between twins of the same pair.

How are the returns to education estimates affected by possible selection bias? First, if returns to education are linear in schooling and do not differ between ability groups, then having a sample, say of highly schooled individuals, should not matter. If the returns are non-linear, then since we have a slightly above average education group, our pooled estimates would understate average marginal returns if, for example, highly educated groups had lower marginal returns.[12] Second, we are not so much concerned here with whether the average characteristics of the group are non-representative, but whether differences in education within twin pairs are non-representative of differences in education in general. There are three reasons why this might be so. First, both twins need to respond to the questionnaire, second, both twins have to

[12] The higher marginal returns in IV studies are often attributed to high marginal returns for a low educated group whose behaviour is frequently the source of variation of the instrument (Card, 1999).

be working and third, both twins need to report their wages and other variables to have complete information. It is not clear which way the biases go.

4. The returns to qualifications

The above results assume the marginal return to education is constant. In this section we relax this assumption and allow for heterogeneity in the returns to education by estimating returns to qualifications.[13] Using the average time it takes to obtain a given qualification it is possible to calculate annual returns to qualifications. These annual returns to qualifications can be compared to the 'overall' return to education found in the previous section. This gives an indication whether returns to education are heterogeneous. It is of course also possible to compare rates of returns for different qualifications.

To estimate returns to qualifications two basic specifications are possible. We can estimate the return to the highest qualification an individual obtained (for an example see Isacsson, 1999) or we can split qualifications into two groups: qualifications obtained at school and post-school qualifications (see Dearden, 1999). We follow Dearden and estimate an equation of the form

$$\log w_{if} = Q^S{}_{if}\beta^S + Q^P{}_{if}\beta^P + \eta_{if} \qquad \textbf{(7)}$$

where Q^S is a vector of dummy variables for qualifications obtained at school (the reference category being no qualifications obtained at school). Q^P is a vector of dummy variables for post-school qualifications (the reference category being no post-school qualifications).[14] With our available qualification our wage equation is

$$\begin{aligned}\log w_{if} = {} & \beta_1^S(<5Olevels)_{if} + \beta_2^S(>5Olevels)_{if} + \beta_3^S(Alevels)_{if} + \\ & \beta_1^P(low\ voc)_{if} + \beta_2^P(middle\ voc)_{if} + \beta_3^P(high\ voc) + \\ & \beta_4^P(degree)_{if} + \eta_{if}\end{aligned} \qquad \textbf{(8)}$$

Given estimates for β^S and β^P and assumptions on the length of obtaining a qualification we can calculate annual rates of return. For example, to calculate the annual rate of return to A-

[13] We use the term 'returns to education' to refer to the returns to each additional year of schooling in a specification like equation (1) and the term 'returns to qualification' for returns to specific qualifications like in equation (8).
[14] For details of classifying qualifications see Data Appendix.

Levels, assuming that it takes two years to obtain A-Levels, we calculate the difference between the coefficient on A-Levels and on 5-plus O-Levels divided by two: $r = \frac{\beta_3^S - \beta_2^S}{2}$.

Table 8 shows the number of twins by qualifications. Whilst we have a fair spread of qualifications, we do not have sufficient pairs in each qualification group to estimate within pair equations with much confidence. We therefore present pooled estimates, recalling that Table 6 suggested pooled estimates return roughly an unbiased estimate. Given the limited number of observations we have for identical working pairs we also include estimates for all working identical twins (pairs and singletons).

Table 9 shows the OLS estimation results for equation (8) using all working identical twins (left panel) and working identical pairs (right panel). The results for A-Levels and degree are quite well determined, but the coefficients of the other qualifications are less precise. To read the table consider the coefficients of 0.113 for 5-plus O-Levels and 0.319 for A-Levels in column 1. The difference between them gives the return to continuing to A-Levels from O-Levels, i.e. 20.6 percent. This translates into an annual rate of return of 10.3 percent. Now consider the significant coefficient on degree of 0.211. This gives the return to a degree relative to not having any post-school qualification. In practice this then is relative to obtaining A-Levels and not proceeding to a degree. Assuming that it takes three years to complete a degree, this gives an annual return of 7.03 percent. This specification can be compared to Dearden's results (see Dearden, 1999, Table 4.2). Generally our estimated returns are lower than Dearden's findings. This is very pronounced for post-school qualifications.

