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Does More Schooling Improve Health Outcomes and Health Related Behaviors? Evidence from U.K. Twins

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Abstract

Several recent studies using instrumental variables based on changes in compulsory schoolleaving age laws have estimated the causal effect of schooling on health outcomes and health-related behaviors in the U.K. Despite using the same identification strategy and similar datasets, no consensus has been reached. We contribute to the literature by providing results for the U.K. using a different research design and a different dataset. Specifically, we estimate the effect of schooling on health outcomes (obesity and physical health) and health-related behaviors (smoking, alcohol consumption and exercise) for women through within-MZ twins estimates using the TwinsUK database. For physical health, alcohol consumption and exercise, the within-MZ twins estimates are uninformative about whether there is a causal effect. However, we find (1) that the significant association between schooling and smoking status is due to unobserved endowments that are correlated with schooling and smoking (2) there is some indication that more schooling reduces the body mass index for women, even once these unobserved endowments have been controlled for.

Keywords

Schooling; health; twins fixed-effects

1. Introduction

More-schooled individuals tend to have better health outcomes and health-related behaviors such as being less likely to smoke. There may exist a direct causal relationship from schooling to health via the influence of schooling on productive and allocative efficiency (Grossman 1972). The productivity hypothesis considers schooling to be an input in the health production function. In this model more-schooled individuals can produce more health from a given set of inputs. The allocative efficiency hypothesis states that schooling improves an individual's ability to make the best choice of inputs from which health is

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produced. Both the productive and allocative efficiency hypotheses provide theoretical foundations for a causal relationship between schooling and health, but they may have different policy implications. Support for the productive efficiency hypothesis implies increasing schooling while support for the allocative efficiency hypothesis might imply providing more information to less-schooled individuals about the prices and efficacies of various health inputs.

Although there are strong cross-sectional associations between more schooling and better health outcomes and health–related behaviors, there may not be a causal relationship for two reasons. First, the causality may be in the opposite direction in that persistent poor health may lead to low schooling attainment. For example, children born with low birth weight obtain less schooling and may be less healthy adults. Second, cross-sectional associations suffer from omitted variable bias due to unobserved family and individual endowments that affect both schooling and health-related behaviors or outcomes.

To study the possible causal link between schooling and health-related behaviors and outcomes, five recent studies have used the 1947 and 1972 United Kingdom schooling reforms, which increased the minimum school-leaving age from 14 to 15 and from 15 to 16 respectively, as an exogenous source of variation in schooling. These studies use data from the same source, mainly the General Household Survey or the Health Survey for England. Despite using the same research design and similar datasets, the results and consequent policy implications are differing and in some cases contradictory. For example, Silles (2009) concludes “this paper provides compelling evidence that there is a causal relation between education and health status” (Silles 2009, pg.127). Powdthavee (2010) in his study of the schooling effects on blood pressure and hypertension concludes “if an additional year of schooling can help reduce the incidence of hypertension among men by up to 10 percentage points, then the implications of a nationwide change in the minimum school-leaving age from 16 to 18, which is scheduled to take place in 2013, on the nation’s wellbeing may have been underestimated if one was simply to look at the market returns to education” (Powdthavee 2010, pg.197). In contrast, Clark and Royer (2010) summarize their results by “our estimates suggest that the health returns to education are small, at best” (Clark and Royer 2010, pg. 35).

We contribute to the literature by providing further evidence on the schooling-health gradient for in the U.K. using a different approach and dataset. Specifically, we estimate the effect of schooling on health outcomes (obesity and physical health) and health-related behaviors (smoking, alcohol consumption and exercise) for women through within-MZ twins estimates, which control for unobserved family and individual endowments at the twin-pair level, using data from the TwinsUK database. We describe the association between schooling and health-related behaviors and outcomes using cross-sectional OLS regressions and estimate the causal impact of schooling through within-MZ twins estimates or, equivalently MZ fixed-effects estimates. Our contribution rests on using within-MZ twins estimators, under the assumptions detailed below, to causally identify the schooling-health gradient, providing alternative evidence to the mixed instrumental variables (IV) estimates for the U.K. Within-MZ twins estimates may also be preferable to IV estimates based on changes in compulsory schooling laws, as changes in compulsory schooling yield local-average treatment (LATE) estimates indicating the effects around the change in the schooling affected by the compulsory schooling law, not for most changes in schooling. In contrast within-MZ twins differences may be across a wide range of schooling levels and thus are likely to be closer to the average treatment effect (ATE).[1]

[1]The previous U.K. estimates based on the 1947 reform may be close to ATE estimates as this reform affected large fractions of the relevant birth cohorts

The plan of the paper is as follows. We first describe the methodology, previous related studies and the data, and then turn to the estimates. For physical health, alcohol consumption and exercise, the within-MZ twins estimates are uninformative about whether there is a causal effect. However, we find (1) that the significant association between schooling and smoking status is due to unobserved endowments that are correlated with schooling and smoking (2) there is some indication that more schooling reduces the body mass index for women, even once these unobserved endowments have been controlled for.

2. Methodology

We are interested in simple reduced-form relations between schooling and health-related behaviors and outcomes. These capture the total or gross associations with and effects of schooling on health-related behaviors and outcomes. These relations do not identify the underlying structural channels through which schooling may be operating and, indeed, the data that we have do not permit the identification of those channels. But understanding better the gross associations with and effects of schooling on these health-related behaviors and outcomes is valuable in itself.

Consider the following linear representation of a reduced-form equation relating adult health-related behaviors or health outcomes H_{ij} for the ith member of paternal family j to his or her schooling S_{ij} and to three sets of unobserved variables representing (i) endowments h_j that are common among all children of the paternal family j (e.g., exogenous features of the paternal family environment in childhood, including prices, family permanent income, parents' human capital, average genetic endowments among children, local schooling and health-related options), (ii) the component of endowments or "innate health" that is specific to child i in j, represented by a_{ij} (e.g., individual-specific deviations from average family genetic endowments) and (iii) a random health shock that is specific to i in j, inclusive of measurement errors in health, represented by v_{ij}.[2]

$$H_{ij}=\beta_s S_{ij}+h_j+a_{ij}+v_{ij}, \quad (1)$$

The coefficient of interest is β_S which measures the effect of schooling. The general prior in the literature is that more schooling results in more healthy behaviors and outcomes so that $\beta_S > 0$, though it is possible to conceive of the opposite result if, for example, more schooling increases the probability of engaging in more stressful occupations that are deleterious to one’s health.

S_{ij} is itself a function of (usually in part unobserved) variables that pertain to the paternal family and to the individual children in the paternal family:[3]

$$S_{ij}=\alpha_h h_j+\alpha_a a_{ij}+\alpha_s a_{kj}+u_{ij}, \quad (2)$$

where α_h is the effect of the family-specific endowment h_j on child schooling investment, α_a is the effect of the individual-specific endowment a_{ij} of child i on schooling investment in that child, α_s is the effect of the individual-specific endowment a_{kj} of sib k (which is a vector if there are multiple siblings) on schooling investment in child i[4] and u_{ij} is a

[2]For simplicity we represent the endowments here as scalars, but they may be vectors with different elements that are not necessarily positively correlated. Some recent studies suggest that innate education and health components of endowments may be negatively correlated (Behrman et al. 2004).

