Returns to Education: Evidence from UK Twins

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Nontechnical Summary

Returns to Education: Evidence from UK Twins

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? Two opposing interpretations have been proposed:

a) *That the relation is causal*: education raises productivity and higher productivity raises wages.
b) *That the relation is spurious*: more able people (higher ability, more favourable family background) are more productive and get a higher wage, but such people acquire more education to signal their high ability and/or because it is easier for them.

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. If the second interpretation is (partially) true and if there is no control for ability and family background estimations would (overstated) find positive returns to education. This situation is referred to as ability bias in the literature.

The present paper attempts to control for ability and family background to avoid ability bias by using a new data set of identical UK twins. We administered a questionnaire to around 6,600 individuals (3,300 same-sex 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.

Identical twins have the great advantage, relative to other siblings, of being genetically identical and growing up in the same environment. Only a very small number of twins on the Twin Registry have been raised apart. Thus, they provide an ideal test for the two hypotheses. We control for ability and family background by applying so called within-twin pair estimator. This is a method where the returns to education are estimated by comparing the difference in the education of the twins in a pair with the difference in their earnings. If the correlation between education and earnings observed in cross-sectional data is causal then we should find that on average the twin with higher qualifications also has a higher wage. The coefficient describing this relationship measures the returns to education. However, if the correlation is spurious then there should be no correlation between the difference in education of twins in a pair and the difference in their earnings. Our study is the first in the UK to apply such methods to identical twins.

The within-twin pair estimation has been criticised. It has been argued that whilst within-pair differencing removes genetic variation and family background, there might be other differences between the twins that are unobservable to the researcher and that affect both the schooling decision and wages. We conducted tests to investigate this criticism.

We present a number of key results. Firstly, our twin estimates suggest a private return to education for women of 7.7 per cent.

Second, we find no evidence that ability bias affects our within-twin pair estimator by more than cross-sectional estimation. Thus we expect ability biases to be less for within pair estimators than for estimators not controlling for ability. Therefore our estimates at least tighten the upper bound for the returns to education.

Third, the paper contains a contribution regarding the use of smoking as an instrumental variable for education as has been suggested in the literature. It is argued that smoking reflects personal discount rates which also affect the educational decision. Using information on reading scores and smoking behaviour available in our data we find that smoking is more likely to reflect family background than discount rates. Therefore we conclude that smoking behaviour should not be used as an instrument for education as it is likely to exacerbate ability bias.

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1. Introduction

This paper attempts to estimate returns to education using a new data set of identical UK twins.[1] We administered a questionnaire to around 6,600 individuals (3,300 same-sex 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 age, birth-weight, smoking *etc.*, we asked the twins additional socio-economic questions on: earnings, occupation and schooling; test scores; and the schooling of the other twin. This paper reports results 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 five main reasons. First, given the interest in genetics and economic success (see *e.g.* Herrnstein and Murray, 1994) data on genetically identical individuals are of particular value.[2] Second, there are comparatively few earnings/education studies based on identical twins (we are aware of seven).[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 twin pairs from the UK National Child Development Study, but there was insufficient variation of education within each twin pair to perform any within-pair regressions. Fourth, we 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. Fifth, our study has more data on twins than other studies including test scores, reading scores and smoking behaviour.

The major criticism of within-twin pair estimates is set out by Bound and Solon (1999) and Neumark (1999), building on earlier work by Griliches (1979). 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

[1] Other returns to education methods that attempt to control for ability and background, use, for example IQ tests and detailed family background data sets (*e.g.* Dearden, 1999), or 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, 1995; Angrist and Krueger, 1991; Card, 1995). 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, the Twinsburg sample (Ashenfelter and Krueger, 1994; Ashenfelter and Rouse, 1998; Rouse, 1999), the NAS study (Taubman, 1976) and the Minnesota studies (Behrman *et al*, 1999), for Sweden (Issacson, 1999) and for Australia (Miller *et al*, 1995).