Including other covariates (columns 2 & 4) increases the coefficients of the school qualification dummies. However the difference between the coefficient of A-Levels and 5-plus O-Levels is reduced and gives a reduced estimate of the annual rate of return to A-Levels of 9.6 percent. The coefficients of post school qualifications are also reduced and the annual rate of return for a degree is estimated as 5.37 percent.

5. Conclusions

We have used a new sample of UK twins to estimate returns to education using the within-twin pair method allowing for measurement error. Our findings as follows.

(a) Our twin estimates confirm the theoretical prediction that measurement error biases estimated returns to education up and omitting ability biases estimates down. These effects roughly cancel each other out.

(b) We find no evidence that ability bias affects our within-twin pair estimator by more than the between family estimator. Thus we expect ability biases to be less for within pair estimators than for estimators not controlling for ability.

(c) Current results indicate a return to years of schooling for women of about 7.7%.

(d) We find some evidence of heterogeneous returns, with an annual return to 1-4 O levels, A-levels and degrees of about 12%, 10% and 6% respectively.

Table 1
Sample statistics
(numbers of individuals, unless specified)

Total number of twins in sample (all working age females)	**1,698**
Monozygotic (Identical) twins	
Number	1,480
Number who are a pair	1,242 (621 pairs)
Number who are a pair and have wage information	428 (214 pairs)
Number of singletons	238
Dizygotic (Fraternal) twins	
Number	420
Number who are a pair	218 (109 pairs)
Number who are a pair and have wage information	76 (38 pairs)
Number of singletons	202

Table 2
Identical twin studies: Comparison

Study	Sample Size (individuals) MZ[b)]	DZ[c)]	Gender	Log earnings Measures	Measurement Error	Estimates[a)] Pooled OLS	Pooled IV	Within pair OLS	Within pair IV
Taubman (1976)	2,038	902	m	Annual	-	0.079	-	0.027	-
Ashenfelter/Krueger (1994)	298		m & f (Dummy)	Hourly	other twin's report	0.084	0.116	0.092	0.167
Ashenfelter/Rouse (1998)	680		m & f (Dummy)	Hourly	other twin's report	0.110	0.091	0.070	0.088
Rouse (1999)	906		m & f (Dummy)	Hourly	other twin's report	0.105	-	0.075	0.110
Behrman/Rosen-zweig (1999)	1,440		m & f (Dummy)	Annual imputed for non-working women	other twin's report	-	0.118	-	0.105
Miller, Mulvey & Martin (1995)	1,204	1,136	m & f (Dummy)	Annual imputed from occupation	other twin's report	0.064	0.073	0.025	0.083[d)]
Isacsson (1999)	4,984	6,736	m & f (separate estimates)	Three year average annual	Administrative vs. reported education	0.046	-	0.022	0.042
Bonjour et al (2000)	428	76	f	Hourly	other twin's report	0.077	0.085	0.039	0.077

Notes: [a)] Reported coefficient of schooling corresponding to the simplest specification, i.e. with only age, age squared and female dummy in some cases. [b)] MZ: Monozygotic (identical) twins. [c)] DZ: Dizygotic (fraternal) twins. [d)] 0.048 when correlated measurement error is assumed.