[3]This formulation is consistent with standard models of intrahousehold allocation of investments in children (e.g., Becker and Tomes 1976, Becker 1991). Behrman et al. (1994) use a similar formulation with MZ and DZ twins to estimate whether such intrahousehold allocations reinforce or compensate for individual-specific endowment differentials among siblings (their estimates suggest reinforcement).

disturbance that affects S_{ij} but not H_{ij} except indirectly through S_{ij}. As is well-known from the parallel literature on labor market earnings (where H_{ij} would represent wages), β_S is not identified in equation (1) if α_a or α_h is not zero. That is, inconsistent estimates of β_S are obtained if equation (1) is estimated across individuals with different values of h_j or a_{ij}. Thus generally cross-sectional estimates of associations between schooling and health are biased estimates of the causal impact because schooling is partially proxying for genetic, family background and other endowments.

Within-MZ-Twin estimators

With no further assumptions, it is clear that β_S, is not identified even if sibling-pair data are used to control in the estimation of β_S for the covariant common components of the endowment and environment h_j. This is because of the specific endowment component a_{ij}. As long as families or individuals respond to individual-specific differences in endowments, and such differences are important, then sibling estimators may not be very useful.[5] To deal with this problem, MZ twins between whom there are as minimal as possible endowment differences at conception, can be used to identify β_S. Equations (1) and (2) can be rewritten for MZ twins:

$$H_{ij}{}^{M}=\beta_S S_{ij}{}^{M}+h_j{}^{M}+v_{ij}{}^{M} \quad (1A)$$

$$S_{ij}{}^{M}=\alpha_h h_j{}^{M}+u_{ij}{}^{M}, \quad (2A)$$

where the superscript M refers to MZ twins. Relations parallel to (1A) and (2A) can be written for the kth MZ twin in the jth family. Within-MZ-twin estimators are obtained by subtracting such relations from (1A) and (2A) for twin 1 and 2 in each twins pairs j. With a within-MZ-twin estimator or equivalently a MZ fixed-effects estimator (MZ-FE), all of the unobserved endowment components in (1A) and (2A) are swept out or controlled.

$$\Delta^{M}H_{ij}=\beta_S\Delta S_{ij}{}^{M}+\Delta v_{ij}{}^{M} \quad (3)$$

$$\Delta^{M}S_{ij}=\Delta u_{ij}{}^{M} \quad (4)$$

These MZ estimators can be used to identify the true reduced-form impact of schooling on health-related behaviors and health outcomes under the assumptions of this section for the own-health behavioral and outcome variables in the data that are introduced in Section 4. Comparisons may be made with estimates of relation (1) for the same health-related behaviors and outcomes to learn to what extent the estimates of the impact of schooling on health-related behaviors and outcomes β_S are biased in cross-sectional estimates because of the failure to control for unobserved endowments h_j and a_{ij} that affect health and are correlated with schooling.

Caveats Regarding Within-MZ-Twin Estimators

There are a number of caveats for the within-MZ twins estimator that may prevent identification of causal schooling effects.

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[4]In general endowments of all members of a sibship affect the investments in any member of the sibship. Within-twins estimates control for the endowments of all other siblings because the non-twin siblings are the same for each member of a twinship.
[5]Behrman et al. (1994, 1996) report evidence that the individual-specific endowments are significant and important in schooling-earning models estimated for the United States.

(1) Are within-MZ twin pair schooling differences exogenous?—The within-MZ twins estimates are identified by twin pairs that differ on schooling attainment. The key assumption for interpreting the estimates to reflect causality is that schooling differences between the twins are due to exogenous events that affect their schooling but not directly their health outcomes (but only indirectly through schooling). If schooling attainment differs between the twins due to such events as the random assignment of teachers (e.g., one twin's school teacher inspired her to obtain a Ph.D while the other twin had less inspiring teachers), then this assumption may be plausible. If the assumption does not hold, then the schooling coefficient in within-MZ-twins estimates is biased upwards (downwards) if u and v in relations (1) and (2) are positively (negatively) correlated.[6]

There could be a number of factors that lead to schooling differences and directly affect health. One of the earliest health differences between MZ twins are differences in birth weight, and recent studies have used the within-twins estimator to identify the effect of birth weight on schooling. Behrman and Rosenzweig (2004), Black et al. (2007), Royer (2009) have found that higher birth weight increases schooling. If diffrences in birth weight also directly improve health, then the within-MZ twins estimate will be upward biased. However, some studies (Bonjour et al. 2003, Miller et al. 2005 and Oreopoulos et al. 2006) have found no effect of birth weight on schooling. We have access to self-reported birth weight data and controlling for birth weight does not change our conclusions.

Given differences in innate endowments such as birth weight, parents may treat twins differently, which could be another source of bias. For example, parents may encourage the more able twin to stay in school and take better care of their health. Recent studies use birth weight differences between twins to proxy for differences in innate endowments, and investigate whether they are correlated with differences in parental treatment.[7] Almond and Currie (2011) using the Early Childhood Longitudinal Study Birth Cohort find no evidence that that parents are more likely to praise, caress, spank or otherwise treat twins differently. Royer (2009) using the same dataset focusing on investments soon after birth finds that breastfeeding and NICU admissions do not vary with within-twin pair birth weight differences. Rosenzweig and Zhang (2009) use data from the Chinese Child Twin Survey and provide within-twins estimates of the effect of birth weight on schooling expenditures for children aged 7–14. They find evidence of a reinforcement of schooling expenditures. Conti et al. (2011) using the same dataset look at the relationship between an early health shock (a dummy variable indicating whether the twin suffered a serious illness during ages 0–3) and parental investment. They find a reinforcement strategy with respect to health, with parents spending more money on the less healthy twin, but a compensatory strategy with respect to schooling.

A recent paper by Sandewall et al. (2009) tests whether unobserved ability is fully differenced out in the within-MZ twin estimator. They use data on 890 pairs of male MZ Swedish twins and show that within-MZ twin pair differences in IQ test scores obtained at age 18 are a significant predictor of within-MZ twin pair schooling differences. They also find that the estimated return to schooling is reduced by 15 percent when controlling for within-MZ twin pair differences in IQ. If IQ test score differences between MZ twins also have an independent effect on health, then our estimates will be upward biased. However, it

[6]Specific details are provided in Behrman et al. (2011) and Kohler et al. (2011).

[7]Consider a relation where measures of parental input such as educational expenditures for twin i in pair j (I_{ij}) is related to the birth weight of twin i (bw_{ij}), birth weight of the co-twin (bw_{kj}), unobserved family variables(μ_j) and an error term (ξ_{ij}): $I_{ij} = \beta bw_{ij} + \theta bw_{kj} + \mu_j + \xi_{ij}$. If $\beta>0$ and $\theta<0$ then parents reinforce differences between twins, whereas $\beta<0$ and $\theta>0$ implies parents compensate for differences between twins. The within-MZ twin relation which eliminates the influence of unobserved common family factors is: $I_{1j}-I_{2j}= (\beta-\theta)(bw_{1j}-bw_{2j}) + (\xi_{1j}\ \xi_{2j})$. A reinforcement strategy by parents implies that $(\beta-\theta)$ is positive and compensation implies that $(\beta-\theta)$ is negative.

is important to note that cognitive test scores at age 18 are likely to have been affected by previous schooling and other prior investments in the children. Meghir et al. (2011) using the same Swedish cognitive test score data as Sandewall et al. (2009) show that the Swedish compulsory schooling reform increased the cognitive test ranking of boys by 2.5 percent of a standard deviation. Similar findings have been reported on U.S. data (Cascio and Lewis 2006) and for Norway (Brinch and Galloway 2012). Thus, although Sandewall et al. (2009) results are suggestive, it is unclear as to why cognitive test scores at age 18 should be unaffected by previous schooling, health and nutrition. Sandwell et al. (2009) acknowledge this concern, and as a robustness test they use birth weight differences instead of IQ. When they control for birth weight, the estimated effect of schooling on earning is only reduced by 0.5 percent. Miller et al. (2005) using data from the Australian Twin Registry find that controlling for birth weight also does not alter the estimated effect of schooling on earnings.

