The Effect of Mother's Schooling on Children's Outcomes: Causal Links and Transmission Channels

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1 Introduction

Investments in human capital have been shown to substantially affect individual and social outcomes such as earnings (e.g., Card (1999)), criminal behaviour (Lochner & Moretti 2004) and health (Grossman 2005, Lleras-Muney 2005). In addition, the human capital level of a generation is likely to directly impact the production of human capital of future generations of individuals, as emphasized in modern growth models (e.g., Becker et al. (1990)). There is a large

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empirical literature in developed and developing countries suggesting that there exists a strong relationship between parental schooling and children's outcomes (see Behrman (1997)). However, most of this literature confounds the effect of parental schooling with the effect of omitted factors correlated with parental schooling.

Several economists have recently tried to isolate the causal effect of parental schooling on child outcomes through the use of different empirical designs, analogous to those used to examine the impact of schooling on wages, namely twin studies and instrumental variables. In this paper we follow the latter strategy and estimate the effect of maternal schooling on children's outcomes. We use white children from the National Longitudinal Survey of Youth 1979 (NLSY79), a rich dataset that contains detailed information on children outcomes at several ages, home environments and maternal characteristics. The available information allows to estimate the importance of maternal schooling for several outcomes of the child at different ages, and potential channels by which an increase in maternal education translates into improved child outcomes. We instrument mother's schooling with the presence of a public four year college in the county of residence at age 14, average tuition in public 4 year colleges in the county of residence at age 17, and average unemployment rate and blue collar wages in the state of residence at age 17.

We realize that the location of an individual in late adolescence is a choice variable (possibly of the individual's parents) and therefore we control for a rich set of maternal background variables (cognitive ability, parental education, and an indicator for family stability). Moreover, we include two sets of fixed effects: one for cohort and another for county of residence at age 17. Therefore our identification comes from variation within county and across time in distance to college, tuition, state unemployment and blue-collar wages. Our fixed effects estimators allow the interpretation as Difference-in-Difference estimators, where identification comes from differential changes of the instruments in different regions. Given that we include a large number of county dummies and that we have a limited sample, in order to get more precise results it is useful to expand the variation in our instruments by allowing their effect on the mother's schooling to depend on her cognitive ability, her parents' education, family stability, and cohort, i.e., we interact our instruments with these variables. We show that our results are robust to including polynomials in the controls in the outcome equations, which gives us confidence that by interacting instruments and controls we are not identifying the model from nonlinearities in the first stage regression. Finally, we present a simple falsification exercise, based on the idea that our set of instruments should affect mostly the college going decision, and therefore should not affect prior individual characteristics. We estimate regressions of maternal high school grades on maternal final schooling and other controls. As expected, we find that both cognitive ability and final schooling are associated with high school grades when we use least squares. However, only cognitive ability is related to high school grades when we instrument for schooling, and the coefficient on final schooling is close to zero and insignificant.

As mentioned above, in recent years we have witnessed the appearance of several papers on this topic. Behrman & Rosenzweig (2002) compare the schooling attainment of children of twin mothers and twin fathers (with different levels of schooling), in an attempt to control for family specific unobserved endowments. After accounting for family fixed effects they find that the effect of father's education remains strong and large in magnitude, but the effect of maternal education on child schooling disappears. They argue that this result may be due to the fact that maternal time is an important input in child development and that mothers with high levels of schooling spend less time with their children than mothers with less levels of schooling (see also Antonovics & Goldberger (2005), Behrman & Rosenzweig (2005)).

Currie & Moretti (2003), Black et al. (2005), Oreopoulos et al. (2003), Chevalier (2004), Chevalier et al. (2005), Maurin & McNally (2005), and Galindo-Rueda (2003) use an instrumental variables strategy (or regression discontinuity, in the case of the latter paper) to estimate the effect of parental education on child outcomes. Currie & Moretti (2003) use college openings as the instrument for schooling, while all the other papers rely on changes in compulsory schooling laws. Each paper focuses on different outcomes. Black et al. (2005) study the effect of parental schooling and child schooling using Norwegian data and find no significant effects of father's schooling and small but significant effects of mother's schooling on son's schooling. Oreopoulos et al. (2003) find strong effects of parental schooling on grade repetition and school dropout rates at age 16 using the US Censuses. Chevalier (2004) concludes that both father and mother's education have strong impacts on child education, but Chevalier et al. (2005) and Galindo-Rueda (2003) find weak or no effects of parental schooling. Finally, Currie & Moretti (2003) analyze US natality data and find that maternal education has significant effects on birthweight and gestational age. It also affects potential channels by which birth outcomes are improved, such as a reduction in smoking, an increase in the use of prenatal care, an increase in the probability that the mother is married and that the spouse is well educated. The study by Maurin & McNally (2005) uses lower examination standards during the 1968 student revolution in France as an instrument for father's schooling. They find a large positive effect on the difference between grade and age, a measure of progress in school.

Related studies by Plug (2004), Sacerdote (2002) and Bjoerklund et al. (2006) which are based on adoptions data compare the correlation between parental schooling and the outcomes of biological children, with the correlation between foster parents' schooling and adopted children's schooling. While the former confounds endowment and environmental effects, the latter (provided that adopted children are randomly allocated to foster families and are adopted at birth) is only driven by the effect of parental schooling on home environments. Adoption studies inform this debate by separating the effect of environmental and genetic factors (although their standard design can be problematic if there are substantial interactions between genes and environments), but they do not tell us directly about the causal effect of parental schooling on child outcomes. First, except in the case of the latter study, we cannot observe the schooling of biological parents which can influence pre-natal conditions and very early environments. Second, these studies cannot distinguish between the role of parental schooling and ability in the provision of better environments. Plug (2004) finds weak effects of adoptive mother's schooling on child's schooling but large effects of father's schooling, and these findings are consistent with those in Bjoerklund et al. (2006) who nevertheless find strong effects of both adoptive father and mother's schooling. Sacerdote (2002) argues that a college educated adoptive mother is associated with a 7% increase in the probability that the adopted child graduates from college.

The results in the literature are quite disparate and a consensus has not formed yet. Economists who argue that estimated effects maternal schooling on the outcomes of children are weak or non-existent suggest that this may occur because: a) maternal time is a very important input in child development and educated mothers work more, depriving their children from valuable time, offsetting other benefits of maternal education; b) there is strong assortative mating, and once we account for father's education the role of maternal education is relatively unimportant; c) there is heterogeneity in the effects of maternal education on child development, and compulsory schooling variation affects a set of mothers for whom the effect of additional schooling does not affect child outcomes, while college openings affect a different set of mothers for whom these effects are quite strong.

Our paper adds to the literature in several important ways, mainly due to the richness of our dataset. Because we can follow several children for several time periods it is possible to examine the impact of maternal education on cognitive and behavioural outcomes at different ages, namely early childhood, the elementary school years, and adolescence. Furthermore, because we can follow the mothers of these children for several time periods, we can also study the impact of maternal education on maternal labor market outcomes and family environments. Since we have a good measure of maternal cognitive ability (the Armed Forces Qualification Test, or AFQT) we can compare the relative roles of cognitive ability and schooling, and we can also examine how our estimates of the effect of schooling vary across ability levels which gives us some idea of the importance of heterogeneity. Furthermore we can analyze the effect of maternal schooling on spouse's schooling and on maternal labor supply at different ages of the child, two important factors to be considered.

We find that maternal education significantly increases human capital of the child as measured by a math test score: According to our estimates for white children aged 7 and 8, an increase in maternal schooling by one year will improve the child's performance in the test by about 13 percent of a standard deviation. Furthermore, white children aged 12 to 14 are significantly less likely to repeat a grade in school. Investigating potential transmission channels, we find that mother's age at birth, family income, and mating effects may be important pathways through which mother's education is transmitted to the child.

2 Children's Outcomes and Mother's Education

Maternal education is likely to affect both the quantity and the quality of investments in children. More educated mothers can make more informed choices about health and education investments, and they are more likely to live in richer households, be married and have a spouse with high levels of education. As a result they are not only able to invest more resources in their children, but also to make better investments. In terms of a simple model of parental investments, maternal education is likely to affect the budget constraint through increased resources, the technology of skill formation by which investments translate into child outcomes, and even the maternal expectations and the maternal discount rate.

An increase in maternal education also translates into an increase in the opportunity cost of maternal time. Therefore, we expect a shift away from time investments in children and towards market investments in children, such as external child care. However, as emphasized in Becker & Lewis (1973) and subsequent work, technologically there may be limited scope for substitution between time spent rearing children and market goods. As a result, mothers may instead substitute quantity for quality of children, by having fewer children and investing more intensively in each one (see also Becker et al. (1990)).