Table 3
Descriptive statistics

	LFS 1999		All Twins		Identical Twins		Fraternal Twins		Identical Twin Pairs	
	All (1)	**Working (2)**	**All (3)**	**Working (4)**	**All (5)**	**Working (6)**	**All (7)**	**Working (8)**	**All (9)**	**Both Work (10)**
Reported Years of Schooling [a)]	12.1 [2.37]	12.3 [2.39]	12.6 [2.88]	12.9 [2.93]	12.6 [2.89]	13.0 [2.92]	12.6 [2.86]	12.8 [2.96]	12.6 [2.89]	13.2 [3.04]
Estimated Years of Schooling [b)]	12.5 [2.32]	12.9 [2.35]	13.4 [2.51]	13.8 [2.47]	13.5 [2.52]	13.9 [2.48]	13.3 [2.44]	13.5 [2.42]	13.5 [2.54]	14.1 [2.50]
Age	38.9 [11.08]	38.6 [10.72]	44.0 [10.37]	42.6 [10.12]	44.3 [10.40]	42.7 [10.15]	43.2 [10.30]	42.5 [10.07]	44.8 [10.3]	42.5 [10.0]
Married (%)	59.5	60.3	64.6	61.5	65.1	61.4	63.0	61.7	65.3	61.3
White (%)	94.9	96.6	98.0	98.3	98.3	98.4	97.0	97.9	98.6	98.3
Non Participation (%)	29.0	0	17.3	0	18.2	0	13.9	0	18.6	0
Hourly Wage Rate		7.09 [4.37]		10.07 (11.23)		10.17 [10.36]		9.77 [13.58]		10.03 [9.12]
Tenure		6.9 [6.84]		11.5 [9.51]		11.7 [9.64]		10.7 [9.08]		11.9 [9.15]
Full Time (%)		58.5		57.5		58.2		55.4		60.8
Self Employed (%)		4.8		5.4		5.1		6.2		4.9
Sample Size (Individuals)	7729	4226	1698	504	1364	748	420	244	1242	428

Notes: Standard deviations in parentheses; [a)] Based on age when finished fulltime education minus five; [b)] Based on highest qualification (see data appendix);

Table 4
Comparing age distribution of working females

AGE GROUP	TWINS [a)]		LFS [b)]	
	Numbers	Percentage	Numbers	Percentage
16-19	0	0	119	3
20-29	60	14	862	20
30-39	88	20	1295	31
40-49	152	36	1097	26
50-59	128	30	853	20
Total	428	100	4226	100

Notes: [a)] Based on the sample of working identical twin pairs counted as individuals. [b)] Based on working females in the Labour Force Survey 1999.

Table 5
Descriptive Statistics By Age

	TWINS [a)]		LFS [b)]	
40 - 59	MEAN	SD	MEAN	SD
Reported Years of Schooling [c)]	12.7	(3.02)	11.8	(2.33)
Estimated Years of School [d)]	13.8	(2.55)	12.6	(2.37)
Age	48.8	(4.84)	48.4	(5.37)
Married (%)	74.9		77.6	
White (%)	98.2		97.4	
Hourly Wage Rate	9.72	(9.34)	7.28	(4.51)
Tenure	14.3	(9.72)	9.3	(7.81)
Full Time (%)	54.8		53.5	
Sample Size	280		1950	
16 - 39				
Reported Years of Schooling	14.1	(2.87)	12.7	(2.35)
Estimated Years of School	14.7	(2.29)	13.2	(2.29)
Age	30.5	(5.31)	30.2	(5.93)
Married (%)	51.0		51.7	
White (%)	98.6		95.8	
Hourly Wage Rate	10.62	(8.71)	6.92	(4.23)
Tenure	7.3	(5.68)	4.9	(5.03)
Full Time (%)	72.1		62.9	
Sample Size	148		2276	

Notes: [a)] Based on the sample of working identical twin pairs counted as individuals. [b)] Based on working females in the Labour Force Survey 1999. [c)] Based on age when finished full-time education minus five. [d)] Based on highest qualification (see data appendix).