Other childhood or youth health differences between MZ twins may affect both schooling and health. Le et al. (2005) investigate the relationship between conduct disorder and schooling using data from the Australian Twin Registry. Treating twins as unrelated individuals, their cross-sectional regressions show that suffering from conduct disorder increases the probability of dropping out from high school and lowers schooling attainment. However, they find no relationship between within-MZ twin pair differences in conduct disorder and schooling. Lundborg et al. (2011) investigate whether within-MZ twin estimates are likely to be biased due to a failure to control for youth health. They use objective measures of health (such as suffering from hypertension, respiratory, musculoskeletal, mental conditions, having a weak hand grip) measured at age 18, when Swedish men enlist in the military. Like Le at al. (2005), the cross-sectional estimates indicate a negative effect of these health measures on schooling attainment, but within-MZ twin pair health differences do not predict schooling differences.

In sum, we do not know exactly what factors lead to schooling differences between MZ twins and whether these factors also directly affect health. This means that we cannot give a causal interpretation to our within-MZ twin estimates with certainty. However, within-MZ twins estimates will still be helpful in tightening bounds on the causal schooling effect. Both cross-sectional and within-MZ twins estimates are likely to be biased, but if there are unobserved factors that increase schooling and improve health directly in addition to any indirect effects through schooling, and if the absolute value of the within-MZ twins estimates lies below the cross-section estimates (as they control for unobserved factors common to both twins) then they can be interpreted as an upper bound of the true causal effect.

(2) Measurement error in schooling—It is well known that differencing (or fixed effects) exacerbates measurement error in schooling, causing within-MZ twins estimates to be downward biased. If the within-MZ twins estimates are smaller than the OLS estimates may be in part due to the fact that the within-MZ twins estimate control for the endogenously determined part of schooling or because of a larger attenuation bias due to measurement error or due to some combination of these two factors. To correct for measurement error, we follow Ashenfelter and Krueger (1994) by instrumenting the reported schooling differences with differences based on reports from the other twin. Although this will correct for measurement error in schooling it will not correct endogenously within-twin pair schooling differences.

(3) Peer effects—There is also a possibility that twins' health behavior can affect another. For example, if twin i starts smoking then there may be a spillover effect on twin k. Twin k may also start smoking or be decide not to take up smoking. The within-MZ twin estimates is biased depending on the direction of the cross-twin effect. If there is a cross-twin effect in health, then relations (1A) can be written as

$$H_{ij}{}^{M}=\beta_{S}S_{ij}{}^{M}+\theta H_{kj}{}^{M}+h_{j}{}^{M}+v_{ij}{}^{M} \quad (5)$$

The within-MZ twin estimator is now given by:

$$\Delta H_{ij}{}^{M}=(\beta_{S}\Delta S_{ij}{}^{M}+\Delta v_{ij}{}^{M})/(1+\theta) \quad (6)$$

Relation (6) suggests that the within-MZ twin estimate of β_S will be biased down (if $\theta>0$) or up (if $\theta<0$), even if within-MZ twin pair schooling differences are random. As the within-MZ twins estimate includes a peer effect, it may not be generalizable to the entire population.

3. Previous Related Studies

A number of studies have used IV estimates to attempt to identify the causal effect of schooling on health outcomes and health-related behaviors. Examples of instruments that have been used include per capita income and per capita expenditures on schooling in an individual's state of birth (Berger and Leight 1989), school regulations on age at entry and school reforms (Adams 2002, Arendt 2005, Lleras-Muney 2005). Grossman and Kaestner (1997) and Grossman (2000) provide extensive reviews of these studies and many more. In this section we focus on results from previous studies addressing the schooling-health gradient in the U.K. and those that also use the within-MZ twins methodology.

3.1 Previous U.K. Studies

Table 1 summarizes the previous studies providing evidence for the U.K. These studies have two common factors. First, they use data from the same two sources- either the General Household Survey (GHS) or Health Survey for England (HSE). Second, they attempt to identify the causal effect of schooling through IV estimates based on exogenous changes in the minimum school-leaving age. In 1947 the school-leaving age was increased from 14 to 15 and it was raised further to 16 in 1972. Individuals born after April 1st 1933 were affected by the 1947 reform and individuals born after September 1st 1957 were affected by the 1972 reform. Despite using data from the same source and the same identification strategy, these studies have mixed results. The IV estimates from Silles (2009) and Powdthavee (2010) provide evidence for a causal relationship between schooling and health, while the estimates from Oreopoulos (2006), Clark and Royer (2010) and Jürges et al. (2012) suggest that there is no causal relationship.

Oreopoulos (2006) finds no significant positive effect of the 1947 reform on self-reported health in the combined General Household Survey and Northern Ireland Continuous Household Survey from 1984 to 2006. The Oreopoulos (2006) paper is widely cited as showing a positive significant effect of schooling on self-reported health, as the IV estimates are highly significant. However, there was a coding mistake in the original paper and in a subsequently published corrigendum the IV estimates for self-reported health in the U.K. are of the wrong sign statistically insignificant.[8] In contrast, Silles (2009), using pooled GHS data from 1980 to 2004, finds a positive effect of schooling on self-reported health- an extra year of schooling increases the probability of being in good health by 4.5–5.5 percentage

[8]The main focus of Oreopoulos (2006) is on earnings, and the revised estimates are unchanged. The corrigendum is available on http://www.aeaweb.org/articles.php?doi=10.1257/000282806776157641

points. Hence, the corrected Oreopoulos (2006) results contradict those from Silles (2009). The Silles's paper differs from Oreopoulos in that she concentrates on the 1920–1979 cohorts, using both reforms as instruments for schooling, whereas Oreopoulos only uses the 1947 reform concentrating on individuals born between 1921–1951. However, when Silles splits her sample to those who are born 1938–1979 (only affected by the 1972 reform) and individual who are born 1920–1962 (primarily affected by the 1947 reform), she finds a significant causal effect of schooling on self-reported good health for the 1920–1962 cohorts but not for the 1938–1979 cohorts.

Powdthavee (2010) investigates whether more schooling reduces blood pressure and the probability of developing hypertension using data from the HSE. He concentrates on cohorts born around the two schooling reforms (1926–1939 and 1952–1965) and finds that an extra year of schooling reduces the probability of men developing hypertension by 7–10 percentage points. Interestingly he finds no effect for women suggesting that women do not appear to have benefited from an extra year of schooling.

Clark and Royer (2010) provide the most extensive study of the schooling-health gradient in the U.K. They use data from the Office of National Statistics to examine the effect of schooling on mortality and HSE data to examine an extensive list of health outcomes and health-related behaviors. Like Powdthavee, they investigate the effect of the 1947 and 1972 reforms separately (on cohorts born between 1926–1940 and 1950–1965) and find little evidence that schooling reduces mortality, improves health outcomes or changes health behaviors. They conclude that "the health returns to this extra education are small at best." As part of their health measures Clark and Royer also use blood pressure and a binary variable for hypertension, but find no causal effect for either outcome. While they do not present estimates for men and women separately, they note on page 28 "for most outcomes, we could not reject that the male and female coefficients were the same." There are two key differences that may possibly explain the differing IV estimates for hypertension between the Clark and Royer and Powdthavee studies. First Clark and Royer have month of birth in their dataset and define treatment based on month of birth, e.g. an individual born in August 1933 would be defined as being affected by the 1947 reform. In contrast Powdthavee (and the other studies) do not have month of birth and base treatment on year of birth, so that individuals born in August 1933 would be defined as not being affected by the 1947 reform. Secondly, Powdthavee's binary hypertension variable is equal to one if the individual has stage 1 hypertension and/or is taking prescribed medicines to help with high blood pressure. Clark and Royer do not include those who are taking medicines to lower blood pressure.