[4] We follow the medical literature and 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 economics literature as between-twins estimates, within-family estimates, first-difference estimates or within-twins estimates.

follow and extend Ashenfelter and Rouse (1998). We calculate the correlation of average family education with those average family characteristics that might plausibly be correlated with ability or discount rates (*e.g.* birthweight, partner's characteristics and smoking). This indicates expected ability bias in a pooled regression. We then calculate the correlation of within-twin pair differences in education with within-twin pair differences in characteristics. This indicates expected ability bias in a within-twin pair regression. Using a range of variables, we find significant correlations in the pooled case, but no significant correlation in the within pair case. This suggests that ability bias in pooled regressions is likely to be higher than that using within pair regressions.

A new contribution of this paper is that we have data on twins' exam and reading scores. Like the other characteristics, we find no correlation between differences in these scores within-twin pairs and differences in their education. Finally, we also have data on smoking at 16 and 18 and we also investigate whether smoking is a valid instrument for education. We find that smoking seems to be correlated with family background rather than reflecting individual discount rates and it is unlikely to be a valid education instrument.[5]

The plan of the rest of this paper is as follows. In the next section we set out some simple theory. In Section 3 we describe the data and in Section 4 the results. Section 5 contains concluding remarks.

2. Method

Following Bound and Solon (1999), suppose the wage of twins 1 and 2 in family f is determined by

$$\begin{aligned} \log w_{1f} &= b S_{1f} + A_{1f} + e_{1f} \\ \log w_{2f} &= b S_{2f} + A_{2f} + e_{2f} \end{aligned} \qquad \textbf{(1)}$$

where S_{if} (i=1,2) is schooling, 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 e_{if}

[5] We also discuss selection issues. Conventional estimates of female earnings equation focus a good deal on selection, but the issue for within pair estimates is whether selection affects not the sample level of education in but education differences.

is an iid error.[6] Since A_{if} is typically poorly measured the usual estimate of (1) omits it (or includes some correlates that may not measure it fully) and estimates (1) pooling across individuals, returning an estimate of β we denote β_{POOL}. This gives rise to the standard omitted variable bias result from excluding A_{if}

$$\hat{b}_{POOL} = b + \frac{\operatorname{cov}(S_{if}, A_{if})}{\operatorname{var}(S_{if})} \quad \textbf{(2)}$$

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

$$A_{if} = a_f + g_{if} + a_{if} \quad \textbf{(3)}$$

where A_{if} is composed of family effects (*e.g.* access to funds) denoted as a_f, genetic effects (*e.g.* the part of intelligence due to genes), denoted g_{if} and the rest is captured by a_{if}, which includes luck, optimisation error etc. Then the equations of twins 1 and 2 in family f are given by

$$\begin{aligned} \log w_{1f} &= b S_{1f} + a_f + g_{1f} + a_{1f} + e_{1f} \\ \log w_{2f} &= b S_{2f} + a_f + g_{2f} + a_{2f} + e_{2f} \end{aligned} \quad \textbf{(4)}$$

A within-twin pair estimator for identical twins is based on differences within families of (5)

$$\log w_{1f} - \log w_{2f} = b\,(S_{1f} - S_{2f}) + (a_{1f} - a_{2f}) + (e_{1f} - e_{2f}) \quad \textbf{(5)}$$

where the family effect a_f and genetic effect g_{if} has been differenced out. Thus the basic idea of the within-twin pair method is to estimate returns to education controlling for the part of ability due to family background and genetic factors. The bias in this case is given by

$$\hat{b}_{WTP} = b + \frac{\operatorname{cov}(S_{1f} - S_{2f}, a_{1f} - a_{2f})}{\operatorname{var}(S_{1f} - S_{2f})} \quad \textbf{(6)}$$

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

There are two issues that arise. First, Rouse (1999) estimates that 10 per cent 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.[7]

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 (2) shows, 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, as (6) shows, 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 if the endogenous variation within families is smaller than the endogenous variation between families, then β_{WTP} is less biased than β_{POOL}. Hence even if there is ability bias in within-twin pair regressions β_{WTP} might still be regarded as an upper bound on the returns to education (if schooling and ability are positively correlated). However, Bound and Solon (1999) argue there is no *a priori* reason to believe that β_{WTP} is less biased than β_{POOL}.

Ultimately the matter is of course an empirical one. Its investigation is subject to the central problem that ability is not observed. Ashenfelter and Rouse (1998) therefore look at the correlation between schooling and potential correlates of ability (*e.g.* employment status, tenure and spouse's education). To investigate the covariance in (2) they examine the correlation between the average level of schooling and the average level of characteristics across different families. To investigate the covariance in (6) they examine the correlation between the difference in schooling and the differences in characteristics within families. They find the former is bigger than the latter and hence 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). We also extend their results by looking at twins exam performance and literacy test scores.