A question of interest is whether the influence of mother's education changes over the course of childhood. In principle, it is perceivable that the influence of mother's schooling changes over time in either direction. For example, as the child gets older, it may be subject to more external influences, and this may reduce the influence of mother's schooling. On the other hand, Becker (1993), Carneiro & Heckman (2003) and Cunha et al. (2005) suggest that differences may grow over time because children that are well prepared may find it easier to accumulate human capital. We will show how mother's education affects school achievement at different ages.

3 Data

We use data from the National Longitudinal Survey of Youth (NLSY79). This data set follows 12,686 young men and women, who are between 15 and 22 years old in the first survey year of 1979. Surveys are conducted annually from 1979 until 1994, and every two years from 1994 onwards. The last currently available survey round is from year 2002. The NSLY79 is a panel in the sense that the same individuals are followed over time.

Apart from the main cross-sectional sample representative for the population, the NLSY79 contains an over-sample representative of blacks and hispanics, an over-sample of economically disadvantaged whites, and a sample of members of the military. We restrict our analysis to the first two sub-samples, excluding the over-sample of economically disadvantaged whites and the sample of the military. This ensures that our sample is drawn according to predetermined characteristics. Attrition rates are very low: In the year 2000, after 19 survey rounds, retention rates are still above 80%. As will be described below, for our purpose only the females of the NLSY79 are of interest.

We measure mother's schooling as completed years of schooling. For example, this variable takes the value 10 if the respondent completes the sophomore year of high school and then drops out, the value 12 if the respondent completes high school, and the value 13 if the respondent completes the first year of college, and 16 if the respondent completes a four-year college degree. Since we observe mothers over a number of years, we have multiple observations of years of schooling. We are interested in the mother's schooling at the time when the outcome is measured. Occasionally, sample members do not answer this question in the year of interest; to include these observations, we take as measure of schooling the maximum number of completed years reported up to the year of interest.

The data contains detailed information on family background. For example, we know about the schooling of the respondents' parents, and whether the mother was raised by both her biological parents. Furthermore, the data set contains the mother's score in the Armed Forces Qualification Test (AFQT). This is a composite score from different sections of the Armed Services Vocational Aptitude Battery, administered in 1980. We use this test as a measure of mother's cognitive ability. The original AFQT score may be influenced by the amount of schooling taking up to the test date, but it is possible to estimate the effect of schooling on the test score (see Hansen et al. (2004)). This estimate can then be used to separate a measure of ability (we apply the same procedure as in Carneiro, Heckman & Vytlacil (2005)). Throughout the paper, we refer to the AFQT score as this schooling-corrected ability measure, normalized to have mean zero and standard deviation one.

In 1986, when the females of the NLSY79 are between 22 and 29 years old, another data set, the Children of the NLSY79, is initiated. This data set follows the children of the female members of the NLSY79 over time and contains detailed observations on the child throughout childhood and adolescence. Questionnaires are tailored to the age of the child, and information is collected from both the mother and the child. We match the information on each child of the NLSY79 to the data of the mother. The group of mothers evolves over time: While the members of the NLSY79 remain unchanged over time, the fraction of females with children increases over time. In the first waves of the Children of the NLSY79, the data set contains mostly children from the earlier cohorts of mothers, and from mothers that are relatively young. In 2000, the women of the NLSY79 have completed an average of 90% of their expected childbearing

(Center for Human Resource Research 2002). Even though the NLSY surveys a random sample of potential mothers, the design of the children's sample leads to an initial oversample of children of younger mothers, until all women are old enough and have completed their child-bearing period, so that all potential children of this sample of mothers are born.

The child survey is quite detailed. We start by focusing on ages 3-14. There are several measures of cognitive ability at these ages, and one focus of this paper is on test score performance in a standardized math test. These test scores reflect a child's "ability to learn or to achieve in school" (Smith et al. 1997). The Peabody Individual Achievement Test (PIAT) in mathematics measures academic achievement in math, and is both widely used and possesses good reliability and validity properties (Center for Human Resource Research 2002). The child is asked to answer 84 multiple-choice questions of increasing difficulty. The child's answers are used to compute a raw score. This raw score in then transformed into an age-specific standardized score, which is informative about the relative performance of a child compared to other children of the same age. We use this standardized score in all of our regressions, because it allows a natural interpretation in terms of movement within the distribution of test scores. Children take these tests at different ages. For the math test, we initially focus on children aged 7 and 8, but we also present results for children aged 12 to 14.

We also consider a second measure of school performance: grade repetition. Mothers are asked whether their child ever repeated a grade in school, if any, which grade the child repeated, and for what reason grade repetition took place. From this information, we construct an indicator whether the child ever repeated a grade. We again limit our attention to one specific age range. Because grade repetition occurs more frequently in later years of high school, and because exposure is higher at a higher age, we focus on the group of pupils aged 12 to 14.

A third outcome of interest is the Behavior Problem Index (BPI). The BPI measures frequency, range, and type of a child's behavioural problems (Center for Human Resource Research 2002), and we take this variable as an age and gender specific standardized score. For all these outcomes we will focus on ages 7 and 8, although we will also examine how our analysis changes when we look at other ages.

We now turn our attention to the potential channels. First, we look at mother's characteristics. The mother's age at birth is the age in years at the birth of the child. We also consider an indicator variable for whether the mother is married. Income effects are addressed by looking at log family income; to get a measure of permanent income, we take the average of all non-missing wage observations over a five-year period, centered around the year of interest. For the schooling aspirations, mother and child are asked separately to indicate how far they believe the child will advance in school. We create two indicator variables, taking the value 1 if the mother, or the child, respectively, believe that the child will graduate from college or get more education than that. We believe that this variable is informative about mothers' and children's scholastic ambitions.

Finally, in order to investigate a quality/quantity-tradeoff, we study the effect of mother's education on the total number of children reported by the mother. For investigating assortative mating effects, we consider the years of schooling of the mother's spouse. And we study maternal employment by looking at hours and weeks worked per year. We observe all these variables at a particular age of the child. Thus, we take the child's age as the relevant reference point for observing the measures of interest.

We will also briefly look at children's outcomes very early in life and in adolescent years. Early measures include birthweight, an assessment of early motor skills and an assessment of knowledge of parts of the body. Adolescent (and young adult) outcomes include enrolment in school, criminal convictions and number of children.

The instruments are average tuition in public four-year colleges in the county of residence at age 17 deflated (to 1993), distance to four-year colleges at age 14 and local unemployment rate in state of residence at age 17. The distance variable, which is from Kling (2001), is an indicator variable whether a four-year college is in the county of residence at age 14. The state unemployment rate data comes from the BLS website. However, from the BLS website it is not possible to get state unemployment data for all states for all the 1970s (data is available for all states from 1976 on, and it is available for 29 states for 1973, 1974 and 1975), and therefore for some of the individuals we have to assign them the unemployment rate in the state of residence in 1976 (which will correspond to age 19 for those born in 1957 and age 18 for those born in 1958). Annual records on tuition, enrollment, and location of all public two- and four year colleges in the United States were constructed from the Department of Education's annual Higher Education General Information Survey and Integrated Postsecondary Education Data System 'Institutional Characteristics' surveys. By matching location with county of residence, we determined the presence of two-year and four-year colleges. Tuition measures are taken as enrollment weighted averages of all public two- or four-year colleges in a person's county of residence (if available) or at the state level if no college is available. County and state of residence at 17 are not available for everyone in the NLSY, but only for the cohorts born in 1962, 1963 and 1964 (age 17 in 1979, 1980 and 1981). However, county and state of residence at age 14 is available for most respondents.

Therefore, we impute location at 17 to be equal to location at 14 for cohorts born between 1957 and 1962 unless location at 14 is missing, in which case we use location in 1979 for the imputation. For a detailed description of the NLSY sample, see Center for Human Resource Research (2001).

The data set, limited to the subsamples of interest, contains information on a total of 4,379 white children (from 1,948 white mothers). We then restrict attention to those children-mother pairs for which we observe maternal characteristics, locations during adolescents, and child outcomes. For some children, we observe the outcome more than once during the age range of interest. To increase precision of our estimates, we pool all available observations within this age range of interest. Since we cluster all standard errors by county of mother's residence at age 17, we allow for arbitrary dependence between repeat observations from a particular child between outcomes of several children from one mother. Our final sample sizes for ages 7 and 8 are for white children 2,400 for the math test for white children, 2,470 for the BPI score, and 1,853 for the measure of grade repetition. The sample sizes differ by outcome because for some children, not all outcomes are observed. When we present results, we always indicate the number of observations included in a particular regression. Sample statistics for white children aged 7 and 8 are reported in Table 1.