Jürges et al. (2012) use a combination of HSE and ELSA (English Longitudinal Survey of Ageing) data examining objective measures of health based on biomarkers (blood fibrinogen and blood C-reactive protein)[9] and self-reported health. They split their analyses by birth cohorts and gender, using the 1947 reform for 1929–1937 cohorts and the 1953–1961 cohorts for the 1972 reform. Their IV estimates indicate no evidence for a causal effect of schooling on the biomarkers, but there is some indication of a causal effect of schooling on self-reported health for women. They hypothesize that the contradiction in their estimates for biomarkers and self-reported health could be due to differential reporting styles of individuals of different schooling levels.

In sum, there is mixed evidence on the causal effect of schooling on health in the U.K. The evidence is also mixed as to whether there are any gender differences in the effect of schooling on health. While Oreopoulos (2006), Sillies (2009), Clark and Royer (2010) find

[9]High levels of blood fibrinogen and blood C-reactive protein are known risk factors for cardiovascular disease and obesity

no evidence for any gender differences, there are indications of gender differences in Powdthavee (2010) and Jürges et al. (2012).

3.2 Previous Studies based on Within-MZ-Twin Estimators

Recently there have been six studies that use the within-MZ twins estimation strategy presented in Section 2 to investigate the impact of schooling on health-related behaviors and health outcomes.

Webbink et al. (2010) analyze the causal effect of schooling on the probability of being overweight by using longitudinal data on Australian MZ twins. Their cross-sectional estimates confirm the well-known negative association between schooling and the probability of being overweight. For men they find that schooling also reduces the probability of being overweight within pairs of MZ twins. The estimated effect of schooling on overweight status increases with age. For women they find no negative effect of schooling on body size in the within-MZ estimates.

Behrman et al. (2011) analyze schooling differentials and health-related behaviors and outcomes utilizing a rich longitudinal dataset obtained through a linkage between the Danish Twins Registry with various population-based registers at Statistics Denmark. This linkage provides longitudinal information for schooling and health-related behaviors and outcomes for all Danish twins born between 1921 and 1950 that have been identified in the Danish Twin Registry. They report that there are strong negative associations between schooling attainment and hospitalization per year during 1980–2002, hospitalization per year up to two years before death and mortality by 2003 for both males and females for both the 1921-35 and 1936-50 birth cohorts. However their within-MZ twins estimates also question the standard inference from other similar estimates that these strong negative associations reflect important direct causal effects of schooling. Instead, schooling seems primarily to be serving as a marker for parental family and individual-specific endowments that are uncontrolled for in the usual cross-sectional estimates.

Madsen et al. (2010) also combine data from the Danish Twin Registry and Statistics Denmark to estimate the the effect of schooling on mortality risk. Their dataset consists of almost 16,000 MZ and DZ twin pairs born 1921–1950. They have a large effective sample size of 1493 discordant DZ twin pairs and 675 discordant MZ twin pairs. They show cross-sectional and within-twins estimates for all same sex twins and separately by zygosity for twins born 1921–1935 and 1936–1950. The cross-sectional results show that more education reduces mortality risk. The within-twins estimates were smaller in absolute magnitude and show no significant effect of schooling on mortality. The exception was for men born 1921–1935 where there still remained a marginally significant association within-twin pairs.

Behrman et al. (2006) use new data on Chinese twins in five major urban areas to investigate the nature of the health gradient with respect to schooling. For health-related behaviors (smoking, alcohol consumption and exercise) their results suggest that there are strong significant associations based on cross-sectional OLS estimates, but that the estimates are much smaller in absolute magnitude and insignificant once there is control for unobserved common genetics and other common aspects of parental family background through within-MZ twins estimates. For health outcomes (self-reported health and symptom occurrence[10]), the within-MZ twins estimates for both outcomes are larger in absolute magnitude compared to cross-sectional OLS estimates using a linear specification for grades of schooling. When using a non-linear specification of schooling, the within-MZ twins estimates for symptom

[10]Symptom occurrence is a dichotomous variable equal to 1 if individuals have hypertension or dysfunction in their back or dysfunction in a leg.

occurrence are also larger in absolute magnitude than the OLS estimates. The within-MZ twins estimates for self-reported health in the non-linear specification are however smaller than the OLS estimates and insignificant.

Lundborg (2008) uses a sample of 694 MZ twins from the 1995 Midlife in the United States (MIDUS) survey with dichotomous schooling indicators for high school, some college and college degree. His results suggest a causal impact of self-reported schooling levels on health, with a significant positive impact on self-reported health and negative impacts on the number of chronic conditions.[11] Like Behrman et al. (2006) the within-MZ twins estimates of schooling impacts are larger for self-reported health than the corresponding OLS estimates. However, when using a continuous measure of grades of schooling, the within-MZ twins estimate for self-reported health is insignificant and smaller than the OLS estimate.

Fujiwara and Kawachi (2009) use 702 MZ twins from the same MIDUS data as Lundborg (2008) with a continuous measure of schooling attainment. They find no significant causal effects of schooling on seven health outcomes and ten health behaviors in within-MZ twins estimates when males and females are combined (an exception is for perceived global health if male and female samples are combined, but not in separate estimates for females and males).[12]

The results from Behrman et al. (2006) and Lundborg (2008) suggest that there is some evidence of a negative correlation between schooling and unobservable health endowments, implying individuals with lower health endowments tend to pursue more schooling while those with a higher health endowment tend to receive less schooling. Furthermore, the contrast between significant and insignificant within-MZ twins estimates in the Behrman et al. (2006) and Lundborg (2008) studies may reflect that the estimates are sensitive to the treatment of possible nonlinearities in schooling effects.

4. Data

Our data comes from the Department of Twin Research and Genetic Epidemiology, King's College London (DTR), which is the largest source of twins data in the U.K. The DTR has built up a list of approximately 11,000 identical (MZ) and non-identical (DZ) Caucasian twins aged 16 to 85 from all over the U.K. All twins in the registry were recruited through national media campaigns and from other twin registries (Institue of Psychiatry and Aberdeen University).The majority of twins are female because the diseases which the DTR was initially interested in are more common in women than men. However, the twins have not been selected for any particular disease, and they volunteer to take part in studies that cover a wide range of traits and common medical conditions (Spector et al. 2006).

The specific data in this study comes from a mailed questionnaire designed by Bonjour et al. (2003) mainly collecting information on socioeconomic characteristics, schooling and income. The questionnaires were originally sent out in June 1999 to all twins in the register, and were resent in 2000 to twins who had been mailed the questionnaire in the previous year but had not replied. Bonjour et al. (2003) note that response rates were above 80 percent, which was achieved by remailing and telephoning nonrespondents. In addition, some limited information on health-related behaviors and outcomes was collected, which we use in this

[11]Lundborg also explores the impacts of schooling on health-related behaviors and reports little evidence of significant impacts.
[12]In their discussion they state: "In summary, the current study showed possible causal effects of education on perceived global health and on smoking habits among males, but did not suggest direct associations between schooling and the other health outcomes studied." (p. 1320). The significant outcomes for males to which they refer, however, do not occur in within-MZ estimates, but only in within MZ and DZ combined estimates.

study. We have data on 933 MZ twin pairs, where both twins returned questionnaires in 1999. Of these, 655 pairs have complete information on schooling and our outcome variables. We have information on a further 143 MZ twin pairs who returned questionnaires in 2000, of which there were 86 have full information on both schooling and health.