[7] 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.

Using the same framework we investigate the suggestion that smoking be used as an instrument for education, since it might proxy discount rates (Fuchs, 1982). Hamermesh (1999) suggested however that youth smoking is a measure of family background and thus not a valid instrument for education. We believe that our twins data allows us to shed some light on the smoking debate. Again, this is based on a comparison of correlations between and within families. A high correlation between family smoking behaviour and educational attainment is consistent with both views. However, significant within twin pair correlation is only consistent with the hypothesis that smoking reflects an individual's discount rate. Finding no within twin correlation provides indirect evidence for the family background view.

3. Data

a. Data set

The Twins Research Unit, St. Thomas' Hospital, London, has built up a list of (mainly female) 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 birthweight, 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 per cent) on these questionnaires, kept up by re-mailing 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.[8]

b. Descriptive statistics and comparisons with other work

We have 1,480 individual, identical twins, all of whom are women. 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.* 1,242 individuals. For 214 of these pairs (428 individuals) we have complete wage information on both twins in the pair. Thus our sample size is between the Ashenfelter and Krueger (1994, 298 individuals) and Ashenfelter and Rouse (1998, 680 individuals) and Rouse (1999, 906 individuals) 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, 2,038 individuals), Behrman and Rosenzweig (1999, 1,440 individuals), Miller *et al* (1995, 1,204 individuals) and Isacsson (1999, 4,984 individuals). However Taubman (1976) had no measurement error correction, Miller *et al* (1995) impute earnings from two-digit occupations and Behrman and Rosenzweig (1999) impute earnings for non-working women.

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 much as one third of identicals can come from double placentas

[8] See Data Appendix. We refer to this education measure as "estimated" years of schooling. In our regressions we use estimated years. We tried different imputations for estimated years and found similar results

(Bryan, 1992). Thus it seems likely that their sample of identicals is identified with substantial error.[9]

An important innovation of the Ashenfelter and Krueger (1994) study is to ask each twin his/her own and their cotwin'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.

Table 1 sets out some descriptive statistics for our data along with comparative data from the Labour Force Survey (LFS) as a check on the representativeness of our sample. Column 1 shows data from the 1999 LFS for all women and all women who report a wage. These women average 12.1 years of schooling, are aged 39 and 59.5 per cent are married. Column 3 sets out data for all identical twins. They have 12.6 years of schooling, are aged 44.3 and 65.1 per cent 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, £10.17 per hour, have worked in the present job for 11.7 years and 58.2 per cent 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 figures are very similar if we only consider twin pairs (columns 5 and 6).

4. Results

a. Returns to education

Table 2 sets out our estimates. Column 1 shows an OLS regression using all working women from the LFS, entering schooling, age and age squared. The return to education is quite precisely estimated at 7.8 per cent. The rest of the columns are estimates for twins. Column 2 is an OLS pooled regression of (1) using all identicals for whom we have complete wage

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Regressions with reported years gave similar coefficients but were less precisely determined (likely due to recall error).

information, 428 individuals, and schooling, age and age squared as regressors. This gives a return to education of 7.7 per cent, similar to figure in column 1. Dearden's (1998) equivalent results on the NCDS are about 12.2 per cent (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 per cent when this is done.

Column 4 estimates the within pair equation (5). Figure 1 illustrates data in this case. The cluster around zero is due to the fact that 55 per cent 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 returns estimates to be less.[10] As column 4 of Table 5 shows, the return is indeed less, at 3.9 per cent, but is poorly determined. This figure might however reflect downward bias due to exacerbated measurement error in the differenced equation. To check this column 5 instruments reported schooling. As expected the point estimate rises to 7.7 per cent, with a standard error of 0.033. Comparison of the pooled IV and the first difference IV estimates therefore provide an estimate of the magnitude of ability bias as both control for measurement error; comparing columns 3 and 5 suggests ability bias is positive.

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 per cent) are lower than the pooled IV estimates (7.9 per cent) that control for measurement error. The within pair estimate (3.8 per cent) is less than the pooled estimate, whilst the within pair estimate controlling for measurement error (7.9 per cent) is more than the simple within pair estimate.