4 Identification

Let the child outcome be determined as

$$\text{Outcome} = \beta S + \delta X + u \qquad (1)$$

where S is mother's years of schooling, X is a set of exogenous covariates, and u is an error term. There are several reasons why OLS estimates may

Table 1: Descriptive sample statistics

	(1) **PIAT Math** age 7-8	(2) **BPI** age 7-8	(3) **Grade repetition** age 12-14
Outcome	104.77	104.31	0.11
	(11.75)	(14.90)	(0.31)
Mother's yrs. of schooling	13.25	13.26	12.99
	(2.20)	(2.22)	(2.11)
Mother's AFQT (corrected)	0.38	0.37	0.27
	(0.87)	(0.87)	(0.90)
Grandmother's yrs. of schooling	11.75	11.77	11.51
	(2.24)	(2.27)	(2.28)
Grandfather's yrs. of schooling	11.83	11.88	11.54
	(3.14)	(3.16)	(3.10)
'Broken home' status	0.20	0.20	0.22
	(0.40)	(0.40)	(0.41)
Child age (months)	95.08	95.07	0.50
	(6.96)	(6.92)	(0.50)
Child female	0.50	0.49	158.44
	(0.50)	(0.50)	(9.02)
College availability	0.54	0.55	0.51
	(0.50)	(0.50)	(0.50)
Local tuition	2117.14	2111.02	2143.20
	(861.84)	(858.21)	(886.38)
Local unemployment	7.17	7.18	7.22
	(1.74)	(1.76)	(1.74)
Local wage rate	5.72	5.73	5.60
	(1.63)	(1.64)	(1.57)
Observations	2400	2470	1853

The table reports sample means and (in brackets) standard deviations. Since sample sizes differ slightly between outcomes, we report means and standard deviations separately for each child outcome (PIAT Math, Grade repetition, BPI). *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15.

be biased: First, unobserved heterogeneity in tastes and preferences may affect both schooling choice and the child's outcome. Such heterogeneity may lead to a correlation between the error term and the schooling variable. Second, mother's schooling may be measured with error. Therefore, we apply an instrumental variable strategy. This strategy exploits the variation in observed mother's schooling that is due to differences in the cost of schooling. We assume that mother's schooling is determined as

$$S = \gamma Z + \theta X + \epsilon \tag{2}$$

where Z is a schooling cost variable and ϵ is the error term of the schooling equation.

We now turn to the choice of the variable measuring cost of schooling. We use geographical and intertemporal variation in both institutional features of the schooling system and labour market conditions. As additional instruments, we also interact these variables with the mother's family background variables.

One form of cost of schooling is the amount of tuition fees a student faces. Tuition variables have frequently been used as instruments (e.g. Kane & Rouse (1993)). Another major cost of acquiring higher education is foregone earnings. If an individual assesses potential earnings as the expected value of earnings when entering the labour market, then this expected value will be affected by the labour market conditions. We choose two aspects of these conditions: The local unemployment rate and the local blue-collar wage rate. The unemployment rate reflects the probability of not finding a job, and the blue-collar wage rate can be interpreted as the relevant wage for an unskilled worker entering the labour force. In particular, business cycles will affect local labour market conditions, and the individuals may respond to temporary economic downturns by choosing to acquire further education. Local earnings has also been used as an instrument by Cameron & Taber (2004), and state unemployment rate has been studied as an instrument for schooling by Arkes (2005).

For our IV strategy to be successful, two condition need to be satisfied: The schooling cost variables need to be correlated with mother's schooling, and the cost variables must not have an independent effect in the outcome equation except through mother's schooling. Considering the former aspect first. A utility-maximizing individual will choose education to equate marginal costs and marginal benefits. If our instruments affect marginal costs, but leave marginal benefits unchanged, standard assumptions yield the prediction that higher schooling costs reduce the chosen level of schooling. In particular, we expect to find tuition rates to be negatively related to schooling attainment, and the presence of a local college to be positively associated with schooling attainment.

Table 2 shows the first stage estimates, where the sample of interest are white children aged 7 and 8. Each column represents one outcome measure. We report the first stage estimates separately for each outcome because of the slight differences in sample size between each outcome regression. The table reports marginal effects of each regressor. Mother's ability level and grandparents' schooling are strong predictors of mother's education. The bottom panel shows the marginal effects of the instruments; both the indicator for local college availability and the tuition rate variable have the predicted signs. The instruments are jointly significant at the 1% level with an F-statistic of 2.54 in the case of the PIAT math regression.

Of course, underlying the use of geographical variation in schooling costs is the presumption that *local* variables matter to the choice of the individual. In principal, individuals might move to a different location for their studies, e.g. in order to avoid high tuition costs. Still, it seems reasonable to believe that

Table 2: First stage regressions: Marginal effects (dependent variable: mother's years of completed schooling)

	PIAT Math age 7-8 (1)	**BPI** age 7-8 (2)	**Grade repetition** age 12-14 (3)
Mother's AFQT (corrected)	0.930	0.955	0.828
	[0.073]***	[0.073]***	[0.090]***
Grandmother's yrs. of schooling	0.178	0.181	0.150
	[0.033]***	[0.033]***	[0.042]***
Grandfather's yrs. of schooling	0.132	0.132	0.124
	[0.029]***	[0.028]***	[0.036]***
'Broken home' status	-0.243	-0.186	-0.388
	[0.144]*	[0.133]	[0.156]**
Child female	0.059	0.080	-0.009
	[0.068]	[0.069]	[0.085]
Child age (months)	-0.008	-0.010	0.001
	[0.004]*	[0.004]**	[0.003]
College availability	0.467	0.499	0.008
	[0.370]	[0.349]	[0.461]
Local tuition/1000	-0.089	-0.028	-0.251
	[0.349]	[0.331]	[0.358]
Local unemployment	-0.170	-0.146	-0.081
	[0.087]*	[0.086]*	[0.113]
Local wage rate	0.127	0.082	0.103
	[0.123]	[0.115]	[0.149]
Observations	2400	2470	1853
R-squared	0.59	0.58	0.24
F-statistic of IVs	2.54	2.24	2.34
p-value of IVs	0.00	0.00	0.00

Note: This table reports estimates from the first stage. Since sample sizes differ slightly between outcomes, we report the first stage separately for each child outcome (PIAT Math, Grade repetition, BPI). Table reports estimated marginal effects of a change in the variable indicated, evaluated at the mean. Regressors not listed here are mother cohort fixed effects and county fixed effects. Asymptotic standard errors reported in brackets, clustered by county of residence at 17. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level.

local variation matters: Moving is costly for a variety of reasons: The student is prevented from the option of living at home (Card 1993, p. 10). Furthermore, movers may be disadvantaged in the form of higher out-of-state tuition. Currie & Moretti (2002, Table 11) report evidence that student mobility is limited: Their analysis shows that the majority of students do not move to a different state to go to college. Hoxby (1997, pp.46-47) shows that in 1968 and 1981, about 90% of students from public colleges attend college in-state. After including private colleges, the figure is about 80%. She also presents evidence that college choice is significantly determined by cost variables: Higher college tuition and larger distance to college significantly reduce the probability of a college-student match.

The second requirement for our instruments is that they do not have an independent effect on the outcome. We assume that the error terms are mean-independent of the instruments Z,

$$E[u|Z] \ = 0 \tag{3}$$

The claim we make is that after controlling for mother's family background, mother's ability, and state fixed effects, there is no systematic relation between the instruments and any unobserved factors that affect the outcome of interest. In the following, we address potential criticism of this assumption. We consider systematic location choice (sorting), college quality, and potential correlation between the instrumental variables and regional quality.

Geographical sorting relates to the question whether individuals move to certain counties in a way which creates a correlation between the instrumental variables and unobserved factors. If these factors are relevant for the outcome of interest, they are captured in the error term of the outcome equation. A correlation between the instrument and this error term would make the instrument invalid. To assess this point it is important to understand who makes the location choice. We consider schooling cost variables at the time when the mothers are in their last years of high school. Most of the respondents still live with their parents, and it is the parents who make location choices. Given the fluctuations in the instruments over time, it is unlikely that location choice will be related to the instruments at the time when the mother takes the college decision. We also control for different characteristics of mother's family background. If location sorting occurs based on observable characteristics, we will capture this with the family background variables. In summary, given our detailed family background controls and the fluctuations in the schooling cost variables, we do not believe that parental sorting is likely to influence our results.

The second concern relates to college quality. If higher tuition is associated with higher college quality, and if higher college quality makes mothers better at child rearing, then this could bias our results. First, we use tuition from public colleges only; any link between cost and quality can be expected to be weaker in comparison to private colleges. Second, a main determinant of college quality is the quality of the students; this aspect is captured by including an ability measure of the mother, and by including family background variables. We also capture any college quality differential between counties by including county fixed effects. Therefore, it does not seem likely that, after controlling for mother's ability, mother's family background, and county fixed effects, endogeneity of tuition due to college quality will pose a problem.