Our key explanatory variable of interest is schooling attainment. The questionnaire asked twins to report their educational qualifications and their co-twin's educational qualifications. To construct our measure of schooling we follow Bonjour et al. (2003). First we determine the highest qualification attained and then assign grades of schooling to each qualification.[13]

In this paper we consider the following health-related behaviors and outcomes:

1. Body Mass Index (BMI): Weight in kilograms divided by height in meters squared.
2. Overweight Status: If BMI is greater or equal to 25.
3. Shortness of breath when walking: Twins were asked whether they have a shortness of breath when walking. The scale is from 0 indicating "never", 1 indicating "yes sometimes" and to 2 indicating "yes frequently". This measure proxies some important dimenions of physcial health.
4. Smoking Status: Twins were asked "have you ever smoked cigarettes, cigars or pipes on a regular basis" with options for never smoked, ex-smoker and current smoker. We analyze indicator variables for never smoking and being a current smoker.
5. Alcohol Consumption: Twins were asked to report pints of beer, cider or lager, glasses of wine, sherry or fortified wine and glasses of spirits currently drunk per week. Assuming that each pint of beer, cider, lager is equivalent to 2 units of alcohol, each glass of wine, sherry, spirits is equivalent to 1 unit and summing across the number and types of drinks produces the amount of alcohol consumed.
6. Exercise: Twins were asked, "during the last 12 months how would you describe the kind of physical activity you performed in your leisure time?" The options for answering these questions are inactive, light, moderate or heavy. We create a dummy variable equal to 1 if twins report moderate or heavy physical activity in their leisure time.

The final dataset is a sample of 741 female MZ twins pairs with complete information on the health measures and schooling. Our sample size, although only limited to women is substantially larger than Lundborg (2008) (347 MZ twins pairs), Fujiwara and Kawachi (2009) (351 MZ twins pairs), Behrman et al. (2006) (386 MZ twins pairs) but smaller than Webbink et al. (2010) (1500 MZ twins pairs) and Behrman et al. (2011) (2647 MZ twins pairs)

Table 2 presents descriptive statistics for our sample of female MZ twins and for women from the pooled 1999/2000 Health Survey for England (HSE) in order to assess the representativeness of the twins data. We only report information on women in the HSE sample who have non-missing information on schooling and from the same birth cohort as our twins (1924–1974). The HSE is an annual health survey of 15,000 to 20,000 respondents in England. Respondents who live in private households are randomly selected for interviews from the postal code address file. In comparison, the mailing list of twins at the

[13]Specifically the schooling attainment groupings and grades allocated are: university, 17; higher vocational, 16; teaching, 16; nursing, 15; A-level, 14; middle vocational, 12; O-level, 12; low vocational, 11; clerical, 11 and other 10. Bonjour et al. also assign 10 grades of schooling to twins for whom there is no information on highest qualification. We drop twins with missing information on schooling.

DTR is based on twins who volunteered to participate in the research. Hence, it is not surprising that our twin sample is not entirely representative of the general population. In terms of schooling, the twins on average have greater schooling attainment. A significantly lower proportion of the twins have less than 12 grades and a significantly higher proportion have 14–16 grades of schooling compared to women in the HSE. In terms of health outcomes and health-related behaviors, the twins have a slightly lower average BMI than women in the HSE but a substantially lower proportion are overweight. The twins on average are also less likely to smoke and more likely to have never smoked.

As the within-MZ twin estimates are identified by twin pairs that differ on schooling attainment, columns 3 and 4 provided descriptive statistics for twin pairs that are concordant and discordant on schooling attainment. The sample of discordant twin pairs have significantly more grades of schooling, are less likely to smoke, but consume slightly more alcohol compared to twin pairs that have the same grades of schooling. There is no significant difference in BMI, overweight status, exercise and shortness of breath when walking.

Since the twins differ some from the representative sample, our results may not be directly generalizable to the entire population. However, our main aim is to provide estimates of the schooling-health gradient controlling for unobserved endowments to compare to mixed IV estimates in the literature. Differences between the twins and HSE sample will not cause biases in our within-MZ twins estimates if these differences from the representative sample are due to the endowments that are controlled for in our within-MZ estimates.

Within-MZ twins estimates may be preferable to IV estimates if there are schooling differences between twins over substantial ranges in the schooling distribution, so that ATE estimates over this range rather than LATE estimates over a much narrower range can be obtained. Table 3 tabulates and summarizes the differences in grades of schooling for all twins pairs in which at least one member has one of four broad educational attainment categories[14]: (1) not completed compulsory schooling (less than 12 grades) (2) completed compulsory schooling (12 grades); (3) some post-compulsory schooling (14–16 grades) and (4) university or higher (17 grades). For the full sample, the twins pairs on average have an absolute difference of 1.03 grades in schooling with a standard deviation of 1.56. Over half of the twins pairs have no difference in schooling attainment. However, there is some modest variation in schooling for the other half that is distributed across the complete range of schooling attainment. Across the educational categories, the least variation occurs in twins pairs where at least one twin has not completed compulsory schooling in which case 53 percent of the twin pairs have no difference in grades of schooling. The most variation occurs where at least one twin has some post-compulsory schooling. In this case 31 percent of twin pairs have the same schooling attainment. The mean absolute difference in grades of schooling is 1.81 (with standard deviation of 1.05). There is also some modest variation where at least one twin has completed compulsory schooling or has a university degree or higher. In these cases the mean absolute difference in grades of schooling is 1.65 and 1.36 respectively. The modest variation in schooling differences across the grades of schooling categories, would suggests that our estimates are likely to be closer to ATE. However, as noted above, the twins are not representative of the overall population, so within-MZ twins estimates will represent ATE for our specific sample but not for the entire population.

[14]This approach is advantageous relative to an alternative tabulation of schooling differences by average twin pair schooling levels because, by construction, the mean difference in grades of schooling will tend to become small for twins pairs that either have a very high or a very low mean schooling level.

5. Results

The main estimates are presented in Table 4. Column 1 shows cross-sectional OLS estimates only controlling for age and age squared. These indicate that more schooling is significantly associated with a lower BMI, less likely to be overweight, less likely to be short of breath when walking, less likely to smoke and more likely to engage in moderate or heavy exercise in leisure time. We find that an additional grade of schooling is associated with .155 more units of alcohol consumption, whereas a priori we expected a negative coefficient. Clark and Royer (2010) also find a significant positive association between schooling and alcohol consumption. The positive association may be plausible if people believe that there are health benefits of modest alcohol consumption or if alcohol is more affordable to more-schooled individuals due to higher income. The estimates in column 1 are biased towards zero if there is random measurement error in schooling. To control for this, column 2 instruments self-reported schooling with the co-twin's report of her sister's schooling. All of the point estimates increase in magnitude (with the exception of shortness of breath when walking), indicating that cross-sectional OLS associations suffer some from attenuation bias due to measurement error.

The descriptive statistics showed that the identifying sample of discordant twin pairs is different from the sample of concordant twin pairs. Column 3 provides cross-sectional OLS estimates for the sample of discordant twin pairs. Now, all of the cross-sectional associations are smaller in magnitude compared to the cross-sectional associations for the full twins sample in column 1. The estimates still indicate that more schooling is associated with having a lower BMI, less (more) likely to currently (never) smoke, but there is no longer any significant relationship between schooling and probability of being overweight, alcohol consumption, exercise during leisure time and shortness of breath when walking. Instrumenting for random measurement error in column 4 does not change the conclusion.