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

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[9] 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.

b. Ability differences within twin pairs

To investigate ability biases within and between families Table 3 shows the results of the correlation analyses. Consider the first column, first row. This shows that the correlation between average family education and average family birthweight is 0.22 and is highly significant. It suggests that families with low average birthweight have low average schooling, consistent with ability and family background affecting schooling choice. The second column shows an insignificant correlation between differences in education within-twin pairs and differences in birthweight within-twin pairs. To the extent that birthweight measures ability therefore, between family differences in education are more affected by ability bias than the within pair education differences.

The rest of the first column shows other family correlations.. 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. 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).

For a sub-sample of twins we managed to collect more detailed data on characteristics that are also likely to be highly correlated with ability. For these twins we have their reading score on the National Adult Reading Test (NART) and whether the twins passed the 11+ exam (an exam taken at age 11). Before the introduction of comprehensive schools, the 11+ was universally applied across Britain as a means of selecting which secondary school to attend. If the pupil passed the 11+ (around 25 per cent of the population) this meant that they were selected to attend a Grammar school where education was largely academically based. If the pupil did not pass they were selected to attend a Secondary Modern school where education was more vocationally based. As a result this 11+ test result can be regarded as an early ability test. However, we only have data on 48 pairs (96 individuals) who reported the answer to this question in a short follow-up questionnaire we conducted. Of these 48 pairs only 3 pairs actually received a different result in the 11+ test. As shown in the lower panel

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

of Table 6, correlations between families and within twins show a pattern similar to upper panel.

In addition to this early ability measure an adult ability measure is also available for a subset of twins. The measure is the National Adult Reading Test (NART) which is based on the ability to read and correctly pronounce each word from a list of 25 words. Of course, being an adult reading test, the result may be affected by the schooling the respondent has received. However, Crawford *et al* (2001) compared NART results of 77 year olds with IQ tests taken when the same individuals were 11 and obtained a correlation of 0.69. We have NART test results for 108 identical twin pairs (the twins' scores had a correlation of 0.71). As shown in Table 3, the NART results confirm the same pattern as the other ability correlates: there is a high and significant correlation between average family NART and average family education but the corresponding correlation of within-twin differences is insignificant. This is additional evidence that educational differences within twin pairs are likely be less correlated with ability difference than across families.

c. Smoking as an instrument?

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) and subsequently been used by Evans and Montgomery (1994) for the US and Chevalier and Walker (1999) for the UK. This was criticised by Hamermesh (1999) who suggests that a youth's smoking behaviour is a measure of family background and thus not a valid instrument for education.

Evans and Montgomery (1994) show that smoking is highly correlated with educational outcomes and use it as an instrument in estimating returns to education. Their IV estimate of the returns to education lies about 10 per cent above the OLS estimate[11]. This would indicate negative ability bias, unlike twins studies where ability bias is small or positive. Evans and Montgomery present indirect evidence that the correlation of smoking and educational attainment is due to differences in time preferences. However, they acknowledge that there is no possibility to test this directly against the alternative hypothesis that the observed correlation is due to unobserved 'ability' in a very broad sense including genes, family and social background as well as peers.

[11] The difference is higher in their estimates for females only.

While not able to perform a direct test, our twin data allow us to give additional – and in our view more compelling – indirect evidence which relies on the correlation method in Table 3. A significant negative correlation between average family smoking and average family education is consistent with either smoking reflecting discount rates or family background. However, if smoking affects individual's discount rates differences in smoking within families should be correlated with differences in education. But the within pair correlation should be insignificant if the cross-sectional correlation between smoking and education is due to family background.

Table 4 shows the correlation results for smoking. There is a significant negative correlation between average family smoking and family education. However, there is no significant correlation between within-twin pair smoking and within-twin pair education. This suggest smoking is more likely to reflect family background than discount rates.