The third concern is about a potential relationship between our labour market variables and some unobserved regional quality. For example, high wage states may also offer good infrastructure and public services. We address this concern by including county fixed effects in all our regressions. Then, any components of our labour market variables that are constant over time will be absorbed by this regional fixed effects, and our labour market variables, which are observed on state level, have the interpretation of business cycle effects. A related concern is about neighbourhood effects (Solon 1999), describing a systematic relation between neighbourhood characteristics and schooling cost variables. Again, inclusion of county fixed effects will absorb any permanent neighbourhood effects, so that our identification relies only on changes in the instruments over time. Furthermore, the mother cohort fixed effects will remove any time trend between the instruments and schooling attainment over the different mother cohorts.

Our instruments should be related mostly with college choice since they are either concerned explicitly with the cost of attending college (such as local tuition, or the presence of a college) or they are measured at age 17 (as in the case of local labor market variables). Therefore, if they are valid instruments, conditional on our extensive set of controls they should be uncorrelated with variables that are set before college going age. In the following, we examine whether these instruments predict high school grades conditional on our controls. Based on the high school transcripts of NLSY respondents, we construct two measures of high school achievement: percentage of subjects where the individual got a classification of A or above, and percentage of subjects where the individual got a classification of B or above. We then regress these two measures on schooling and our control variables, and we instrument schooling using our instruments described above. To be consistent with the rest of the paper, the unit of observation in each regression is the child at age 7 or 8, even though this regression is concerned with mother only. In particular, we have one observation for each child that is aged 7 or 8 in the sample, the ages at which we measure our main set of child outcomes. Therefore there may be more than one observation per mother, since each mother can have several children, or one child may be observed twice in the age range. Running the regression using mothers as the unit of observation (i.e. using only a single observation per mother) essentially the same results.

Table 3: Instrument validity

	fraction A-grades or above		**fraction B-grades or above**	
	(1) OLS	(2) IV	(2) OLS	(1) IV
Mother's yrs. of schooling	0.032	0.003	0.029	-0.008
	[0.005]***	[0.020]	[0.005]***	[0.022]
Mother's AFQT (corrected)	0.115	0.140	0.110	0.143
	[0.010]***	[0.020]***	[0.010]***	[0.022]***
Grandmother's yrs. of schooling	0.005	0.009	0.003	0.009
	[0.004]	[0.006]*	[0.004]	[0.006]
Grandfather's yrs. of schooling	-0.002	0.001	-0.002	0.002
	[0.003]	[0.003]	[0.003]	[0.004]
'Broken home' status	-0.037	-0.045	-0.029	-0.039
	[0.019]*	[0.021]**	[0.020]	[0.022]*
Child female	-0.004	-0.003	-0.004	-0.002
	[0.008]	[0.009]	[0.010]	[0.010]
Child age (months)	-0.000	-0.000	0.000	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]
Observations	3511	3511	3511	3511
R-squared	0.56	0.54	0.50	0.46

Dependent variable is fraction of A-grades or above (columns (1) and (2)) and fraction of B-grades or above (columns (3) and (4)). Regressors not listed here are county fixed effects and mother cohort fixed effects. Asymptotic standard errors reported in brackets, clustered by county of residence at 17. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level.

Table 3 presents OLS and IV results for each high school achievement measure. Notice that final maternal schooling and AFQT are strongly associated with high school achievement in the OLS regressions, but only AFQT is associated with high school grades in the IV regressions. In the latter the coefficient on schooling is quite small and statistically it is not different from zero. This is exactly what we would expect if our identification strategy was valid.

5 Results

5.1 Effects on Child Outcomes and Maternal Characteristics at Ages 7 and 8 of White Children

Having described our identification strategy in the previous section, we now turn to the results. We regress a number of different outcomes on maternal schooling and a set of controls, instrumenting maternal schooling with the presence of a college, average tuition, local unemployment and local blue collar wage in the area of residence of the mother in late adolescence (and interactions of these variables with controls). Our vector of control variables includes maternal AFQT, grandparents education, whether the mother lived in a broken home at 14 ('family stability indicator'), and dummy variables for maternal cohort and county of residence at 17. We start by measuring outcomes when the child is aged 7 or 8, although we will also look at outcomes measured at other ages. We also focus on white children, although later we extend our analysis to black children as well.

Our main set of child outcomes at ages 7 and 8 are the standardized score in the PIAT-Math test, the standardized score in the BPI assessment, and an indicator for grade repetition. OLS and IV estimates of the effect of maternal education on these outcomes are presented in Table 4.

One year of additional mother's education increases mathematics standardized scores by roughly 1.925 points, which is short of 0.13 of a standard deviation (the test is normalized to have mean 100 and standard deviation 15). Notice that this is higher than the OLS estimate which is 0.742. The estimate of the effect of mother's cognitive ability on children's mathematics performance

Table 4: Child outcomes: White children aged 7 and 8

	PIAT Math		**BPI**		**Grade repetition**	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Mother's yrs. of schooling	0.742	1.925	-1.307	-0.234	-0.007	-0.009
	[0.185]***	[0.887]**	[0.257]***	[1.077]	[0.004]	[0.014]
Mother's AFQT (corrected)	2.677	1.561	0.566	-0.470	-0.010	-0.008
	[0.424]***	[0.912]*	[0.612]	[1.150]	[0.008]	[0.014]
Grandmother's yrs. of schooling	0.588	0.388	-0.521	-0.712	-0.003	-0.003
	[0.177]***	[0.214]*	[0.263]**	[0.313]**	[0.004]	[0.004]
Grandfather's yrs. of schooling	-0.140	-0.315	0.130	-0.023	0.003	0.003
	[0.132]	[0.183]*	[0.166]	[0.221]	[0.003]	[0.003]
'Broken home' status	-1.300	-0.967	2.259	2.536	-0.014	-0.014
	[0.702]*	[0.751]	[1.103]**	[1.182]**	[0.021]	[0.021]
Child female	-0.833	-0.906	1.607	1.513	-0.004	-0.004
	[0.529]	[0.538]*	[0.646]**	[0.660]**	[0.009]	[0.009]
Child age (months)	0.086	0.096	-0.005	0.007	0.001	0.001
	[0.036]**	[0.037]***	[0.043]	[0.043]	[0.001]	[0.001]
Observations	2400	2400	2470	2470	1153	1153
R-squared	0.28	0.26	0.21	0.20	0.22	0.22
F-statistic of IVs (first stage)		2.54		2.24		2.79
p-value of IVs (first stage)		0.00		0.00		0.00

Note: *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade. Regressors not listed here are county fixed effects and mother cohort fixed effects. Asymptotic standard errors reported in brackets, clustered by county of residence at 17. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. F-test refers to the hypothesis that all instruments are jointly zero on the first stage. See text for details.

decreases from 2.677 to 1.561 when we go from least squares to instrumental variables, but both coefficients are statistically strong. Our effects are not only statistically strong but they are also quantitatively large. As a comparison, the large and expensive class size reduction of the STAR experiment (a reduction from 22 to 15 studies per class, studied by Krueger (2002) yielded test score gains of 0.2 standard deviations, while an increase in maternal education by one year increases child achievement by 0.13 standard deviations.

At first sight it is surprising that IV estimates of the effect of maternal education are larger than OLS estimates, since a simple ability bias intuition would tell us otherwise. However, this result is common in the large returns to schooling literature (Card 1999) and it is also present in the papers by Currie & Moretti (2003) and Oreopoulos et al. (2003). The usual argument is that if the effect of schooling varies across mothers then standard intuitions that are valid in the fixed coefficient model no longer apply, and IV estimates may well exceed OLS estimates of the effect of maternal schooling on child outcomes (see also Carneiro & Heckman (2002), Carneiro, Heckman & Vytlacil (2005)). Later in this paper we assess the importance of heterogeneity in the effect of maternal education on child outcomes.

When we examine the importance of mother's education on child behavioural problems as measured by the BPI index we do not find strong effects when we instrument, although the least squares association is strong. Therefore, we find strong effects of maternal schooling (and ability) on the school achievement of their children at ages 7 and 8, but not on their children's behavioural problems.

Columns (5) and (6) of Table 4 show the estimates for our measure of grade repetition for the children aged 7 and 8. At this young age, grade repetition is extremely rare. We do not find any significant effect of maternal education, neither in the OLS nor in the IV results. Grade repetition is a much more relevant phenomena at later points in the children's schooling career. To assess this, we now turn to children aged 12 to 14. The estimation results for the three outcomes of interest are reported in Table 5.

The last column of this table shows that an additional year of maternal schooling reduces the probability of grade repetition by almost 8 percentage points. This estimate is highly significant and suggests that there is a strong effect of maternal education on her child's school performance as measured by grade repetition. It is also interesting to consider columns (1) through (4) of this table, which provides estimates of the PIAT math test and the BPI score for this older age group. These estimates essentially confirm our earlier conclusion about the impact of maternal education in that there is a strong effect on the math score, but not on the behavioural problem index. Interestingly, the coefficient estimate in the math test regression is higher for children aged 12 to 14 than for children aged 7 to 8, suggesting that the effect of maternal education may in fact increase over time.