Table 6
OLS IV and Fixed Effects Estimates of the Return to Education for Identical Twins

	LFS	Twins							
		Without Other Covariates				Controlling for Other Covariates			
	Pooled	Pooled		Within pair		Pooled		Within pair	
	OLS	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Education	0.078 (0.002)**	0.077 (0.011)**	0.085 (0.012)**	0.039 (0.023)	0.077 (0.033)*	0.072 (0.011)**	0.079 (0.012)**	0.038 (0.024)	0.079 (0.036)*
Age	0.058 (0.004)**	0.078 (0.021)**	0.077 (0.021)**			0.058 (0.024)*	0.057 (0.024)*		
Age^2 (÷100)	-0.001 (0.000)**	-0.097 (0.027)**	-0.095 (0.027)**			-0.081 (0.029)**	-0.079 (0.029)**		
Married						-0.007 (0.059)	-0.007 (0.059)	-0.051 (0.091)	-0.045 (0.092)
Tenure (Years)						0.012 (0.003)**	0.012 (0.003)**	-0.002 (0.006)	0.000 (0.006)
Part Time						-0.097 (0.064)	-0.093 (0.065)	-0.110 (0.097)	-0.114 (0.097)
Observations	4398	428	428	214	214	374	374	187	187
R-squared	0.31	0.15	0.15	0.01	0.0009	0.21	0.21	0.02	0.009

Notes: Standard errors in parentheses. Columns 1,2,3 and 6,7 include a constant (not reported), the other columns exclude a constant. For the IV estimates twin 1's education is instrumented by twin 2's report of twin 1's education and vice versa. Within-twins IV estimates the difference in education is the difference within each twin 1 and twin 2's self-reported education instrumented by the difference within-twin 2's report of twin 1's education and twin 1's report of twin 2's education. The stars indicate the following significance levels: * 5%, ** 1%.

Table 7
Between family and within family twin pair correlation

Correlation of average family education with average family characteristics		Correlation of within-twins differences in education with within-twins difference in other characteristics	
	Education		Δ Education
Birthweight	0.2153***	Δ Birthweight	-0.0765
Married	-0.1279***	Δ Married	-0.031
Self Employed	-0.0876*	Δ Self Employed	-0.03
Part Time	-0.2067***	Δ Part Time	0.0379
Partner's Tenure	-0.2124***	Δ Partner's Tenure	-0.0093
Partner's Occupation	0.4908***	Δ Partner's Occupation	0.0305
Smoking at 16	-0.2680***	Δ Smoking at 16	-0.0241
Smoking at 18	-0.2699***	Δ Smoking at 18	-0.0541

Note: stars indicate the following significance levels: * 10%, ** 5%, *** 1%.

Table 8

Highest Qualifications – Both School and Post School

(all identicals)

Qualification	Number of Individuals (Pairs and Singletons)	Number of Individuals (Pairs Only)
School Qualifications:		
No School Qualifications	159	84
O Levels 1-4	149	82
O Levels 5+	188	101
A Levels	252	161
Total with school qualifications	748	428
Post-school Qualifications:		
No Post School Qualifications	127	72
Low Vocational	194	99
Middle Vocational	84	46
Higher Vocational	150	87
Degree	193	124
Total with post school qualifications	748	428

