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Maternal human capital and infants' health outcomes: Evidence from minimum dropout age policies in the US☆

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ABSTRACT

The purpose of this cross-sectional study is to examine the causal relationship of maternal education and infants' health outcomes. Using birth certificate data over the years 1970–2004 and exploiting the space-time variation in Minimum Dropout Age laws to solve the endogeneity of education, we find a sizeable effect of mothers' education on their birth outcomes. An additional year of maternal education is associated with a reduction in incidences of low birth weight and preterm birth by 15.2 and 12.7 percent, respectively. The estimates are robust across various specifications and even when allowing mothers' cohort-of-birth to vary across regions. The results suggest that the candidate mechanisms of impact include improvements in timing, quantity, and quality of prenatal care, lower negative health behavior during pregnancy such as smoking and drinking, and higher spousal education.

1. Introduction

Economic theory and empirical evidence suggest that higher educated mothers have children with higher health endowment at birth. Several channels build a pathway for the observed correlation. First, education raises family income either through increases in women's earnings or their spouses' earnings under assortative mating (Chiappori, Iyigun, & Weiss, 2009; Jeanne Lafortune, 2013). The higher income is associated with improved birth outcomes (Douglas Almond, Hoynes, & Schanzenbach, 2011; Amarante, Manacorda, Miguel, & Vigorito, 2016; Currie, 2009; Hoynes, Miller, & Simon, 2015). Second, education may raise women's awareness and their ability to implement better antenatal care as well as starting prenatal care in earlier stages of pregnancy, both of which are shown to result in higher infants' health (Conway & Kutinova, 2006; Currie & Grogger, 2002; Reichman & Florio, 1996; Sonchak, 2015). Third, education exposes mothers to a wider network of knowledge about determinants of birth outcomes while improves their reasoning on implementing this information. Hence, it might affect their habits (such as switching to a better diet) or their prenatal behavior (such as smoking and drinking) (Colman, Grossman, & Joyce, 2003; Fertig & Watson, 2009; Markowitz, 2008; Ramakrishnan, Young, & Martorell, 2017; Wu, Bazer, Cudd, Meininger, & Spencer, 2004).

Investigating the determinants of infants' health outcomes and specifically the influence of maternal human capital on birth ouctomes is important for two main reasons. First, it provides policymakers with possible areas and the required pathways to improve health among infants. The fact that an investment in human capital may have externalities for the next generation's health capital has important policy implications for both health and education policymakers. Therefore, it is essential to go beyond cross-sectional correlations between mothers' education and infants' health and establish a causal path. Second, since birth outcomes are linked to a wide array of later-life outcomes, it provides channels to influence children and adult outcomes by investing resources during the period of prenatal development. These long-term relationships are primarily based on theories such as Fetal Development Hypothesis and Fetal Origins of Adult Diseases which indicate the

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relevance of in-utero exposures in programming of growth and later-life diseases (Aizer & Currie, 2014; Almond & Currie, 2011b; Barker, 1990, 1994; Godfrey & Barker, 2000; Osmani & Sen, 2003; Samaras, Elrick, & Storms, 2003; Sotomayor, 2013). In this regard, a growing body of literature in medical sciences and other social science settings highlight the importance of in-utero conditions on later-life outcomes including infant mortality (A. Chen, Oster, & Williams, 2016; Gage, Fang, O'Neill, & DiRienzo, 2013; Lau, Ambalavanan, Chakraborty, Wingate, & Carlo, 2013), cognitive development (Figlio, Guryan, Karbownik, & Roth, 2014; Mamluk et al., 2021), education (Fletcher, 2011; Fuller, 2014), adulthood earnings (Behrman & Rosenzweig, 2004; Black, Devereux, & Salvanes, 2007; Currie & Moretti, 2007; Maruyama & Heinesen, 2020; Royer, 2009a), next generations' birth outcomes (East, Miller, Page, & Wherry, 2021; Lahti-Pulkkinen et al., 2018; Noghanibehambari, 2022), and old-age health and mortality (Basso, Wilcox, & Weinberg, 2006; Belbasis, Savvidou, Kanu, Evangelou, & Tzoulaki, 2016; Huxley et al., 2007).

The contribution of this paper to the literature is twofold. To the best of our knowledge, this is the first study to link the MDA laws to infants' health outcomes. Using this instrument, we find marginal effects that are substantially larger than studies that use school entry policies (McCrary & Royer, 2011) and school desegregation (Shen, 2018) as the source of exogenous influence on education. Second, it adds to the literature on the benefits of education by providing evidence of its externality for the health capital of the next generation.

2. Literature review

Education affects a wide range of social and economic outcomes, which in turn could impact infants' health. These channels mainly include income, changes in demand for health inputs, prenatal behavior, and fertility timing. This section reviews the theoretical background and empirical literature behind these channels.

In a recent study, McCrary and Royer (2011) explored the effect of mothers' schooling on infants' birth outcomes in Texas and California, using school entry policy as the exogenous source of variation in education. They found little evidence to support this link. While school entry policies had a sizeable and significant effect on education, they did not change the fertility timing of mothers. Although they found a significant connection between school entry policy and infants' health in some sub-populations, these links were economically small. Chou, Liu, Grossman, and Joyce (2010) investigated the effect of parents' education on child health in Taiwan and found significant and economically sizeable effects. They used a change in compulsory education alongside school constructions as the shock to education and showed that the reform was successful in increasing the schooling of parents by about 0.16–0.26 more years of schooling. This change was associated with a decrease in low birth weight of roughly 5 percent.