The richness of our data also allows us to explore potential channels by which maternal education affects children's outcomes.

Table 6 report the effects of maternal education on maternal age at birth, mother's marital status and log family income. An increase in mother's schooling by one year leads to an increase in maternal age at birth by 0.95 years, an increase in family income by 13.3% and an increase in the probability of being married of 5.8%. However, the latter is imprecisely measured and we cannot reject that the effect is equal to zero. Nevertheless, the increases in both maternal age at birth and family resources are quite substantial and are likely to positively impact home environments and child development. There are several estimates of the effect of family income on child development. Two important examples are Mayer (1997), who argues that these effects are small, while Dahl

Table 5: Child outcomes: White children aged 12 to 14

	PIAT Math		**BPI**		**Grade repetition**	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	OLS	IV	OLS	IV
Mother's yrs. of schooling	0.509	2.404	-1.381	-1.137	-0.028	-0.079
	[0.247]**	[1.159]**	[0.324]***	[1.389]	[0.007]***	[0.025]***
Mother's AFQT (corrected)	3.578	2.088	1.088	0.895	-0.026	0.015
	[0.545]***	[1.073]*	[0.696]	[1.196]	[0.012]**	[0.025]
Grandmother's yrs. of schooling	0.498	0.251	-0.347	-0.384	-0.008	0.000
	[0.213]**	[0.262]	[0.251]	[0.322]	[0.005]	[0.005]
Grandfather's yrs. of schooling	0.118	-0.166	-0.021	-0.055	0.003	0.010
	[0.167]	[0.211]	[0.199]	[0.262]	[0.004]	[0.005]*
'Broken home' status	-1.415	-0.692	1.179	1.277	0.014	-0.008
	[0.969]	[1.217]	[1.275]	[1.369]	[0.028]	[0.029]
Child female	-2.688	-2.679	1.157	1.155	-0.061	-0.060
	[0.660]***	[0.693]***	[0.765]	[0.767]	[0.016]***	[0.017]***
Child age (months)	-0.075	-0.071	-0.002	-0.002	-0.000	-0.000
	[0.027]***	[0.028]**	[0.030]	[0.030]	[0.001]	[0.001]
Observations	2008	2008	2146	2146	1853	1853
R-squared	0.35	0.31	0.24	0.24	0.29	0.24
F-statistic of IVs (first stage)		2.19		2.44		2.34
p-value of IVs (first stage)		0.00		0.00		0.00

Note: *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade. Regressors not listed here are county fixed effects and mother cohort FE. Asymptotic standard errors reported in brackets. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. F-test refers to the hypothesis that all instruments are jointly zero on the first stage. See text for details.

Table 6: Mother characteristics (of white children aged 7 to 8)

	mother age at child birth		**Mother married**		**number of children**		**Spouse schooling**		**log family income**		**annual hours worked**		**mother aspirations**	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV	(7) OLS	(8) IV	(9) OLS	(10) IV	(11) OLS	(12) IV	(13) OLS	(14) IV
Mother's yrs. of schooling	0.994	0.945	0.018	0.058	-0.042	-0.007	0.507	0.597	0.119	0.133	68.601	109.292	0.041	0.078
	[0.054]***	[0.267]***	[0.007]**	[0.035]	[0.025]*	[0.128]	[0.043]***	[0.175]***	[0.012]***	[0.053]**	[13.463]***	[79.446]	[0.008]***	[0.030]**
Mother's AFQT (corrected)	0.056	0.101	0.051	0.014	0.025	-0.007	0.064	-0.020	0.180	0.167	70.638	33.227	0.047	0.012
	[0.132]	[0.282]	[0.014]***	[0.035]	[0.054]	[0.124]	[0.098]	[0.196]	[0.028]***	[0.055]***	[39.237]*	[82.895]	[0.025]*	[0.037]
Grandmother's yrs. of schooling	0.133	0.141	0.002	-0.005	-0.003	-0.009	0.097	0.079	0.014	0.012	-6.128	-13.020	0.007	0.000
	[0.055]**	[0.069]**	[0.007]	[0.009]	[0.025]	[0.029]	[0.038]**	[0.053]	[0.012]	[0.014]	[14.877]	[20.305]	[0.007]	[0.009]
Grandfather's yrs. of schooling	-0.021	-0.014	-0.001	-0.006	0.006	0.001	0.090	0.078	-0.007	-0.009	-15.437	-21.077	0.013	0.008
	[0.043]	[0.051]	[0.005]	[0.007]	[0.015]	[0.025]	[0.030]***	[0.038]**	[0.008]	[0.011]	[11.035]	[14.542]	[0.006]**	[0.008]
'Broken home' status	-0.150	-0.165	-0.069	-0.057	0.224	0.234	-0.041	-0.006	-0.108	-0.104	-59.446	-48.283	-0.081	-0.079
	[0.252]	[0.268]	[0.033]**	[0.033]*	[0.160]	[0.163]	[0.210]	[0.219]	[0.060]*	[0.063]	[72.138]	[78.174]	[0.048]*	[0.046]*
Child female	-0.036	-0.032	-0.014	-0.017	0.009	0.007	0.013	0.012	0.010	0.009	1.319	-1.770	0.047	0.042
	[0.159]	[0.162]	[0.015]	[0.016]	[0.051]	[0.054]	[0.085]	[0.086]	[0.027]	[0.027]	[37.424]	[37.429]	[0.028]*	[0.028]
Child age (months)	-0.027	-0.028	-0.000	0.000	0.000	0.001	-0.003	-0.003	0.002	0.003	-0.511	-0.220	-0.001	-0.000
	[0.007]***	[0.008]***	[0.001]	[0.001]	[0.002]	[0.002]	[0.004]	[0.004]	[0.001]**	[0.001]**	[1.895]	[2.064]	[0.002]	[0.002]
Observations	4215	4215	4212	4212	4215	4215	3194	3194	4131	4131	4132	4132	1194	1194
R-squared	0.40	0.40	0.24	0.22	0.30	0.30	0.52	0.52	0.41	0.41	0.23	0.23	0.35	0.34
F-statistic of IVs (first stage)		2.24		2.24		2.24		3.12		2.37		2.07		2.57
p-value of IVs (first stage)		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Note: *Mother's age at birth* is the age of the mother in years at birth of the child. *Mother married* is an indicator variable, taking the value 1 if the mother is married, and 0 otherwise. *Log family income* is the logarithm of average family income; average family income is the average of all non-missing family income observations within a five year window centered at the year of interest. *Number of children* is the total number of children ever reported. *Spouse's schooling* is the number of years of schooling completed by the mother's spouse. *Annual hours worked* is the number of hours worked by the mother in the year of interest. *Mother's aspirations* is an indicator variable, taking the value 1 if the mother believes the child will graduate from college or get more than 4 years of college education, and 0 otherwise. See text for details.

Regressors not listed here are county fixed effects and mother cohort fixed effects. Asymptotic standard errors reported in brackets. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. F-test refers to the hypothesis that all instruments are jointly zero on the first stage. See text for details.

& Lochner (2006) find strong effects of family income on mathematics and reading achievement (a $1000 increase in income leads to an increase in math test scores by 2% of a standard deviation).

Several economists have recently argued that it is very important to account for the effects of assortative mating because the causal effect of maternal education on child performance may come only through her ability to find a more educated father for the child. They also argue that maternal education can have offsetting effects because if on one hand the child benefits from better home environments and perhaps richer investments, she will benefit of less maternal time since more educated mothers spend more time in the labor market. Two important examples are Behrman & Rosenzweig (2002) and Plug (2004), who argue that maternal education has small or no effects on child's schooling, while father's education has large and strong effects on this outcome. Unfortunately we do not have good instrumental variables for either spouse's schooling or for maternal labor supply and therefore cannot directly assess the validity of these arguments in our data. However, we can examine the effect of maternal schooling on spouse's schooling and on maternal labor supply.

In column (6) we estimate the effect of maternal education on fertility. Surprisingly, the effect is small and insignificant, at least for white mothers, although the OLS coefficient is quite small to start with. In the next section we show that the effects for black mothers are much larger.

Column (8) of the table looks at spouse's schooling and shows that an increase of one year in maternal education leads to an increase of 0.6 years of spouse's education. This means that if we were to attribute all the effects of maternal education to assortative mating one would need father's schooling to have almost twice as large effects as the ones we estimate, which can be quite unreasonable in some cases. Therefore, assortative mating effects are strong but they are probably not driving the whole story here. Furthermore, our instruments may not be valid in this case because, if both parents grew up in the same area and have similar ages, whatever affects maternal schooling is also likely to affect paternal schooling (see also Currie & Moretti (2003)). In this case, we believe that it is more likely that the bias in the coefficient is upward rather than downward.