Column 5 gives within-MZ-twins estimates without including any covariates. All of the estimates are statistically insignificant with the exception of BMI, suggesting that one additional grade of schooling reduces BMI by .146 units. A comparison of the cross-sectional associations for the full sample of twins to the within-MZ twin estimates, suggests that the effect of schooling on the health measures examined is essentially zero, and that the cross-sectional associations are upward biased. However, this comparison is problematic as the sample of discordant twin pairs differs from the sample of concordant twin pairs. A comparison of the cross-sectional estimates for discordant twin pairs for overweight status, shortness of breath when walking, alcohol consumption and exercise during leisure time to the within-MZ twins estimates suggests that there is no bias as the cross-sectional and within-MZ twins estimates are insignificant. A similar comparison for bmi and smoking does indicate that the cross-sectional associations are upward biased.[15],[16]

[15]As an alternative to schooling attainment, appendix Table A.1 provides estimates using responses to the question "at what age did you leave full time education". We are not able to take account of measurement error as the twins were not asked to report the age at which their twin sister's left full time education. The estimates also show strong associations between schooling and health for the sample of all twins. The associations are smaller in magnitude for the sample of discordant twins but remain significant with the exception of alcohol consumption and exercise during leisure time. The within-MZ twins estimates are all insignificant suggesting that cross-sectional associations are upward biased.

[16]Throughout this paper, for binary outcomes the tables show within-MZ twins estimates based on a linear probability model. This can give rise to the problem of prediction outside the unit interval, so we also used conditional fixed-effects logit models. See appendix Table A.2, where we present cross-sectional logit estimates, conditional fixed-effects logit estimates that control for unobserved endowments and finally conditional fixed-effects logit estimated taking account of measurement error. The conclusions from this table is the same as from table 4-strong cross-sectional associations for the full sample of twins, no significant cross-sectional associations for the sample of discordant twins, with exception of smoking status and within-MZ twins estimates that are also insignificant.

Although within-MZ twins estimates control for the endogenously determined part of schooling, they also suffer larger attenuation bias due to measurement error or due to some combination of these two factors. In column 6 the difference in self-reported schooling is instrumented using the difference in the co-twin's report of the other's schooling to control for random measurement error. While most of the point estimates increase, the estimate for BMI surprisingly decreases from −.146 in column 3 to −.052 in column 6. We do not know the reason for this odd result. There is no problem of lack of explanatory power or weak instruments in the first stage regression. Kohler et al. (2011) is the only other study of which we are aware in which instrumenting for random measurement error in the within-MZ twins regression does not increase the magnitude of the estimated schooling coefficient.[17],[18]

Table 5 presents results using a non-linear specification for schooling. We introduce non-linearities through four dichotomous variables: (1) if the twin has 11 grades of schooling or lower, (2) if the twin has 12 grades of schooling, (3) if the twin has 13–16 grades of schooling and (4) if the twin has 17 grades of schooling or more. No measurement error corrected IV estimates are presented because when binary variables are used, measurement error is non-classical. Individuals in the lowest educational category cannot under-report their education and individuals in the top categories cannot over-report their education. Kane et al. (1999) show with multiple binary indicators of highest educational attainment one cannot sign the bias in OLS and IV estimates due to measurement error.

For the full sample of twins, the cross-sectional OLS regressions again suggest strong associations between schooling and health-related behaviors and outcomes, with the magnitude for having 17 grades or more of schooling being the largest. For the sample of discordant twins, the associations are smaller in magnitude and insignificant for overweight, alcohol consumption, exercise in leisure time and shortness of breath when walking. The within-MZ twins estimates are statistically insignificant suggesting that there are no differences across completed schooling categories. The exception again is bmi, where the within-MZ twin estimates are highly significant and larger in magnitude than the corresponding cross-sectional associations for both the full and discordant sample of twins. Like Behrman et al. (2006) and Lundborg (2008), using a non-linear functional form for schooling leads to a slightly different conclusn suggest strong associations between schooling and health-related behaviors and outcomes, with the magnitude for having 17 grades or more of schooling being the largest. For the sample of discordant twins, the associations are smaller in magnitude and insignificant for overweight, alcohol consumption, exercise in leisure time and shortness of breath when walking. The within-MZ twins estimates are statistically insignificant suggesting that there are no differences across completed schooling categories. The exception again is bmi, where the within-MZ twin estimates are highly significant and larger in magnitude than the corresponding cross-sectional associations for both the full and discordant sample of twins. Like Behrman et al. (2006) and Lundborg (2008), using a non-linear functional form for schooling leads to a slightly different conclusion.

Overall, our results suggest that there is no causal effect of schooling on smoking status. Rather the significant cross-sectional relationship is due to unobserved family and individual endowments that affect both health and schooling, which are not controlled for. This finding is consistent with Clark and Royer (2010), whose IV estimates also indicate no causal effect of schooling on smoking status. We do however find some indication that more schooling

[17]Using data from the Minnesota Twins Registry Kohler et al. (2011) estimate the effect of schooling on fertility, where the within-MZ twin estimate is −0.0239. The within-MZ twins IV estimate is the same at −0.232.

[18]As an alternative to instrumenting, we restricted the sample to 602 twin pairs who agree on their schooling differences. Of the 602 twin pairs, 212 differ on schooling attainment. The within-MZ twins estimate for bmi is − 0.078 with a standard error of 0.082

reduces bmi for women. This contrasts with the IV estimates from Clark and Royer (2010) who find no causal relationship. It also differs with the within-MZ twins estimates from Lundborg (2008) who finds no significant effect and from Webbink et al. (2010) who find that more schooling reduces bmi for men but not for women.

We acknowledge that the within-MZ twins estimates may still be biased if schooling differences are endogenously determined. The most common concern is that our estimates will be upward-biased if schooling differences are due to shocks that positively affect schooling and health. For smoking status such a positive bias would be inconsistent with our estimates. Schooling is hypothesized to increase the probability of never smoking and an upward bias would be inconsistent with negative point estimates close to zero in Table 4. In unreported results we carried out two robustness checks to deal with possible endogenously determined schooling differences. First we excluded twin pairs with large schooling differences as one might believe the assumption of random schooling differences is less likely to hold for these pairs. Second we included birth weight as an additional covariate to proxy for individual-specific innate endowments that may not be fully differenced out within-twin pairs. For smoking status and bmi, we still found significant cross-sectional associations in the sample of discordant twin pairs. The within-MZ twins estimates were insignificant for smoking status using linear grades of schooling and the non-linear schooling specification. For bmi, the within-MZ twins estimate based on grades of schooling remained significant, but still became smaller and insignificant when instrumenting for random measurement error. In the non-linear specification the within-MZ twins estimates still indicate a significant effect of schooling reducing bmi, with the absolute magnitude being larger than the cross-sectional estimates.

6. Summary

Whether schooling causes better health outcomes and health-related behaviors is an important policy and research question. If the observed schooling-health gradient reflects an association driven by unobserved family and individual endowments affecting both schooling and health, then a policy to increase schooling provision (such as the increase in the school-leaving age from 16 to 18, which will take place in 2013 in the U.K.) will have no additional benefits on health. Previous evidence for the U.K. from IV estimates based on changes in compulsory school leaving age laws has reached opposing conclusions. We provide alternative evidence for the U.K. based on the within-MZ twins methodology, which relates differences in schooling between MZ twins to differences in health measure to control for unobserved endowments.

Our cross-sectional estimates indicate strong associations between schooling and health-related behaviors and outcomes. Specifically, we find that schooling is associated with a lower BMI, lower probability of being overweight, and lower (higher) probability of currently (never) smoking. More-schooled individuals also report better physical health, as they are less likely to report being short of breath when walking and more likely to engage in moderate or heavy exercise in their leisure time. However, we find no significant cross-sectional relationship between schooling and probability of being overweight, shortness of breath when walking, alcohol consumption and exercise during leisure time for the sample of discordant twin pairs, which identifies the within-MZ twins estimates. For these outcomes, we are unable to learn whether there is a true causal relationship as the within-MZ twin estimates are also zero.