It is widely documented that education raises permanent income (Acemoglu & Angrist, 2000; Brunello, Fort, & Weber, 2009; Griliches & Mason, 1972). Under assortative mating, it also could raise the spouse's education and earnings (Boulier & Rosenzweig, 1984; Lafortune, 2013). An increase in total disposable family income shifts the demand curve for all normal goods. The income channel of education has a positive effect on women's fertility decisions and their prenatal behavior (Grossman, 1972). Some known determinants of health inputs, such as health insurance and health care spending, are shown to be normal goods (Alfonso, Ding, & Bishai, 2016; Cameron & Trivedi, 1991; Di Matteo, Matteo, & Di Matteo, 2003; Olsen, 1993; Parkin, McGuire, & Yule, 1987). Therefore, an increase in income may encourage households to allocate more resources for infants' health. A relatively small literature provides evidence that income is positively associated with improved birth outcomes (Almond & Currie, 2011a; Bhalotra & Rawlings, 2013; Currie & Moretti, 2007; Kämpfen, Zahra, Kohler, & Kidman, 2022; Kane, Miles, Yourkavitch, & King, 2017; Noghanibehambari & Salari, 2020; Williams & Finch, 2019).

Increases in family income caused by an increase in education may shift mothers' demand for prenatal care and insurance. This shift can be due to increases in the number of visits, the timing of visits (e.g., earlier in pregnancy), obtaining health insurance, or choosing better health insurance, all of which are associated with better pregnancy outcomes (Conway & Deb, 2005; Corman et al., 2019; Lagarde, Lépine, & Chansa, 2022; Sonchak, 2016). Another important health input that may increase by income is nutrition. It is well documented that better nutrition leads to better health outcomes of infants (Almond & Mazumder, 2011; Almond, Mazumder, & van Ewijk, 2015; East, 2018; Ga & Feng, 2012; Haeck & Lefebvre, 2016; Hoynes, Schanzenbach, & Almond, 2016; Majid, 2015; Ewijk & Van Ewijk, 2011).

Another likely channel is changes in fertility timing. For instance, there are evidence that education could reduce teenage fertility (Black, Devereux, & Salvanes, 2008; Girma & Paton, 2015; Paton, Bullivant, & Soto, 2020). A relatively small strand of studies document the negative birth outcomes associated with teenage pregnancy (Alio, Mbah, Grunsten, & Salihu, 2011; Chen et al., 2007; Gilbert, Jandial, Field, Bigelow, & Danielsen, 2009). Therefore, to the extent that education postpone pregnancy it could improve infants' health outcomes. However, the relationship is not linear and is confounded by pregnancy in the so-called *Advanced Ages*. Some studies show that pregnancy in ages above 35 (advanced maternal age) and above 40 (very advanced maternal age) are associated with increased likelihood of pregnancy complications (Ben-David et al., 2016; Carolan & Frankowska, 2011; Jacobsson, Ladfors, & Milsom, 2004; Liou et al., 2010).

Education may raise women's awareness and knowledge regarding unhealthy behavior during pregnancy, the strength of the effect of these behaviors on infants' health, and also the importance of infants' health endowment on their later-life outcomes. Although it is hard to determine the exact pathway, the overall effect of education on healthy behavior is testable. Some studies document the externality of education on smoking cessation (de Walque, 2007) and also alcohol consumption (Cutler & Glaeser, 2005; Cutler & Lleras-Muney, 2010). Smoking and drinking have long been linked to negative birth outcomes (Evans & Ringel, 1999; Fertig & Watson, 2009; Nilsson, 2017; Yan, 2014).

3. Methodology

In the final sample, most states have a minimum school leaving age of 16, 17, or 18.[1] Based on these values, we define a dummy for MDA of 18 years that equals one if MDA in the state of birth of the mother, when she was 14 years old, was 18 and zero otherwise.[2]

The identification strategy compares the birth outcomes of mothers who were born in states with an MDA of 18 to those who were born in states with an MDA less than 18 (first difference) before and after the laws changed in their state of birth (second difference). The main assumption in this strategy is that in the absence of the MDA law changes, the birth outcomes of mothers in states with MDA = 18 would have followed the same path and been influenced by the same factors as the birth outcomes of mothers in states with MDA less than 18. The empirical model can be summarized in the two-stage least-square regressions of the following form:

$$Educ_{istby} = \alpha_0 + \alpha_1 X_i + \beta MDA18_{by} + \eta_s + \theta_t + \varphi_b + \mu_y + Region_b \times Cohort_y + \varepsilon_{istby} \tag{1}$$

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[1] Only 0.8% of mothers were born in states with minimum school leaving age of 14 or 15.

[2] In Appendix A, we show the results for the case of two dummies for MDA = 18 and MDA = 17 as the instruments. The estimated coefficients and standard errors are, however, quite similar to the main results.