Column (12) looks at the effects of maternal education on maternal employment measured in terms of annual hours worked. We estimate that annual hours worked increase by 109 hours per additional year of maternal schooling (roughly 9.6% of the mean which is about 1142 hours worked per year). While this is a strong effect, it amounts to roughly 3 weeks of full-time work per year. If we were to compare two mothers, one with a college degree and one without, our estimates suggest that the former would work 12 more weeks per year than the latter. Cumulating over several years of childhood, these will translate into both substantial more family resources for the mother with a college degree, but substantial less time with the child. The latter can have a strong offsetting effect on the former, although it depends on what kind of substitutes educated mothers can find for their time with their child.

Column (14) shows that more educated mother's have significantly higher aspirations with respect to their children's schooling: They are 7.7 percentage points more likely to believe that their offspring will complete college. To the extent that these expectations translate into different behavior on the side of the mother and the child, they may be an important contributing factor in shaping the educational career of the child.

In this literature is quite standard to separately analyze the effects of maternal schooling on girls' and boys' outcomes. In Table 12 in the appendix we show these results separately by gender.

In summary, there exist strong effects of maternal education on child development. Two important channels by which educated mothers provide better environments for their children is by postponing childbearing and by increasing family resources. Even though it could be possible that all the effect of maternal education on child outcomes and family environments is due to assortative mating, we doubt this is the case given the magnitude of the estimates. Furthermore, we also show that the effect of education on maternal labor supply (and therefore, on maternal time at home) is sizeable.

5.2 Differences between Black and White Families

It is now well documented that there are large differences in the process of human capital accumulation of blacks and whites (see, e.g., Currie/Thomas (1995), Jencks & Phillips (1998), Fryer/Levitt (2005), Carneiro, Heckman & Masterov (2005), Neal (2005)). Furthermore, ethnic differences in skill formation are an important source of concern for education policies in many countries. Therefore it is of great interest to compare the role of maternal education in child development for white and black families.

In Table 7 we present estimates of the effect of maternal education on black children outcomes and family environments. Column (2) shows that the effect on mathematics scores is just slightly below that for whites (although the effect of AFQT is higher than for whites). As for white children, we find no significant effect on the BPI score.

Columns (8) and (10) show that the effect on maternal age at birth and marital status are very similar compared to the estimates for white children. The effect on family income, if anything, is slightly smaller than for whites (column (16)). The same is true of the effect of maternal education on the her spouse's education, as shown in column (14). However, black mother's

Table 7: Child outcomes and mother characteristics of black children (ages 7 and 8)

PIAT Math		BPI		Grade repetition		mother age at child birth		Mother married		number of children		Spouse schooling		average family income		annual hours worked		mother's aspirations	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
1.178	1.587	-0.593	-0.727	-0.001	0.021	0.977	1.078	0.027	0.054	-0.214	-0.345	0.401	0.195	0.116	0.106	171.993	131.574	0.069	-0.023
[0.317]***	[0.962]	[0.528]	[1.323]	[0.010]	[0.020]	[0.074]***	[0.224]***	[0.013]**	[0.040]	[0.041]***	[0.115]***	[0.083]***	[0.147]	[0.013]***	[0.054]*	[16.609]***	[64.396]**	[0.019]	[0.039]
1298	1298	1267	1267	411	411	2694	2694	2693	2693	2694	2694	958	958	2627	2627	2669	2669	439	439

Note: Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade.

Mother's age at birth is the age of the mother in years at birth of the child. *Mother married* is an indicator variable, taking the value 1 if the mother is married, and 0 otherwise. *Log family income* is the logarithm of average family income; average family income is the average of all non-missing family income observations within a five year window centered at the year of interest. *Number of children* is the total number of children ever reported. *Spouse's schooling* is the number of years of schooling completed by the mother's spouse. *Annual hours worked* is the number of hours worked by the mother in the year of interest. *Mother's aspirations* is an indicator variable, taking the value 1 if the mother believes the child will graduate from college or get more than 4 years of college education, and 0 otherwise.

experience larger effects of mother's education on maternal labor supply (column (18)) and especially on fertility (column (12)): there is roughly one less offspring per three years of education. It is in these two variables, especially the latter, that there exist major differences in our results for blacks and white families.

Strong effects on fertility for black mothers may arise for several reasons. For example, education leads to an increase in the cost of time and therefore in the cost of children, inducing mothers to trade-off quantity for quality of children, as suggested in Becker & Lewis (1973). Since fertility rates are higher for black mothers than for white mothers there is more room for this mechanism for the former group than for the latter group. Education may also affect maternal awareness of family planning methods, change maternal marriage market opportunities or her peer groups, all of which can affect her fertility.

5.3 Differences between Mothers with High and Low Levels of AFQT

It is possible that there is considerable heterogeneity on the effects of maternal education. From a policy perspective it is crucial to assess the importance of such heterogeneity since an increase in maternal education can have very different effects on the children of different mothers, so that the large effects we present in Table 4 are not uniform in the population. From an academic perspective a careful analysis of heterogeneity can help us understand why our IV estimates of the effect of maternal education on child achievement exceed the OLS estimates (as in the analysis of the effect of schooling on wages in Carneiro, Heckman & Vytlacil (2005)). Unfortunately, a full analysis of heterogeneity as in Carneiro, Heckman & Vytlacil (2005), is constrained by data limitations. First, our schooling variable is multivalued and we do not have multiple exclusion restrictions to analyze heterogeneity in each schooling transition. Second, even when we made our schooling variable binary, as in Carneiro, Heckman & Vytlacil (2005), our estimates of the marginal treatment effect are quite imprecise. Therefore we pursue a much simpler route, although it is also much less rich in information. In particular, we characterize how our estimates of the role of maternal schooling vary across mothers with high and low levels of AFQT, which is an important determinant of both maternal schooling and child outcomes, and has been shown in other work to be an important determinant of the returns to schooling (e.g., Murnane/Willet/Levy (1995), Heckman/Vytlacil(2001), Carneiro, Heckman & Vytlacil (2005)).

We divide white mothers into two groups: high AFQT mothers have a score above or equal to 0.4, while low AFQT mothers have a score below 0.4 (0.4 is approximately the median in our sample of white mothers). There are two reasons why the effect of maternal education on child outcomes can vary across these two groups of mothers. First, this parameter can be a function of AFQT. Second, even within AFQT cells, this parameter can vary across observationally similar mothers. In that case the instrumental variables estimate will be an average of the effects of maternal education for the set of mothers affected by the instrument, and this set can be very different in the high and low AFQT groups, since AFQT and unobservable ability both determine the schooling decision of mothers. Unfortunately, our procedure confounds the two phenomena, but it is still of great interest especially if we can interpret it as (within each AFQT group) the effect of schooling for those mothers most likely to change schooling in response to a decrease in the costs of attending university (measured by our set of instrumental variables).

In the upper panel of Table 8 we report the effect of maternal education and AFQT on our (child and family) outcome of interests for mothers with low levels of AFQT, while the lower panel presents estimates of the same pa-

Table 8: Comparison low versus high AFQT mothers (white children aged 7 and 8)

	PIAT Math		**BPI**		**Grade repetition**		**mother age at child birth**		**Mother married**		**number of children**		**Spouse schooling**		**average family income**		**annual hours worked**		**mother's aspirations**	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV	(7) OLS	(8) IV	(9) OLS	(10) IV	(11) OLS	(12) IV	(13) OLS	(14) IV	(15) OLS	(16) IV	(17) OLS	(18) IV	(19) OLS	(20) IV
	0.408	0.687	-1.106	-0.458	-0.001	-0.025	1.052	1.112	0.013	0.009	-0.036	0.121	0.401	0.579	0.107	0.081	105.461	123.664	0.057	0.081
LOW	[0.329]	[1.047]	[0.441]**	[1.278]	[0.016]	[0.025]	[0.088]***	[0.268]***	[0.014]	[0.045]	[0.052]	[0.156]	[0.081]***	[0.193]***	[0.020]***	[0.058]	[19.241]***	[62.275]**	[0.021]***	[0.047]*
	1168	1168	1213	1213	459	459	2274	2274	2274	2274	2274	2274	1574	1574	2241	2241	2235	2235	491	491
	0.918	3.080	-1.223	0.040	-0.008	-0.003	0.983	1.560	0.022	0.092	-0.054	-0.055	0.524	0.396	0.135	0.213	68.748	135.543	0.031	0.060
HIGH	[0.265]***	[1.025]***	[0.303]***	[1.238]	[0.004]*	[0.011]	[0.081]***	[0.297]***	[0.009]**	[0.042]**	[0.034]	[0.127]	[0.069]***	[0.257]	[0.017]***	[0.055]***	[22.505]***	[85.635]	[0.009]***	[0.026]**
	1232	1232	1257	1257	694	694	1941	1941	1938	1938	1941	1941	1620	1620	1890	1890	1897	1897	703	703

Note: The upper panel of the table (*LOW*) shows results for mothers with low (corrected) AFQT scores (< 0.4), the lower panel (*HIGH*) shows results for mothers with high (corrected) AFQT scores ($>= 0.4$) only. Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade.