However, there is a significant cross-section between schooling and smoking status and bmi for the sample of discordant twin pairs. The within-MZ twins estimate suggests that there is no causal effect of schooling on smoking status. Rather the cross-sectional association is upward biased because it does not control for unobserved family and individual endowments that affect both smoking and schooling. The finding of no causal effect smoking status is in line with Clark and Royer (2010). There is some indication that schooling reduces bmi of women and that the function form of schooling matters. The within-MZ twins estimates using linear grades of schooling are smaller than the cross-sectional estimates but suprising larger when using a nonlinear specification for schooling.

There are three limitations with our study. First, due to data limitations our study concentrates on the schooling-health gradient for women and does not provide any results for men. We only study subjective and intermediate measures of health behaviors and outcomes, which prevents us from investigating possible causal mechanisms. Second, our effective sample size of twin pairs who are discordant on schooling attainment is not large enough to precisely identify any possible schooling effects. Third, although within-MZ twins estimates are based on differences in twins schooling that are distributed across the schooling distribution, our twins sample is very selective and not representative of the overall population. The results are unlikely to be generalizable to the entire population and will not represent ATE. Furthermore, for policies that increase schooling attainment through compulsory schooling laws, the LATE is probably a more relevant policy parameter compared to the ATE.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Appendix Table A.1

Cross-Sectional and Within-MZ Twins Estimates Using Age Left Full Time Education

	Cross-Sectional All Twins	Cross-Sectional Discordant Twins	Within-MZ Twins
	(1) OLS	**(2) OLS**	**(3) OLS**
Health Outcomes			
BMI	−0.301 (0.055)***	−0.226 (0.076)***	0.033 (0.066)
Overweight	−0.023 (0.007)***	−0.017 (0.008)***	−0.011 (0.012)
Short of Breath When Walking	−0.020 (0.007)***	−0.016 (0.009)*	−0.017 (0.016)
Health-Related Behaviors			
Never Smoked	0.031 (0.006)***	0.024 (0.008)***	−0.012 (0.009)
Current Smoker	−0.017 (0.004)***	−0.011 (0.005)**	−0.002 (0.008)
Alcohol Consumption	0.061 (0.091)	−0.098 (0.115)	−0.131 (0.150)
Moderate or Heavy Exercise during Leisure Time	0.016 (0.024)	0.002 (0.008)	0.018 (0.015)
N	1382	522	691

Notes: Columns 1 and 2 control for age and age squared. Standard errors in parentheses clustered by twin pairs.

*** significant at 1%

** significant at 5%;

* significant at 10%.

Appendix Table A.2

Logit and Conditional Fixed-Effects Logit Estimates

	Cross-Sectional All Twis	**Cross-Sectional Discordant Twins**	**Within-MZ Twins**	**Within-MZ Twins**	**Within-MZ Twins Twin pairs who agree on schooling differences**
	Logit	**Logit**	**Conditional FE Logit**	**Conditional FE IV Logit**	**Conditional FE Logit**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Health Outcomes					
Overweight	−0.096 (0.023)*** [1482]	0.006 (0.035) [622]	0.018 (0.072) [70]	0.062 (0.126) [70]	0.105 (0.086) [51]
Health-Related Behaviors					
Never Smoker	0.108 (0.022)*** [1482]	0.067 (0.034)* [622]	0.003 (0.077) [77]	−0.214 (0.136) [77]	−0.030 (0.093) [50]
Current Smoker	−0.146 (0.035)*** [1482]	−0.114 (0.050)** [622]	−0.008 (0.092) [50]	−0.040 (0.172) [50]	−0.053 (0.118) [30]
Moderate or Heavy Exercise during Leisure time	0.051 (0.022)** [1482]	0.010 (0.035) [622]	−0.029 (0.063) [113]	0.163 (0.110) [113]	−0.008 (0.071) [82]

Notes: Columns 1 and 2 control for age and age squared. Standard errors reported in (.) and N reported in [.]. For the conditional fixed-effects logit estimates, N refers to the number of twin pairs who differ on schooling attainment and the binary health measure. Estimates in column 4 are based on a two step procedure. In the first stage we do a MZ-fixed-effects regression of self-reported schooling on the estimate of the co-twin's schooling. The second stage performs conditional fixed-effects logit regressions using the predicted values from the first stage in place on self-reported schooling. Both stages are performed with bootstrap standard errors based on 500 replications.

*** significant at 1%

** significant at 5%

* significant at 10%

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Highlights

- There is mixed evidence about the causal effect of schooling on health in the UK
- Recent studies have identified the causal effect using instrumental variables
- We find provide alternative evidence using the within-MZ twins methodology
- We find some evidence that more schooling reduces BMI for women

Table 1

Summary of Previous U.K. Studies

Author(s)	Dataset(s)	Outcomes	Reform used as instrument	Sample and Estimation	Results
Oreopoulos (2006)	1984 to 1998 GHS and CHS	binary variables for self-reported good and poor health	1947	Individuals born between 1921 and 1951. Regressions control for survey year fixed effects, birth year fixed effects, county fixed effects, a quartic in age and gender	OLS estimates are highly significant. IV estimates are insignificant
Silles (2009)	1980 to 2003/4 GHS	binary variables for self-reported good, no longer term illness, no activity-limiting illness, no work-limiting illness	1947, 1972	Individuals born 1920–1979. Regressions control for survey year fixed effects, a quadratic in age and gender	IV estimates are significant and larger than OLS. When estimation is done separately for those born 1938–1957 and 1920–1960 no causal effect of schooling on self reported health for the 1938–1957 cohorts who are only affected by 1972 reform
powdthavee (2010)	HSE 1991–2007	blood pressure and hypertension	1947, 1972 separately	Regressions control for survey year fixed effects, and a cubic in both year of birth and age. For individuals born between 1926–1939, the 1947 reform is used as the instrument and the 1972 reform is used as an instrument for those born between 1952–1965.	IV estimates for men in both cohort samples are significant and larger than OLS. IV estimates for women are insignificant.
Clarke and Royer (2010)	ONS data to investigate mortality. HSE 1991–2004 to Look at health outcomes and behaviors	mortality, self-reported health, BMI, overweight, blood pressure, hypertension, smoking, alcohol consumption	1947, 1972 separately	Regressions control for gender, month and year of survey fixed effects, month of birth fixed effects and an interaction between month of birth and the relevant reform. 1947 reform is used as an instrument for those born between 1920–1940. 1972 reform is used as an instrument for those born between 1950–1965	Apart from a few exceptions, IV estimates are insignificant
Jürges et al. (2012)	HSE 1993, 1994, 1998–2000 2003–2006. ELSA 2006	biomarkers: blood fibrinogen levels and blood C-reactive protein Levels. Self-reported health	1947, 1972 separately	Regressions control for year and month of birth. survey year and height 1947 reform is used as an instrument for 1929–1937 birth cohorts 1972 reform is used as an instrument for 1953–1961	No evidence of a causal effect of schooling on the biomarkers. Some evidence of a causal effect on self reported health for women