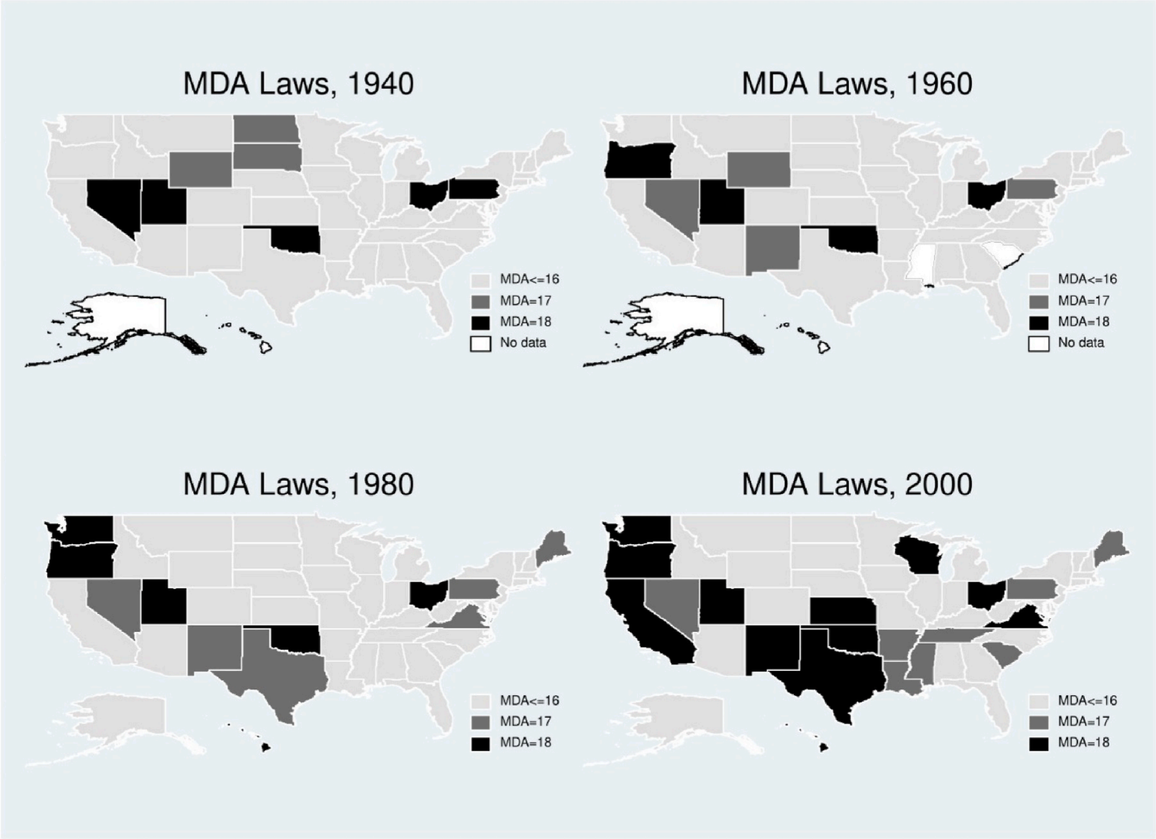

Fig. 1. Distribution of MDA laws across states and over time.

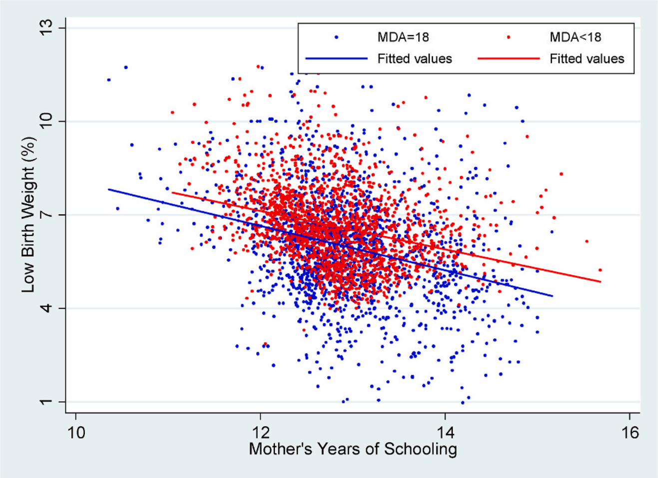

Fig. 2. Mothers' Education and Low Birth Weight
Notes. Each point represents the average values of the final sample collapsed at state-year level.

$$y_{istby} = \delta_0 + \delta_1 X_i + \lambda \widehat{Educ}_{istby} + \Upsilon_s + \Omega_t + \Theta_b + \Lambda_y + Region_b \times Cohort_y + \varepsilon_{istby} \tag{2}$$

Where y is infant's health outcomes born to mother i in state s and time (year and month) t who was born in state b and year y. The parameters η and θ (Υ and Ω) represent fixed effects of state of residence of the mother and year-month for the first stage (second stage) regression. The parameters φ and μ (Θ and Λ) are mothers' state of birth and year of birth fixed effects for the first stage (second stage) regression. In X is included a series of dummies to capture mothers' race and father's race. In the preferred specification, we also allow the main effects of the mother's region of birth to vary by her cohort of birth. Finally, ε and ε are the disturbance terms of the first and second stages. Following Acemoglu and Angrist (2000), Mazumder (2008), and Stephens and Yang (2014), we cluster the standard errors at the mother's state of birth and year of birth.[3]