Mother's age at birth is the age of the mother in years at birth of the child. *Mother married* is an indicator variable, taking the value 1 if the mother is married, and 0 otherwise. *Log family income* is the logarithm of average family income; average family income is the average of all non-missing family income observations within a five year window centered at the year of interest. *Number of children* is the total number of children ever reported. *Spouse's schooling* is the number of years of schooling completed by the mother's spouse. *Annual hours worked* is the number of hours worked by the mother in the year of interest. *Mother's aspirations* is an indicator variable, taking the value 1 if the mother believes the child will graduate from college or get more than 4 years of college education, and 0 otherwise.

rameters for mothers with high levels of AFQT (we ran different regressions for each group). It is striking that the effects of mother's education on child's mathematics achievement are strong (and large in magnitude) for high AFQT mothers only. Furthermore, the effect of schooling on marital status, family income and maternal employment are also higher for high AFQT mothers than for low AFQT mothers. In contrast, the effect of mother's schooling on spouse's schooling is larger for mothers with lower levels of AFQT. Notice that the p-value of the first stage regressions is low for high and low AFQT mothers alike, indicating that our set of instruments is a strong predictor of schooling for both high and low AFQT mothers. These findings suggest that there is considerable heterogeneity in the effects of maternal schooling, and that, for most measures of child achievement and family environments, IV estimates are larger for high ability than for low ability mothers. Furthermore, we show in the appendix that for low AFQT mothers there are no large difference between OLS and IV estimates for most outcomes (except spouse's schooling), while for high AFQT mothers there exist large differences between these two sets of estimates. This indicates that endogeneity may be an important source of concern mainly for mothers of high ability. Notice also that the effects of AFQT are much stronger for low rather than high AFQT mothers.

5.4 Early Childhood and Young Adulthood

Given the strength of maternal schooling effects on child cognitive achievement, but not on behavioural problems, we decided to investigate two issues: first, are these effects visible at earlier ages of the child; second, is there any evidence of effects of maternal schooling on behaviour during adolescence and young adulthood, when behavioural anomalies such as engagement in criminal activities, early dropping out of school, or early child bearing, may be the source of long run problems. It would be also interesting to see whether the effects of mother's schooling on mathematics achievement in childhood persist into late adolescence but, unfortunately, in this dataset we do not have data for such an analysis (the mathematics test we use is useful for measuring skill mainly in pre-adolescence ages).

Examining what happens at early ages in detail is of great interest because skill gaps between children of different socioeconomic status emerge very early and persist (e.g., Carneiro & Heckman (2003)). In order to understand the role of education policy at different ages one needs to understand the process of skill formation at different ages.

In Table 9 we present estimates of the effect of maternal schooling and AFQT on birthweight (in ounces), the probability of being a low birthweight baby (weighting less than 5.5 pounds at birth), assessments of motorskills and knowledge of parts of the body at ages 0 and 1, and maternal employment at ages 0 and 1. The table has three panels: in the first we present the result for white mothers, in the second we divide the sample of white mothers into high and low AFQT groups, and in the third we present results for black mothers.

Currie and Moretti (2003) find that one extra year of maternal education reduces the probability that a child is born with low birthweight by 1 percentage point. Our estimates are statistically weaker (but our sample size is also much smaller) and they are larger in magnitude. Our effects are only statistically strong for white low ability mothers, with an additional year of maternal education reducing the incidence of low birthweight by almost 3 percentage points (in our sample the incidence of low birthweight is 6.4% for whites, 7.3% for low ability whites, 5.5% for high ability whites, and 14.3% for blacks).

There are no statistically significant effects of maternal schooling on either the assessment of motor skills or of the knowledge of body parts at ages 0 and

Table 9: Early child outcomes and channels (white children aged 0 and 1)

	Birthweight		**Low birthweight indicator**		**Motor and Social Development**		**Assessment 'Parts of the Body'**		**Maternal employment**		**Annual hours worked**		**Annual weeks worked**	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV	(7) OLS	(8) IV	(9) OLS	(10) IV	(11) OLS	(12) IV	(13) OLS	(14) IV
ALL	0.221	-0.092	-0.002	-0.001	-0.678	0.223			0.045	0.063	106.612	104.503	2.774	3.269
	[0.320]	[1.262]	[0.003]	[0.014]	[0.289]**	[1.222]	TBC	TBC	[0.006]***	[0.034]*	[11.440]***	[58.804]*	[0.255]***	[1.382]**
	5369	5369	5369	5369	2067	2067			5651	5651	5714	5714	5803	5803
LOW AFQT	0.767	2.437	-0.005	-0.014	-0.819	-1.924			0.058	0.075	133.674	180.268	3.427	4.173
	[0.537]	[1.877]	[0.005]	[0.019]	[0.592]	[1.753]	TBC	TBC	[0.009]***	[0.035]**	[15.787]***	[55.482]***	[0.391]***	[1.512]***
	2751	2751	2751	2751	906	906			2854	2854	2862	2862	2911	2911
HIGH AFQT	-0.256	-0.514	-0.000	0.007	-0.523	-0.924			0.046	0.077	103.046	167.176	2.704	4.979
	[0.482]	[1.298]	[0.005]	[0.013]	[0.359]	[0.876]	TBC	TBC	[0.009]***	[0.031]**	[17.010]***	[57.740]***	[0.388]***	[1.355]***
	2618	2618	2618	2618	1161	1161			2797	2797	2852	2852	2892	2892

Note: The top panel (*ALL*) shows results for all white children aged 0 and 1. The second panel (*LOW AFQT*) then restricts attention to children whose mothers have low scores on the AFQT (< 0.4). The third panel (*HIGH AFQT*) restricts attention to children whose mothers have high scores on the AFQT ($>= 0.4$). Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. *Birthweight* is the child's weight at birth in ounces, *Low birthweight indicator* takes the value 1 if the child weighed less than 5.5 pounds at birth. *Motor and Social Development* is the child's score on the Motor and Social Development scale (MSD), measured on a normalized scale of mean 100 and standard deviation 15. *Assessment 'Parts of the Body'* is the score of the Parts of the Body assessment, with scores ranging from 0 to 10. *Maternal Employment* is an indicator variable for employment of the mother. *Annual hours worked* is the number of hours worked by the mother, and *Annual weeks worked* is the number of weeks worked by the mother.
is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade.

1 (although notice that there are strong effects of maternal AFQT on the latter test), and if anything these effects seem to be negative. Finally, the effect of maternal education on hours worked by the mother when the child is ages 0 or 1 is large for both whites and blacks, although the effects for whites only become statistically strong when we estimate them for high and low ability mothers separately. If anything, these estimates seem larger than the estimates we obtained for ages 7 and 8, and they indicate a substantial difference in the time spent spent at work (which probably reflects on the time spent with the child) of mothers with different levels of schooling. In summary, even though there may exist important effects of maternal education on early child outcomes, they are not easily discernible in our dataset. One possible hypothesis is that there are offsetting effects of increased maternal education and decreased time at home.

Finally, we examine engagement in risky behaviours in late adolescence and adulthood early dropping out of school, early sexual activity, and criminal activity. In doing this analysis it was very useful to separately examine mothers with high and low levels of AFQT for both blacks and whites. However, in order to keep the sample sizes similar in each group we used different thresholds to define who is high and low ability within each race group: white mothers are high ability if their AFQT score is above 0.4, while black mothers are high ability if their AFQT score is above -0.25 (these are roughly the median AFQT scores for each race group). Therefore, the way we define this generates a large overlap in the ability levels of low AFQT white mothers and high AFQT black mothers.