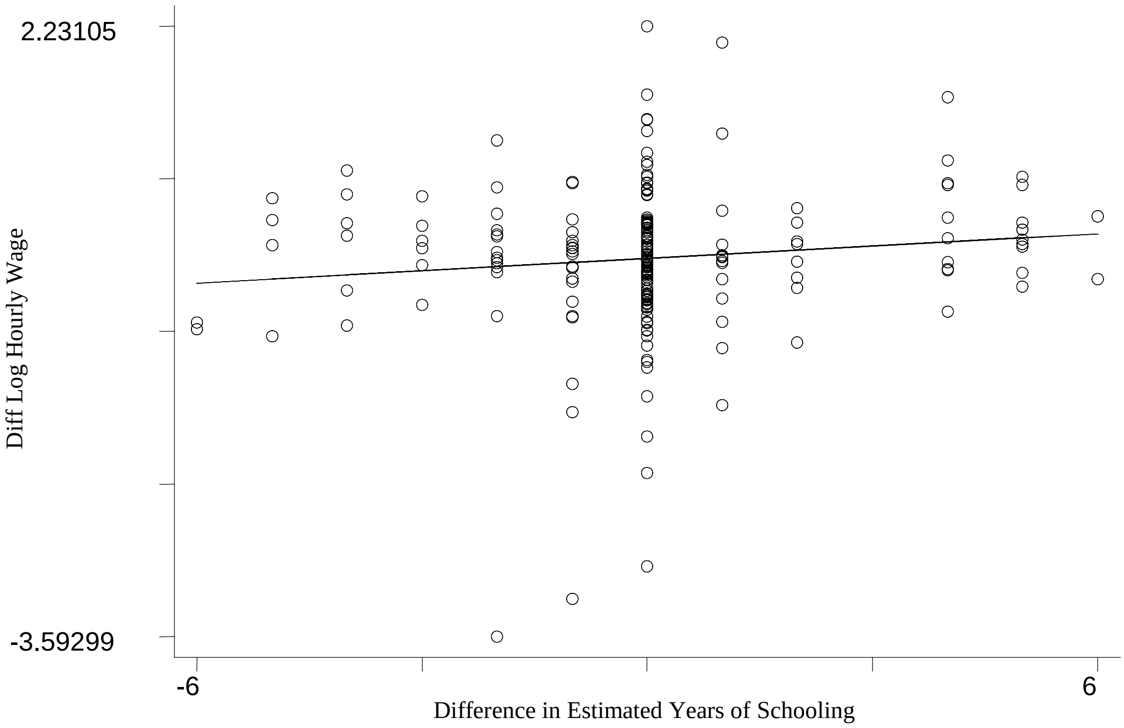
Note: Column 1 shows individual identical twin data for reported qualifications. Column 2 shows those for whom we have data on the twin and her sister.

Table 9
Returns to Qualifications (OLS)
(Dependent variable is log earnings)

	WORKING IDENTICALS ALL		**WORKING IDENTICALS PAIRS**	
	(1)	(2)	(3)	(4)
Constant	0.618	0.740	0.317	0.716
	(0.333)	(0.349)*	(0.421)	(0.451)
Highest School				
O-Levels 1-4	0.186	0.240	0.257	0.310
	(0.064)**	(0.063)**	(0.084)**	(0.085)**
O-Levels 5+	0.113	0.135	0.139	0.169
	(0.062)	(0.062)*	(0.083)	(0.084)*
A-Levels	0.319	0.327	0.412	0.435
	(0.068)**	(0.068)**	(0.087)**	(0.089)**
Highest Post-School				
Low Vocational	-0.035	-0.050	-0.109	-0.142
	(0.063)	(0.064)	(0.082)	(0.085)
Middle Vocational	0.106	0.091	0.136	0.083
	(0.079)	(0.079)	(0.102)	(0.103)
Higher Vocational	0.130	0.097	0.096	0.039
	(0.069)	(0.068)	(0.087)	(0.089)
Degree	0.211	0.161	0.169	0.097
	(0.072)**	(0.072)*	(0.088)	(0.091)
Age				
Age	0.059	0.055	0.077	0.058
	(0.017)**	(0.018)**	(0.021)**	(0.023)**
Age Squared	-0.001	-0.001	-0.001	-0.001
	(0.000)**	(0.000)**	(0.000)**	(0.000)**
Other Covariates				
Married		-0.006		-0.008
		(0.046)		(0.058)
Tenure		0.011		0.010
		(0.002)**		(0.003)**
Part Time		-0.158		-0.124
		(0.047)**		(0.061)*
Observations	748	687	428	399
R-squared	0.11	0.17	0.18	0.23

Notes: Standard errors in parentheses. * significant at 5% level; ** significant at 1% level

Figure 1
Differences in log hourly earnings against differences in schooling
(schooling based on highest qualifications)



References

Angrist, J. and Krueger, A., (1991), "Does compulsory School Attendance Affect Schooling and Earnings", Quarterly Journal of Economics, 106, pp. 979-1014

Ashenfelter, O. and Krueger, A., (1994), "Estimating the Returns to Schooling Using a New Sample of Twins", American Economic Review, 84, pp. 1157-1173.

Ashenfelter, O and Rouse, C, (1998), "Income, Schooling and Ability: Evidence from a New Sample of Identical Twins", Quarterly Journal of Economics, Feb 1998, pp. 253-284.