Table 2

Descriptive Statistics

	All Twins (1)	Pooled 1999/2000 HSE (2)	Discordant Twins (3)	Concordant Twins (4)
Demographic Characteristics				
Age	49.79 (12.16)	47.26 (14.05)	49.05 (11.09)	50.32 (12.84)
Schooling				
Grades of completed schooling	13.44 (2.55)	12.43 (2.46)	13.63 (2.43)	13.31 (2.61)
Proportion with				
Less than 12 grades of schooling	0.27 (0.44)	0.40 (0.49)	0.24 (0.43)	0.29 (0.45)
12 grades of schooling	0.28 (0.45)	0.30 (0.46)	0.25 (0.43)	0.30 (0.46)
14–16 grades of schooling	0.27 (0.44)	0.16 (0.37)	0.36 (0.48)	0.20 (0.40)
17 grades of schooling	0.19 (0.39)	0.13 (0.33)	0.15 (0.36)	0.21 (0.41)
Health Outcomes BMI	24.55 (4.35)	26.82 (5.37)	24.51 (4.21)	24.58 (4.45)
Overweight	.37 (.48)	.57 (.50)	0.36 (0.49)	0.36 (0.48)
Shortness of breath when walking	0.30 (0.53)		0.29 (0.50)	0.30 (0.55)
Health-Related Behaviors				
Never Smoked	.61 (.49)	.40 (.49)	0.59 (0.49)	0.63 (0.48)
Current Smoker	.12 (.33)	.26 (.44)	0.15 (0.36)	0.10 (0.30)
Alcohol Consumption	5.39 (7.94)		5.90 (9.43)	5.02 (6.64)
Moderate or Heavy Exercise during leisure time	.63 (.48)		0.64 (0.48)	0.63 (0.48)
N	1482	6846	622	860

Notes: Standard deviations in parentheses.

Table 3

Differences in grades of schooling, within-MZ pairs by educational attainment

Differences in grades of schooling	Twin pairs where at least one twin has				
	Not completed compulsory schooling (under 12 grades)	Completed Compulsory Schooling (12 grades)	Some Post Compulsory Schooling (14–16 grades)	University or higher (17 grades)	Total
0 grades difference	52.56%	45.45%	30.47%	49.20%	58.03%
1 grade difference	30.34%	11.89%	21.86%	22.46%	17.81%
2 grades difference	5.98%	10.84%	13.62%	5.88%	7.02%
3 grades difference	0%	5.59%	9.32%	5.35%	3.51%
4 grades difference	3.85%	16.43%	20.07%	0%	7.56%
5 grades or more difference	7.26%	9.79%	4.66%	17.11%	6.07%
Mean	0.94	1.65	1.81	1.36	1.03
SD	1.44	1.85	1.65	1.84	1.56
N	234	286	279	187	741

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Table 4

Cross-Sectional and Within-MZ Twins Estimates

	Cross-Sectional All Twins		Cross-Sectional Discordant Twins		Within-MZ Twins	
	(1) OLS	**(2) IV**	**(3) OLS**	**(4) IV**	**(5) OLS**	**(6) IV**
Health Outcomes						
BMI	−0.280 (0.056)***	−0.329 (0.074)***	−0.157 (0.077)**	−0.129 (0.206)	−0.146 (0.067)**	−0.052 (0.108)
Overweight	−0.022 (0.006)***	−0.029 (0.008)***	0.001 (0.009)	0.008 (0.025)	0.003 (0.010)	0.009 (0.018)
Short of Breath When Walking	−0.016 (0.007)**	−0.016 (0.009)*	−0.013 (0.009)	−0.003 (0.024)	−0.014 (0.012)	−0.012 (0.019)
Health-Related Behaviors						
Never Smoked	0.025 (0.006)***	0.037 (0.009)***	0.017 (0.009)*	0.050 (0.024)**	0.000 (0.010)	−0.026 (0.017)
Current Smoker	−0.015 (0.004)***	−0.021 (0.005)***	−0.014 (0.006)**	−0.040 (0.017)*	−0.001 (0.008)	−0.003 (0.014)
Alcohol Consumption	0.155 (0.082)*	0.236 (0.115)**	−0.007 (0.127)	0.024 (0.367)	−0.064 (0.161)	−0.188 (0.295)
Moderate or Heavy Exercise during Leisure Time	0.012 (0.006)**	0.019 (0.008)**	0.002 (0.008)	0.023 (0.023)	−0.006 (0.012)	−0.032 (0.021)
First Stage Coefficient	---	0.739	---	0.373	---	−0.586
First Stage T-statistic	---	41.83	---	9.86	---	−19.01
First Stage F-Statistic	---	665	---	43.25	---	361.49
N	1482	1482	622	622	741	741

Notes: Columns 1–4 control for age and age squared. For cross-sectional IV estimates, twin 1's schooling is instrumented by twin 2's report of twin 1's schooling and vice versa. For within-MZ twins IV estimates, the difference in self reported schooling is instrumented by the difference in the co-twin's report of the other's schooling. Standard errors in parentheses clustered by twin pairs.

*** significant at 1%

** significant at 5%;

* significant at 10%.

Table 5

Cross-Sectional and Within-MZ Twins Estimates, Non-Linear Specification of Schooling

	Cross-Sectional All Twins	Cross-Sectional Discordant Twins	Within-MZ Twins
	(1) OLS	(2) OLS	(3) OLS
Health Outcomes			
BMI			
12 grades	−0.950 (0.340)***	−.819 (.557)	−1.452 (0.546)***
14–16 grades	−1.228 (0.401)***	−1.22 (.550)**	−1.493 (0.549)***
17 grades	−2.339 (0.427)***	−1.39 (.624)	−1.805 (0.641)***
Overweight			
12 grades	−0.040 (0.041)	0.027 (0.055)	−0.041 (0.058)
14–16 grades	−0.077 (0.042)	0.010 (0.058)	0.005 (0.068)
17 grades	−0.182 (0.045)	−0.025 (0.068)	−0.030 (0.083)
Short of Breath When Walking			
12 grades	−0.082 (0.049)*	−0.016 (0.065)	−0.117 (0.078)
14–16 grades	−0.043 (0.050)	−0.053 (0.063)	−0.126 (0.082)
17 grades	−0.181 (0.050)***	−0.115 (0.071)*	−0.150 (0.092)*
Health-Related Behaviors			
Never Smoked			
12 grades	0.048 (0.041)	−0.028 (0.058)	−0.031 (0.061)
14–16 grades	0.114 (0.043)***	0.100 (0.059)*	−0.022 (0.071)
17 grades	0.179 (0.046)***	0.056 (0.069)	−0.003 (0.077)
Current Smoker			
12 grades	−0.054 (0.028)*	−0.013 (0.044)	0.010 (0.056)
14–16 grades	−0.078 (0.028)***	−0.090 (0.04)**	−0.027 (0.061)
17 grades	−0.115 (0.028)***	−0.066 (0.048)	0.027 (0.065)
Alcohol Consumption			
12 grades	0.484 (0.552)	1.07 (0.915)	0.545 (0.781)
14–16 grades	1.261 (0.696)	0.625 (1.15)	0.403 (1.122)

	Cross-Sectional All Twins	Cross-Sectional Discordant Twins	Within-MZ Twins
	(1) OLS	(2) OLS	(3) OLS
17 grades	1.089 (0.648)	0.725 (1.02)	0.491 (0.986)
Moderate or Heavy Exercise during Leisure Time			
12 grades	0.058 (0.039)	0.005 (0.056)	−0.088 (0.077)
14–16 grades	0.056 (0.039)	0.022 (0.052)	−0.065 (0.083)
17 grades	0.102 (0.043)***	0.014 (0.065)	−0.090 (0.094)
N	1482	622	741

Notes: Columns 1 and 2 control for age and age squared. The reference schooling category is less than 12 grades. Standard errors in parentheses, clustered by twin pairs.

*** significant at 1%

** significant at 5%;

* significant at 10%.

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