Table 10 present estimates of the effect of maternal schooling on several outcomes: a dummy for school enrollment at ages 16 and 17, a dummy for engagement in sexual activity by ages 16 and 17, a dummy for criminal convictions

Table 10: Adolescent outcomes

	School enrollment age 16-17		Sexual activity age 16-17		Criminal convictions age 20-21		Number of children age 20-21	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV	(7) OLS	(8) IV
Panel A: White Adolescents								
ALL	0.005	-0.016	-0.023	0.084	-0.012	0.013	-0.037	-0.017
	[0.008]	[0.023]	[0.013]*	[0.043]*	[0.015]	[0.026]	[0.018]**	[0.037]
	1171	1171	1378	1378	663	663	623	623
LOW AFQT	0.009	-0.023	-0.043	-0.049	-0.044	-0.080	-0.011	-0.018
	[0.011]	[0.024]	[0.020]**	[0.042]	[0.021]**	[0.036]**	[0.026]	[0.038]
	677	677	827	827	420	420	393	393
HIGH AFQT	0.007	-0.013	-0.018	0.018	-0.018	-0.019	-0.083	-0.095
	[0.015]	[0.024]	[0.019]	[0.041]	[0.029]	[0.027]	[0.048]*	[0.047]**
	494	494	551	551	243	243	230	230
Panel B: Black Adolescents								
ALL	0.023	0.027	-0.022	-0.020	-0.044	-0.069	-0.053	0.015
	[0.007]***	[0.014]*	[0.015]	[0.035]	[0.014]***	[0.037]*	[0.027]*	[0.071]
	844	844	1135	1135	654	654	610	610
LOW AFQT	0.018	0.013	0.004	0.005	-0.053	-0.042	-0.014	0.005
	[0.008]**	[0.010]	[0.022]	[0.030]	[0.018]***	[0.029]	[0.035]	[0.049]
	575	575	781	781	467	467	439	439
HIGH AFQT	0.027	0.037	-0.051	-0.076	-0.063	-0.063	-0.116	-0.125
	[0.011]**	[0.020]*	[0.020]**	[0.033]**	[0.034]*	[0.035]*	[0.059]*	[0.060]**
	269	269	354	354	187	187	171	171

Note: Panel A shows results for all white adolescents. Within this panel, the sample is then split up according to the AFQT score of the mother, where the cutoff value is an AFQT score of 0.4. Panel B shows results for all black adolescents. Within this panel, the sample is then split up according to the AFQT score of the mother, where the cutoff value is an AFQT score of -0.25. Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. *School enrollment*, *Sexual activity*, and *Criminal convictions* are indicator variables. *Number of children* is the number of children the adolescent has.

at ages 20 and 21, and number of children at ages 20 and 21. The top panel of the table refers to whites and the bottom refers to blacks. Among whites there are no statistically significant effects of maternal education on schooling attainment and sexual behaviours in late adolescence and young adulthood, at least the way we are measuring them. However, for children of low AFQT white mothers each additional year of maternal schooling reduces the probability of ever being convicted by ages 20 and 21 by 8%.

We find much stronger effects for blacks. Among children from high AFQT mothers an additional year of maternal education leads to an increase in the probability of being enrolled in school at ages 16 and 17 by 3.7%, a decrease in the probability of first time sexual activity by ages 16 and 17 by 7.6%, a decrease in the average number of children at ages 20 and 21 by 0.125, and a decrease in the probability of ever being convicted of a crime by ages 20 and 21 of 6.3%. Similar patterns are observed for children of low ability black mothers, but the results are statistically weaker.

5.5 Sensitivity Analysis

In this section we examine the sensitivity of our main results, presented in section 5.1. One possible criticism of our procedure is that, since we are relying on interactions between controls and instruments to create exogenous variation in maternal schooling, if the outcome equation is misspecified then some of our results might be driven by the introduction of nonlinearities in the controls instead of genuine variation in the instruments. Therefore we reestimate our model with a more much flexible specification of the outcome equations, where we add to the set of controls the following variables: AFQT squared, grandmother's education squared, grandfather's education squared, and all two-way interactions between AFQT, grandmother's education, grandfather's education and whether the mother lived in a broken home at age 14. The IV estimates of the coefficient on maternal schooling for each outcome are presented in Table 11.

It is quite clear that our results are robust to flexible specifications of the outcome equations.

Second, we present the sensitivity of our estimates of the effect of maternal schooling on child cognitive and non-cognitive outcomes to the use of different combinations of instrumental variables. Each line of Panel C in Table 11 corresponds to a different set of instruments, as explained in the table. Across lines, the estimated coefficients can vary because the data is weak or the specification of the equation is not solid, and therefore the results are not robust. However, this variation can be explained but a different reason. Even if the data is strong and the specification is correct, if the effect of mother's education varies across families then different combinations of instruments estimate different parameters (Heckman and Vytlacil, 2005). Our results show that across different sets of instruments the effect of maternal education on mathematics achievement is between 1.7 and 4.6 (0.115 and 0.31 of a standard deviation), and it is always statistically significant either at the 5 or 10% levels. The effect on grade repetition at ages 12 to 14 is stable between 6.2 and 8.6 percentage points.

Table 11: Sensitivity analysis (white children)

	PIAT Math (aged 7+8)		**BPI** (aged 7+8)		**Grade repetition** (aged 12-14)	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV
Panel A						
base case	0.742 [0.185]*** 2400	1.925 [0.887]** 2400	-1.307 [0.257]*** 2470	-0.234 [1.077] 2470	-0.028 [0.007]*** 1853	-0.079 [0.025]*** 1853
Panel B						
including polynomials and interactions	0.687 [0.178]*** 2400	1.805 [0.801]** 2400	-1.405 [0.259]*** 2470	-0.885 [1.096] 2470	-0.030 [0.007]*** 1853	-0.068 [0.024]*** 1853
Panel C						
excluding local wages		1.725 [1.012]* 2470		0.316 [1.356] 2541		-0.062 [0.027]** 1931
excluding local unemployment		2.838 [1.105]** 2400		-0.467 [1.296] 2470		-0.086 [0.029]*** 1853
excluding wages, unemployment		3.017 [1.530]** 2470		0.432 [1.693] 2541		-0.080 [0.029]*** 1931
excluding wages, unemployment, and tuition		4.634 [2.752]* 2471		3.172 [2.916] 2542		-0.084 [0.050]* 1931

Note: Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade.
Panel A shows the main results of the paper, using as instruments college availability, tuition rates, local wages, and local unemployment, and interactions. *Panel B* includes polynomials and interactions in the controls. *Panel C* shows results when only subsets of these instruments are used. All specifications include interactions with controls as discussed in the text. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level.

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Table 12: Comparison female versus male (white children aged 7 and 8)

	PIAT Math		BPI		Grade repetition		mother age at child birth		Mother married		number of children		Spouse schooling		average family income		annual hours worked		mother's aspirations	
	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) OLS	(6) IV	(7) OLS	(8) IV	(9) OLS	(10) IV	(11) OLS	(12) IV	(13) OLS	(14) IV	(15) OLS	(16) IV	(17) OLS	(18) IV	(19) OLS	(20) IV
	0.731	1.919	-1.259	-2.153	-0.005	-0.006	1.000	0.837	0.013	0.075	-0.027	-0.001	0.470	0.238	0.099	0.100	62.900	64.390	0.039	0.043
FEMALE	[0.242]***	[0.904]**	[0.417]***	[1.320]	[0.007]	[0.021]	[0.079]***	[0.296]***	[0.011]	[0.038]**	[0.029]	[0.101]	[0.053]***	[0.202]	[0.016]***	[0.053]*	[16.587]***	[83.917]	[0.016]**	[0.034]
	1190	1190	1218	1218	575	575	2061	2061	2058	2058	2061	2061	1544	1544	2018	2018	2020	2020	584	584
	0.733	2.016	-1.203	-0.269	-0.005	-0.030	0.975	1.232	0.025	0.026	-0.051	-0.102	0.543	0.653	0.133	0.087	69.607	28.879	0.037	0.083
MALE	[0.273]***	[1.194]*	[0.290]***	[1.093]	[0.006]	[0.017]*	[0.067]***	[0.264]***	[0.009]***	[0.028]	[0.033]	[0.118]	[0.057]***	[0.174]***	[0.016]***	[0.053]*	[19.911]***	[82.698]	[0.012]***	[0.044]*
	1210	1210	1252	1252	578	578	2154	2154	2154	2154	2154	2154	1650	1650	2113	2113	2112	2112	610	610

The upper panel (*FEMALE*) restricts attention to female children, the lower panel (*MALE*) to male children in the relevant age range. Each cell of the table lists the coefficient estimate, asymptotic standard errors reported in brackets, and number of observations included in the regression. * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at 1% level. *PIAT Math* is the child's score in the Peabody Individual Achievement Test (PIAT), measured on a normalized scale of mean 100 and standard deviation 15. *BPI* is the score in the Behavioral Problems Index, on a normalized scale with mean 100 and standard deviation 15. *Grade repetition* is an indicator variable for whether the child ever repeated a grade.

Mother's age at birth is the age of the mother in years at birth of the child. *Mother married* is an indicator variable, taking the value 1 if the mother is married, and 0 otherwise. *Log family income* is the logarithm of average family income; average family income is the average of all non-missing family income observations within a five year window centered at the year of interest. *Number of children* is the total number of children ever reported. *Spouse's schooling* is the number of years of schooling completed by the mother's spouse. *Annual hours worked* is the number of hours worked by the mother in the year of interest. *Mother's aspirations* is an indicator variable, taking the value 1 if the mother believes the child will graduate from college or get more than 4 years of college education, and 0 otherwise.