Ashenfelter, O. and Rouse, C., (1999), "Schooling, Intelligence and Income in America: Cracks in the Bell Curve", NBER Working Paper 6902.

Ashenfelter, O. and Zimmerman, D., (1997), "Estimates of the Returns to Schooling from Sibling Data: Fathers, Sons, and Brothers", Review of Economics and Statistics, 79, pp. 1-9.

Behrman J. and Rosenzweig, M., (1999), "“Ability” Biases in Schooling Returns and Twins: A Test and New Estimates ", Economics of Education Review, 18, pp. 159-167.

Behrman J., Rosenzweig, M., and Taubman, P, (1994), "Endowments and the Allocation of Schooling in the Family and in the Marriage Market: The Twins Experiment", Journal of Political Economy, 102, 6, pp. 1131-1174.

Blanchflower, D., and Elias, P., (1999) "Ability, Schooling and Earnings: Are Twins Different?" unpublished manuscript.

Bound J., and Solon, G., (1999), "Double Trouble: On the Value of Twins-Based Estimation of the Return to Schooling", Economics of Education Review, 18, pp. 169-182.

Bryan, E., (1992) "Twins and Higher Multiple Births - A Guide to their Nature and Nurture", London/Melbourne/Auckland: Edward Arnold.

Card, D., (1995), "Using Geographic Variation in College Proximity to Estimate the Return to Schooling", in L. Christofides, E. Grant, and R. Swidinsky, editors, Aspects of Labour Market Behaviour: Essays in Honour of John Vanderkamp, University of Toronto Press, Toronto: pp. 201-222.

Card, D, (1999), "The Causal Effect of Education on Earnings", in O. Ashenfelter and D. Card, editors, Handbook of Labor Economics, Elsevier Science B.V.

Deardon, L., (1998), “Ability, Families, Education and Earnings in the UK”, IFS working paper No. W98/14.

Dearden, L., (1999), "Qualifications and Earnings in Britain: how reliable are conventional OLS estimates of the returns to education?", IFS working paper No. W99/7.

Fuchs, V.R. (1986), "Schooling and Health: The Cigarette Connection", Journal of Health Economics, 1, pp 217-30.

Griliches, Z., (1979), "Sibling Models and Data in Economics: Beginnings of a Survey", Journal of Political Economy, 87, pp. S37-S65.

Hamermesh, D (1999) "The Art of Labormetrics", NBER Working Paper 6927.

Harmon, C., and Walker, I., (1995), "Estimates of the Economic Return to Schooling for the United Kingdom", American Economic Review, 85, pp.1278-1286.

Herrnstein, R., and Murray, C., (1994), The Bell Curve, New York: Free Press.

Isacsson, G. (1999), Essays on the Twins Approach in Empirical Labor Economics, Swedish Institute for Social Research, Stockholm.

Miller, P., Mulvey, C., and Martin, N., (1995), "What do Twins Studies Reveal About the Economic Returns to Education? A Comparison of Australian and U.S. Findings", American Economic Review, 85, pp. 586-599.

Neumark, D., (1999), "Biases in Twin Estimates of the Return to Schooling", Economics of Education Review, 18, pp.143-148.

Rouse, C., (1999), "Further Estimates of the Economic Return to Schooling from a New Sample of Twins", Economics of Education Review, 18, pp.149-157.

Taubman, P., (1976), "Earnings, Education, Genetics, and Environment", Journal of Human Resources, 11, pp. 447-461.

DATA APPENDIX

The identification of the twins as identical or fraternal is generated at the Twins Unit using a set of standardised questions. In addition these results are compared, where possible, to DNA data held at the Unit.

If both twins are present in the sample they are recorded as a pair, if only one twin is present they are recorded as a singleton.

Reported Years of Schooling are found by subtracting five years from the age reported for finishing full-time education. This does not account for pre-school or adult education. For example someone who reports that they left school at 17 will have 17 - 5 = 12 reported years of schooling.