3.1. Endogeneity issues

Fig. 2 depicts the cross-sectional correlation between mothers' education and low birth weight. The negatively sloped fitted curve reveals a visually similar relationship. It suggests that, at each level of mothers' education, states with an MDA of 18 have lower rates of low birth weight. A state-by-year level distribution of these variables suggests the same connection. As shown in Fig. 3, The distribution of mothers' education is slightly shifted to more years of schooling for states with MDA of 18 years, while their distribution of low birth weight is slightly shifted leftward. Fig. 4 depicts the same pattern for another important measure of infants' health and their lifetime outcomes, the incidence of preterm birth. However, these visual distributions do not point to any causation. High-educated mothers might have been reared in more affluent families and have had better family-specific health endowments for other reasons, except their education, which also leads to better birth outcomes of their infants. Similarly, healthier mothers, potentially with

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[3] In Appendix B, we examine the robustness of the results to other levels of clustering including the current year, year of birth, state of residence, and current state-year.

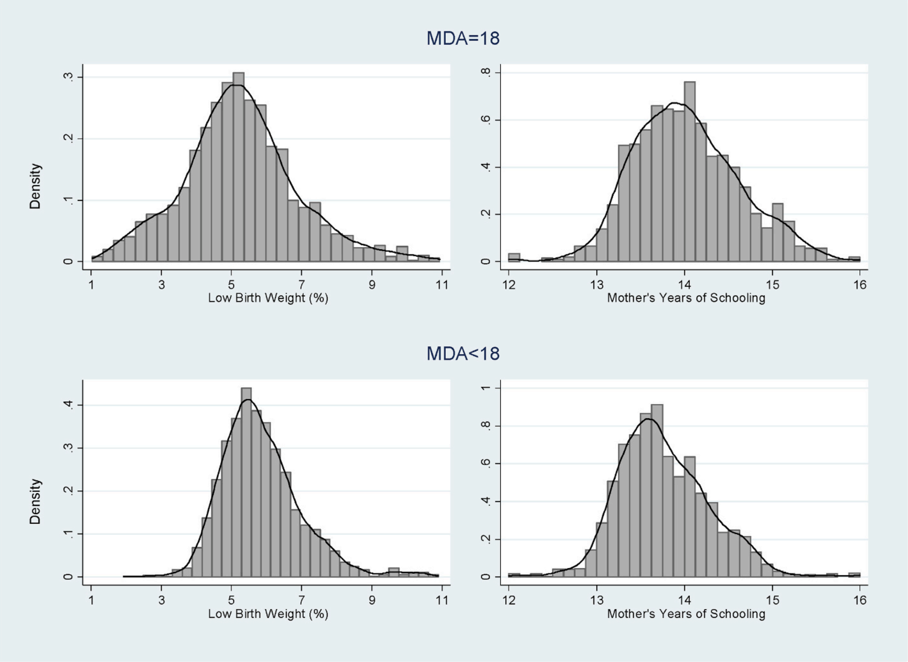

Fig. 3. The distribution of Mothers' Education and Low Birth Weight Across States with MDA = 18 and MDA<18
Notes. The final sample of this study is collapsed at state-year level by two types of states: MDA = 18 and MDA<18.

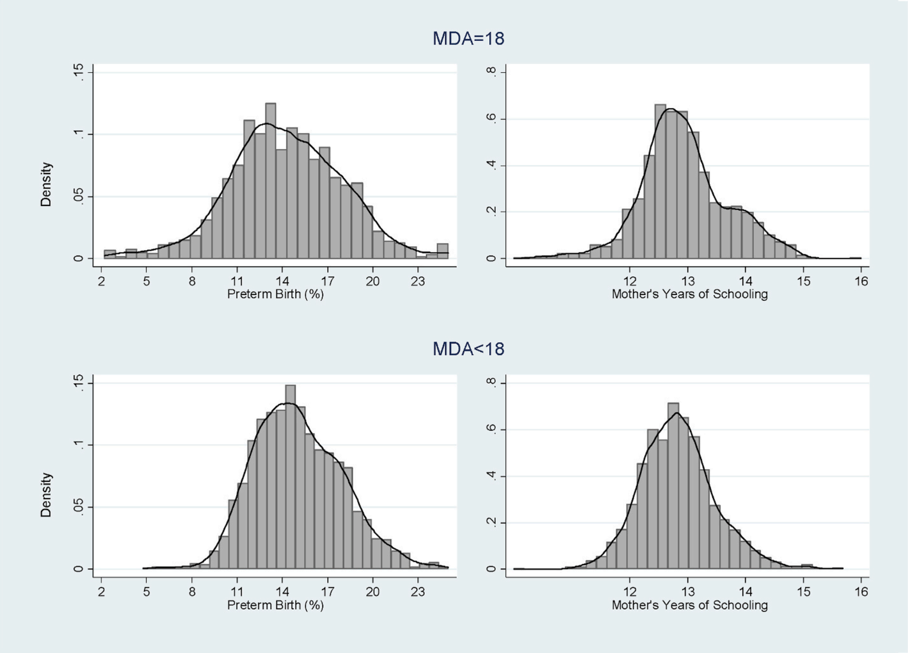

Fig. 4. The distribution of Mothers' Education and Preterm Birth Across States with MDA = 18 and MDA<18
Notes. The final sample of this study is collapsed at state-year level by two types of states: MDA = 18 and MDA<18.

healthier infants, might have different discount rates regarding their future income and decide to invest more in their human capital. This endogeneity in observables and unobservables may overestimate the true effects of mothers' education on birth outcomes. On the other hand, an equal job market may encourage the disadvantaged population, for instance, Blacks or Hispanics, to earn more education. Poor infants' health is more prevalent among disadvantaged mothers. Therefore, the resulting estimates will underestimate the true effects.