Furthermore, if the family background view is true and if ability bias is positive – as is the case for our data – then using smoking as an instrument is likely to exacerbate ability bias. Table 5 investigates this. Column 1 upper panel shows, for comparison, the pooled OLS results from column 2 of Table 3. The return of 0.077 compares closely with two smoking studies in the literature set out in the lower panel, Evans and Montgomery (1994, 0.079) and Chevalier and Walker (1999, 0.099). The second and third columns shows returns to education when using smoking at 16 and 18 as an instrument. The returns rise just as in the Chevalier/Walker and Evans/Montgomery studies (see lower panel), consistent with an exacerbation of positive ability bias. The final column investigates smoking at 18 and finds a similar effect. In sum, evidence seems to suggest that smoking reflects family background rather than discount rates. Thus the higher estimated returns in studies using smoking as an instrument are more likely caused by an augmentation of (positive) ability bias than the existence of negative ability bias.

d. Selection bias

How are the returns to education estimates affected by possible selection bias? There are several selection processes going on. Here we will focus on two: taking part in the study (volunteering to be on the data base and returning the specific questionnaire) and participating in the labour market. They might affect pooled estimations differently form within-twin pair estimations.

Consider first the effects on the pooled estimates. Selection into the study arises since twins have to volunteer to be on the database and return the questionnaire. Better educated twins seem more likely to do this as they are more likely to be in our sample (see Table 2). However, if returns to education are linear in schooling, then having a sample of highly schooled individuals should not matter. If returns are non-linear but characterised by diminishing marginal returns[12] then, since we have a slightly above average education group, our pooled estimates would understate average marginal returns. As in all studies that are concerned with wages there is the potential of selection bias due to the participation decision. As our sample consists of female twins selection issues of this kind do potentially affect our estimates. We therefore experimented with traditional Heckman-correction models (using children and husband's occupation in the selection equation) but found no evidence that selection affected our estimates significantly.

Our main estimates are however of within-twin pair differences. The key point with respect to selection is that we are not concerned 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. The two main selection issues discussed above could also affect the differences. First, both twins need to respond to the questionnaire, and second, both twins have to be working. It is not straightforward to show how these selection processes affect differences within-twin pairs and which way potential biases would go.

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 suggest a number of key results. Firstly, 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 indicating a private return to education for women of 7.7 per cent. Second, 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

[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).

less for within pair estimators than for estimators not controlling for ability. Therefore our estimates at least tighten the upper bound for the returns to education.

Third, we present evidence that smoking behaviour used in the literature as an instrument for education is more likely to reflect family background than the assumed discount rates. Therefore, smoking behaviour should not be used as an instrument for education as it is likely to exacerbate ability bias.

In future work we hope to be able to extend the data set to consider male twins and, with an increased sample size consider the issue of heterogeneous returns to education both with respect to different qualifications and to parental background.

Table 1

Descriptive Statistics

	LFS 1999		**Identical Twins**		**Identical Twin Pairs**	
	All (1)	**Working (2)**	**All (3)**	**Working (4)**	**All (5)**	**Both Work (6)**
Reported Years of Schooling [a)]	12.1 (2.37)	12.3 (2.39)	12.6 (2.89)	13.0 (2.92)	12.6 (2.89)	13.2 (3.04)
Estimated Years of Schooling [b)]	12.5 (2.32)	12.9 (2.35)	13.5 (2.52)	13.9 (2.48)	13.5 (2.54)	14.1 (2.50)
Age	38.9 (11.08)	38.6 (10.72)	44.3 (10.40)	42.7 (10.15)	44.8 (10.3)	42.5 (10.0)
Married (%)	59.5	60.3	65.1	61.4	65.3	61.3
White (%)	94.9	96.6	98.3	98.4	98.6	98.3
Non Participation (%)	29.0	0	18.2	0	18.6	0
Hourly Wage Rate		7.09 (4.37)		10.17 (10.36)		10.03 (9.12)
Tenure		6.9 (6.84)		11.7 (9.64)		11.9 (9.15)
Full Time (%)		58.5		58.2		60.8
Self Employed (%)		4.8		5.1		4.9
Sample Size (Individuals)	7729	4226	1364	748	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 2

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

(Estimates of 1-Pooled- or 5-Within Pair- Plus Other Regressors)

	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 per cent, ** 1 per cent.

Table 3

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
For reduced sample:			
Passing 11+	0.1095	Δ Passing 11+	-0.0556
Adult Reading Score [a)]	0.4933***	Δ Adult Reading Score	0.2111

Note: stars indicate the following significance levels: * 10 per cent, ** 5 per cent, *** 1 per cent. [a)] The reading score used is the National Adult Reading Test (NART).