Estimated Years of Schooling are based on the highest qualification reported. The qualifications were ranked and assigned the number of years necessary to achieve the qualification as follows (in descending order). In addition the LFS data were matched into our qualifications groups as below.

Twins Groupings	Years Allocated	LFS Grouping
University	17	Higher Degree NVQ Level 5 First Degree Other Degree
Higher Vocational	16	NVQ Level 4 Diploma in Higher Education HNC/HND, BTEC Higher etc RSA Higher Diploma Other Higher Education Below Degree Level
Teaching	16	Teaching – Further Education Teaching – Secondary Teaching – Primary Teaching – Level Not Stated
Nursing	15	Nursing etc
A-Level	14	A-Level or Equivalent SCE Higher or Equivalent AS Level or Equivalent Scottish 6th Year Certificate (CSYS)
Middle Vocational	12	NVQ Level 3 GNVQ Advanced RSA Advanced Diploma OND/ONC, BTEC/SCOTVEC National City and Guilds Advanced Craft
O-Level	12	O Level, GCSE Grade A-C or Equivalent CSE Below Grade 1, GCSE Below Grade C

Low Vocational	11	Trade Apprenticeship NVQ Level 2 GNVQ Intermediate RSA Diploma City and Guilds Craft BTEC/SCOTVEC First or General Diploma
Clerical	11	
Other	11	NVQ Level 1 GNVQ/GSVQ Foundation Level BTEC/SCOTVEC First or General Certificate SCOTVEC Modules RSA Other City and Guilds Other YT/YTP Certificate Other Qualifications
No Qualifications	10	No Qualifications Don't Know

Married is a dummy variable equalling 1 for married women and 0 otherwise.

White is a dummy variable equalling 1 for white women and 0 otherwise.

Non participation is a dummy variable equalling 1 for women reporting "Not working, not actively seeking work" in the questionnaire and 0 otherwise.

Hourly Earnings were calculated as follows for those working:

(1) For those reporting hourly earnings these were taken as given.

(2) For those reporting daily earnings, a working day of eight hours was assumed. Hourly earnings therefore were found to be reported daily earnings multiplied by reported weekly hours divided by eight. This was then all divided by reported weekly hours. This calculation can cause some problems for part-time workers. However, only ten twins in the whole sample and two twins in the sample of working twin pairs reported daily wages.

(3) For those reporting weekly earnings, hourly earnings were found by dividing reported weekly earnings by reported weekly hours.

(4) For those reporting monthly earnings, a working month of four weeks was assumed. Hourly earnings therefore were found to be reported monthly earnings divided by four all divided by reported weekly hours.

(5) For those reporting annual earnings, a working year of fifty-two weeks was assumed (full time staff are generally have paid during vacations). Hourly earnings therefore were found to be reported annual earning divided by fifty two all divided by reported weekly earnings.

Tenure is the years spent in present occupation.

Full-time is a dummy equalling 1 for women reporting "Working in a job, full-time" and 0 otherwise.

Self-employed is a dummy variable equalling 1 for women reporting "Working as self-employed" and 0 otherwise.

Partner's Occupation is an index variable ranking from 1 to 8 with the following categories: plant and machine operatives, sales occupations, personal and protective services, crafts and related occupations, clerical and secretarial occupations, associate professional occupations, professional occupations.

Partner's tenure is partner's years spent in present occupation.

Returns to Qualifications – the approach taken for the returns to qualifications follows Dearden (1999) very closely. Dearden considers the highest qualification achieved both in school and further education. Our twins highest qualification groups were transformed as shown below to match with Dearden groupings (ranked as represented here in descending order for each sub category).

Dearden's Grouping	Twins Groupings
School Qualifications:	
A Levels	A-Levels
5+ O Levels	O-Levels 5+
O Levels	O-Levels 1-4
None	None of the above school qualifications
Post-school Qualifications:	
Degree	University
Higher Vocational	Higher Vocational Teaching Nursing
Middle Vocational	Middle Vocational
Lower Vocational	Low Vocational Clerical Other
None	None of the above post school qualifications