One solution is to find a factor that does change education but is uncorrelated with observable and unobservable influences on infants' health. State-level educational policies are usually among proper candidates. As a notable example, minimum dropout age laws force the students to stay at school up to a specific age, a shock that is arguably orthogonal to students' other characteristics. Table 2 shows that an MDA law of 18 is associated with 0.07 more years of schooling and a 1.3% higher probability of completing high school. These effects are strongly significant, statistically and economically, and robust to the inclusion of mother and father characteristics and also when we allow the region of birth to vary by birth cohort.

To show that the MDA laws are not correlated with other observable

Table 1
Summary statistics.

	Mean	Standard Deviation	Median	Observations
Natality 1970–2004:				
Birth Weight (Grams)	3306.37	571.48	3345.00	28,855,341
Low Birth Weight (BW < 2500)	0.067	0.250	0.000	28,855,341
Very Low Birth Weight (BW < 1500)	0.011	0.104	0.000	28,855,341
Full-Term Birth Weight	3408.25	467.86	3402.00	21,130,890
Gestational Age (Weeks)	39.31	2.68	40.00	27,072,889
Preterm Birth (GW < 37)	0.157	0.364	0.000	27,072,889
Apgar Score	8.95	0.844	9.00	21,433,525
Mothers' Age	23.27	5.41	22.00	28,855,341
Mothers' Years of Schooling	12.76	2.31	12.00	28,855,341
Mothers' Education ≥ 12	0.78	0.41	1.00	28,855,341
Mothers' Race White	0.832	0.373	1.000	28,855,341
Mothers' Year of Birth	1965.94	9.84	1973.00	28,855,341
Number of Prenatal Visits	11.34	3.83	12.00	26,912,469
Month Prenatal Care Began	2.62	1.47	2.00	28,139,686
Natality 1989–2004:				
Cigarettes Smoked During Pregnancy	1.19	4.08	0.00	13,140,478
Drinks During Pregnancy	0.021	0.519	0.000	13,644,021
Kessner Index (1–3)	2.72	0.53	3.00	13,690,859
State Covariates 1970–2004:				
Log Current Transfers	17.89	0.97	17.89	28,855,341
Log Income Maintenance Benefits	15.64	1.09	15.58	28,855,341
Log Other Welfare Payments	17.73	0.96	17.74	28,855,341
Minimum Wage	7.72	0.99	7.40	28,855,341
Tax Tobacco Per Capita ($1000)	0.043	0.019	0.040	25,966,963
Tax Alcohol Per Capita ($1000)	0.025	0.016	0.020	25,966,963
Educational Expenditure Per Capita ($1000)	1.42	0.38	1.37	25,966,963
Health Expenditure Per Capita ($1000)	0.149	0.079	0.130	25,966,963
Share of Whites	0.842	0.086	0.850	28,855,341
Share of Blacks	0.124	0.081	0.119	28,855,341

Notes. All dollar values are converted into 2017 dollars.

Table 2
First Stage Effects of MDA laws on Mothers' Education.

	Mothers' Years of Schooling			Mothers' Education$\geq$12 ($\times$ *100*)		
	(1)	(2)	(3)	(4)	(5)	(6)
Minimum Dropout Age = 18	0.081*** (0.011)	0.082*** (0.011)	0.073*** (0.010)	1.365*** (0.372)	1.501*** (0.302)	1.346*** (0.289)
F-Statistics	2693.98	7057.59	6998.98	1429.76	3621.48	4164.83
R^2	0.45	0.47	0.47	0.29	0.34	0.34
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Mothers' Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Father's Characteristics	No	Yes	Yes	No	Yes	Yes
Mothers' Region of Birth × Birth Cohort	No	No	Yes	No	No	Yes
Observations	28,855,341	28,855,341	28,855,341	28,855,341	28,855,341	28,855,341

Notes. Mothers' Characteristics include mothers' race. Fathers' Characteristics include race and age dummies. Standard errors, reported in parentheses, are clustered on mothers' birth state-year. Fixed effects include state of residence, current year, current month, year of birth, and state of birth of the mother.

determinants of infants' health, we construct a weighted index of potential observable determinants of birth outcomes. In so doing, we run a regression of some important birth outcomes on mothers' race, father's race, mothers' marital status, and a series of state-level covariates, including the log of current transfer receipt per capita, log of income maintenance receipt per capita, log of all other state-level welfare payments, minimum wage, tobacco and alcohol tax per capita, health expenditure per capita, educational expenditure per capita, and percentage of White population. If state authorities change their level or composition of welfare programs to compensate for funds required for additional mandatory education, one might observe a positive correlation between MDA-induced changes in education and the portion of health outcomes that can be explained by states' welfare payments. Furthermore, if MDA laws proportionately affect the education of Whites and Blacks, the weighted index becomes correlated with MDA-induced education. However, Table 3 provides no evidence of such connections. The endogenous changes in education are strongly associated with predicted preterm birth (column 1), birth weight (column 3), and low birth weight (column 5). This is expected as education is determined by other characteristics of parents (like race) or other state-level policies (such as welfare payments) that also correlate with birth outcomes. Therefore, one would observe a significant association between education and covariates-explained part of birth outcomes.