Table 4

Between Family and Within Family Twin Pair Correlation of Education and Smoking

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
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 per cent, ** 5 per cent, *** 1 per cent.

Table 5

Smoking as an Instrument: OLS and IV Estimates of the Return to Education For Identical Twins (Pooled Estimates of 5, Dependent Variable Log Wages)

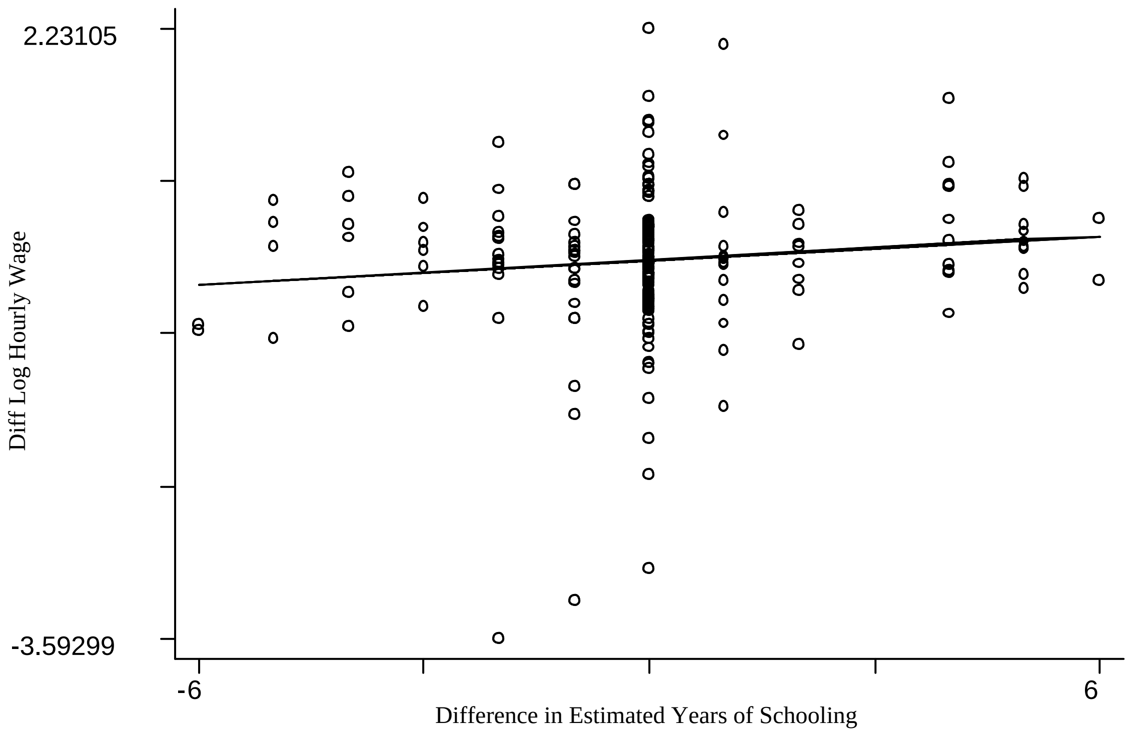
Instrument:		Smoking at 16	Smoking at 18
	OLS	IV	IV
Education	0.077 (0.011)**	0.110 (0.044)*	0.104 (0.045)*
Age	0.078 (0.021)**	0.074 (0.022)**	0.074 (0.022)**
Age^2 (÷100)	-0.097 (0.027)**	-0.089 (0.029)**	-0.091 (0.029)**
Smoking (1 yes, 0 no)			
Constant	-0.428 (0.435)	-0.873 (0.719)	-0.782 (0.719)
Observations	428	428	428
R-squared	0.15	0.13	0.14
Evans and Montgomery (1994) a)			
Education	0.079 (0.003)**		0.122 (0.030)**
Chevalier and Walker (1999) a)			
GHS: Education	0.099 (0.003)**	0.163 (0.011)**	

Note: stars indicate the following significance levels: * 5 per cent, ** 1 per cent. a) Results from Table 10. b) Results from Table 23 (General Household Survey, GHS). The age of smoking is not specified in their paper..

Figure 1

Differences in Log Hourly Earnings Against Differences in Schooling

(Schooling Based On Highest Qualifications)



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.

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