The portion of education that is driven by MDA laws is not correlated with some observable drivers of birth outcomes. There is no evidence that MDA-induced changes in mothers' education are correlated with the weighted index of state policies and composition of birth to White and Black mothers, potential drivers of birth outcomes including preterm birth (column 2), birth weight (column 4), and low birth weight (column 6). Overall, one can argue that MDA laws have a significant effect on education and are orthogonal to a series of potential observable drivers of birth outcomes.

3.2. *Data*

The main source of data is US Vital Statistics Natality Detailed files. It covers almost [4] all birth records in the US over the years 1970–2004.[5] It contains information on infants' health measures, specifically birth weight and estimated gestational age in weeks ("gestational weeks"). The data also contains several maternal characteristics, including race, marital status, education, age, and parity. Moreover, there are some limited father's characteristics, including age, race, and education.

We dropped observations with missing values on birth weight and gestational weeks. We included a missing indicator for all missing values of mother and father characteristics. For instance, we included a white dummy that equals one if mother is white and zero for all other caeses. We continued to define black dummies and a dummy for other races. For mothers whose race information is missing, we defined a dummy that equals one if race is missing and zero for all other caeses. We applied the same method for all father and mother characteristics.

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[4] DC started reporting data in publicly available Natality files from 1982. Besides, the data lacks the information for four states in 1972 (plus DC): Arkansas, New Mexico, Nevada, Montana.

[5] Information on education and place of birth are not reported in Natality files prior to 1970. The last year of state-identified publicly available data is 2004. Furthermore, the Natality files stopped recording state of birth of mother, an important variable in this paper, from 2005-onwards. Instead, it reports mothers' place of birth by country and so aggregate the place of birth values for all US-born mothers into one category.

Table 3

Effect of endogenous and exogenous changes in education on predicted outcomes.

	Predicted Preterm Birth (× *100*)		Predicted Child Weight		Predicted Low Birth Weight (× *100*)	
	(1)	(2)	(3)	(4)	(5)	(6)
OLS	−0.307*** (0.003)		7.148*** (0.091)		−0.184*** (0.002)	
2SLS		−0.411 (0.675)		25.862 (18.523)		−0.576 (0.448)
Full Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,966,963	25,966,963	25,966,963	25,966,963	25,966,963	25,966,963

Notes. Mothers' Characteristics include mothers' race. Fathers' Characteristics include race and age dummies. Standard errors, reported in parentheses, are clustered on mothers' birth state-year. Fixed effects include state of residence, current year, current month, year of birth, state of birth of the mother, and interaction of mothers' region of birth by birth cohort.

We restricted the sample to singleton births since outcomes of plural births might be driven by factors other than intrauterine determinants of infants' health. We also restricted the sample to first-born children for two reasons. First, as noted by Wolpin (1997), mothers may respond to the health of their first infant by their choice of future fertility. This fact may confound the effects of education on birth outcomes if, for instance, the poor health of the first child discourages mothers from having additional children. Therefore, second-and-higher order infants become systematically healthier since healthier and more educated mothers give birth to more children (and vice versa). Second, this sample selection is a common choice in the literature.[6] Besides, it enabled us to compare the estimated effects with those documented in similar studies. We also restricted the sample to mothers of at least 15 years old and at most 45 years old since births out of this age range are highly uncommon, and their outcomes could have been strongly driven by age-related factors. In Appendix D, we show that the results are quite robust and similar in magnitude to the main results when we focus on women aged 18–49, as an alternative age limit.

State-level MDA laws are extracted from Stephens and Yang (2014) and Anderson (2014). Fig. 1 shows the variation of MDA laws across states and over time. Consistent with the literature, we use mothers' birth state and the year they turned age 14 to merge the Natality file and MDA-laws data. The final sample consists of 28,855,341 births to mothers born between 1925-1989.[7] A summary statistic of this sample is reported in Table 1.

In the robustness checks, we use a series of state-by-year variables. These variables include the share of Black population, the share of White population, the share of females, the share of the population aged 25–55 (from SEER (2019)), and minimum wage (form Federal Reserve Bank of St. Louis). The state-level government expenditure by category data is extracted from Pierson, Hand, and Thompson (2015). All dollar figures are converted into 2017 dollars using June Consumer Price Index to reflect real values.

4. Main results

4.1. Main results

Table 4 reports the endogenous and exogenous changes in mothers' education on their infants' birth outcomes. Estimates of OLS suggest that mothers' education is associated with improved birth outcomes. On average, an additional year of schooling of the mother is associated with roughly 22 g higher birth weight, 0.64 percentage-points lower likelihood of low birth weight (birth weight <2500 g), and 0.73 percentage-points lower probability of having a premature birth (gestational age of fewer than 37 weeks).

The second row reports the results for two-stage-least-square instrumental-variable (hereafter 2SLS-IV) regressions. The point estimates are substantially larger than those of OLS. For instance, one more year of maternal education leads to about 33 g higher birth weight, two times the OLS estimate, and also 2.78 percentage-points lower probability of incidence of low birth weight, more than four times the OLS effect. Besides, notice that F-statistics of the first stage are well above the conventional thresholds and reject the null hypothesis of the weak instrument and that there is arguably a strong first-stage effect.

The considerable difference in marginal effects of low birth weight and very low birth weight points to the possible heterogeneity of the effects across different thresholds under which birth weight is considered risky. In Fig. 5, we depart from the usual thresholds in the literature[8] and investigate the effects on low birth weight at different thresholds of birth weight. For instance, the point estimate at 600 represents the marginal effect of mothers' education (conditional on the full specification of fixed effects and covariates) on the likelihood that infants' birth weight is less than 600 g. Although the effects are statistically significant, they are small at the very low thresholds. However, the magnitude of the effects rises at thresholds below 3000 g.

All marginal effects are economically large and statistically significant at 1% level. The effects are more pronounced for adverse outcomes such as low birth weight and preterm birth than mean outcomes such as birth weight and gestational age. This implies that education helps to improve birth outcomes for the general population, but more noticeably for the population at risk. For instance, one additional year of schooling is associated with roughly 1% increase from the mean of birth weight, 41% reduction from the mean of low birth weight, 70% reduction from the mean of very low birth weight, 0.81% rise from the mean of gestational age, and 24% decrease from mean of preterm birth.

4.2. Possible mechanisms

Mother education may influence infants' health outcomes through various channels, including increases in income, improvements in partner's quality, increases in quantity and quality of prenatal care, reducing harmful health behavior, and higher general awareness of prenatal health determinants (Cardona et al., 2021; Currie & Moretti, 2003; Elder, Goddeeris, & Haider, 2016; Nadella, Subramanian, & Roman-Urrestarazu, 2021; Shen, 2018; Wisborg, Kesmodel, Henriksen, Olsen, & Secher, 2001). We use available information in Natality files to explore several channels of impact. As shown and discussed in Appendix C, the results suggest reductions in teenage fertility, increases in mate quality, and improvements in prenatal care. For instance, an additional year of maternal education is associated with roughly 1.3 more prenatal doctor visits.

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[6] See, for example, Currie and Moretti (2003) & McCrary and Royer (2011).

[7] Births in Natality data files over the years 1970–2004 add up to 119,028,836 counts. About 12.2% have missing or uncertified information on mothers' education, age, or state of birth, the most relevant variables in this study. Among those with non-missing values, roughly 34% are first-time mothers. Among first-born observations, 98.7% are singleton births. Restricting the sample by mothers' age loses only 0.7% of the data. All these figures together, the final sample cover approximately 25% of the initial observations.

[8] There are usually three thresholds: low birth weight for birth weights less than 2500 g, very low birth weight for birth weights of less than 1500 g, and extremely low birth weight for birth weights of less than 1000 g.

Table 4
OLS and 2SLS effects of mothers' education on infants' birth outcomes.

	Birth Weight (Grams)		Low Birth Weight (× *100*)		Very Low Birth Weight (× *100*)		Gestational Age (Weeks)		Preterm Birth (× *100*)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
OLS										
Mothers' Education	25.232*** (0.170)	22.184*** (0.161)	−0.732*** (0.005)	−0.639*** (0.004)	−0.126*** (0.001)	−0.105*** (0.001)	0.049*** (0.004)	0.036*** (0.004)	−0.900*** (0.006)	−0.725*** (0.005)
2SLS-IV										
Mothers' Education	50.105*** (16.015)	33.760** (15.417)	−3.314*** (0.588)	−2.780*** (0.621)	−0.905*** (0.201)	−0.778*** (0.240)	0.002 (0.075)	0.319*** (0.082)	−2.022** (0.861)	−3.761*** (1.039)
First Stage:										
MDA18	0.081*** (0.011)	0.073*** (0.010)	0.081*** (0.011)	0.073*** (0.010)	0.081*** (0.011)	0.073*** (0.010)	0.082*** (0.011)	0.067*** (0.011)	0.082*** (0.011)	0.067*** (0.011)
F-Statistics (First Stage)	52.90	45.70	52.90	45.70	52.90	45.70	49.24	36.99	49.24	36.99
Fixed Effects:										
Current Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State of Residence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State of Birth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year of Birth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region of Birth × Birth Cohort	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	28,855,341	28,855,341	28,855,341	28,855,341	28,855,341	28,855,341	27,072,889	27,072,889	27,072,889	27,072,889

Notes. Controls include dummies for mother and father's race and age. Standard errors, reported in parentheses, are clustered on mothers' birth state-year. Fixed effects include state of residence, current year, current month, year of birth, and state of birth of the mother.

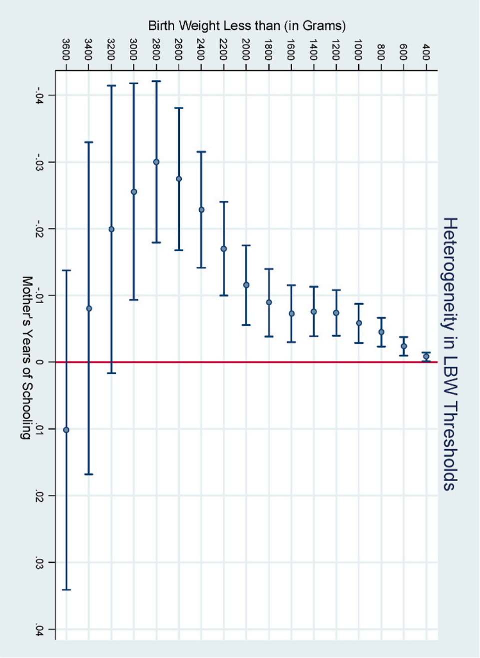

Fig. 5. 2SLS Results of Mothers' Education on Low Birth Weight by Different Thresholds of Definition of Low Birth Weight
Notes. Each point represents a separate 2SLS-IV regression. All regressions control for parents' race, current state and year fixed effect, mothers' state and year of birth fixed effects, and an interaction of region of birth by birth cohort. Data covers the years 1970–2004. Standard errors are clustered at state-year of birth of mother. 90% confidence intervals are shown around each estimated point.

5. Discussion

The evidence presented here complements a small literature on education and infants' health. The results of preterm birth are in line with the findings of Shen (2018), who examined the effect of school desegregation over a similar time frame (1970–2002) and found that exposure to school desegregation had positive effects on mothers' education and reduced preterm birth specifically among mothers in southern counties. Güneş (2015) used changes in compulsory schooling in turkey and found that completion of primary school was associated with a reduction in the incidence of very low birth weight by 17 percentage point. However, our findings contradict those of McCrary and Royer (2011), who exploited school entry policies in Texas and California and found little evidence that mothers' education affected birth outcomes.

To put the results into perspective, we should note that, in the year 2000, roughly 307,000 births were categorized as low birth weight. The respective marginal effect of 2SLS-IV implies a reduction of roughly 8600 incidences of low birth weight in the year 2000. Each incidence of low birth weight is associated with adverse short-run and long-run effects. For instance, the hospital discharge costs associated with low birth weight infants are higher than those with normal birth weight. Almond, Chay, and Lee (2005) used the twin strategy to calculate the hospital costs of being born below normal birth weight in excess of the costs for normal birth weight. Using their estimated marginal costs, an additional year of education could save up to $74 million in hospital costs related to low birth weight in the year 2000.[9,10]

Education also has a sizeable impact on mean birth weight. The marginal impact of an additional year of education is an increase of 33 g in birth weight. Using the cost-benefit calculations of Almond et al.

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[9] The dollar figures are in year 2000 dollars.

[10] This number is calculated using Table V in their paper. We calculate the share of each strata of birth weight in 2000 Natality files and compute the weighted average cost based on the costs associated with each strata of birth weight in their paper to get average excess cost of low birth weight of $8654. Since the marginal effect of low birth weight (as a response to one more year of schooling) point to a reduction of 8542 fewer incidences in year 2000, one can obtain a cost saving of $73.92M.

(2005), an additional 33 g in weight at birth is associated with $165 lower hospital discharge fees. Almond et al. (2005) also looked at infant mortality rate as infants with higher birth weight have a lower risk of morbidity up to their first year in life. An increase of 33 g could avoid up to 7.3 deaths per 10,000 live births, representing roughly an 11% drop in 1-year infant mortality in the year 2000. Besides the short-run impacts, an increase in health capital at birth has some medium and long run impacts. Royer (2009b) investigated the effect of birth weight on a series of adults outcomes. Based on their calculations, an additional 33 g is associated with a roughly 0.6% increase in their earnings when they reach adulthood.

These calculations reveal only a back-of-an-envelope estimates and only reveal partial implications of improvements in infants' health outcomes for later-life outcomes and wellbeing. The evidence documented in this study in combination with the linked-long-term effects call for policy interventions that aim at increasing educational outcomes such as minimum dropout age as potential pathways for a healthier next generation.

Overall, this study has one limitation that we should be aware in interpreting the results. While we find significant first-stage effects which suggests that MDA laws were successful in increasing educational outcomes, we do not detect the treated population. Indeed, we are unable to distinguish compliers with those that would have obtained more education in the absence of educational policies. Therefore, it is worth noting that the results reveal only intent-to-treat effects and the true values could be larger.

6. Conclusion

There are benefits to education that goes beyond labor market outcomes. This paper studied one important externality of education among females: infants' health outcomes at birth. Using the universe of birth records in the US over the years 1970–2004 and solving the endogeneity of education by exploiting changes in minimum school leaving age laws, we showed that education has the potential to improve birth outcomes. The point estimates suggest that omitted factors substantially underestimate the true effects in OLS regression. The 2SLS-IV estimates imply that each additional year of maternal education is associated with a reduction in incidences of low birth weight, very low birth weight, and preterm birth by 2.8 percentage-points, 0.8 percentage-points, and 3.8 percentage-points.

Ethical statement

1) This material is the authors' own original work, which has not been previously published elsewhere.

2) The paper is not currently being considered for publication elsewhere.

3) The paper reflects the authors' own research and analysis in a truthful and complete manner.

4) The paper properly credits the meaningful contributions of co-authors and co-researchers.

5) The results are appropriately placed in the context of prior and existing research.

6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.

7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

CRediT author statement

Hamid Noghanibehambari: Idea, Conceptualization, Methodology, Data Analysis, writing first draft.

Mahmoud Salari: Methodology, Review & Edit.

Nahid Tavassoli: Visualization, Review & Edit.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101163.

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