American Economic Journal: Applied Economics 2016, 8(1): 33–57
http://dx.doi.org/10.1257/app.20140323

Birthdays, Schooling, and Crime: Regression-Discontinuity Analysis of School Performance, Delinquency, Dropout, and Crime Initiation†

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Dropouts have high crime rates, but is there a direct causal link? This study, utilizing administrative data for six cohorts of public school children in North Carolina, demonstrates that those born just after the cut date for enrolling in public kindergarten are more likely to drop out of high school before graduation and to commit a felony offense by age 19. We present suggestive evidence that dropout mediates criminal involvement. Paradoxically, these late-entry students outperform their grade peers academically while still in school, which helps account for the fact that they are less likely to become juvenile delinquents. (*JEL* H75, I21, J13, J24, K42)

Laws governing school attendance have a well-documented effect on educational attainment, and plausibly may influence involvement in criminal activity. Under a standard economic model of crime (Becker 1968, Freeman 1999), education increases the stock of human capital and hence increases the rewards to legitimate work, inducing a substitution away from crime. That there is a close association between education and crime is well established. In particular, high-school dropouts are greatly overrepresented among convicted criminals (Harlow 2003, Raphael and Sills 2008, and Lochner 2011). Recent quasi-experimental evidence offers support for a causal interpretation of this association: in particular, extensions of the mandatory schooling age in the United States, Great Britain, and Sweden appear to have increased educational attainment and reduced lifetime involvement in criminal activity (Lochner and Moretti 2004; Anderson 2014; Hjalmarsson, Holmlund, and Lindquist 2015; Machin, Marie, and Vujić 2011; and Clay, Lingwall, and Stephens 2012).[1]

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† Go to http://dx.doi.org/10.1257/app.20140323 to visit the article page for additional materials and author disclosure statement(s) or to comment in the online discussion forum.

[1] Some published results from the analysis of compulsory-schooling extensions in the United States were recently challenged by Stephens and Yang (2014), who demonstrate that a reasonable modification of the regression specification nullifies claims about wages, unemployment, and divorce. They did not assess the crime literature.

It should be noted, however, that the mechanisms by which an increase in school-leaving age affects criminal involvement is not entirely clear. While such reforms increase human capital, they also keep youths in school longer at an age (mid teens) when crime rates are high; teens who spend their days in school may have more limited criminal opportunities than are available to those who have dropped out (Jacob and Lefgren 2003, Luallen 2006), and be exposed to a less crime-involved peer group (Anderson, Hansen, and Walker 2013).

This paper employs another approach to exploring the link between schooling and crime. We use as a source of variation in educational achievement the interaction between the child's birthdate and the minimum school-entry age. A series of articles beginning with Angrist and Krueger (1991) have analyzed the effects of birth date on academic achievement, high-school dropout, earnings, and other outcomes. This literature is consistent in finding that youths born just after the school-entry eligibility cut date (and hence relatively old for their grade) perform better academically than their younger classmates but are more likely to drop out before receiving their high school diplomas. The elevated dropout rate is likely due to the fact that the old-for-grade youths have a longer window of time during which they are legally entitled to drop out. Thus, there appear to be two potentially opposing human-capital mechanisms in the delayed-entry "experiment."

First, older students are likely to be more mature than their classmates, and hence better prepared for the challenges of learning new material and managing relationships with other students and adults. The positive link between students' relative age and academic achievement has been documented in a number of recent papers (Bedard and Dhuey 2006; Datar 2006; Puhani and Weber 2007; McEwan and Shapiro 2008; Elder and Lubotsky 2009; Crawford, Dearden, and Meghir 2010; Black, Devereux, and Salvanes 2011; and Clay, Lingwall, and Stephens 2012). The possibility that the early advantage may have persistent impacts on students' educational experiences has convinced some parents to delay enrolling their children. This practice of "academic redshirting" has gained popularity in recent years, and is considered an important aspect of the "lengthening of childhood" (Deming and Dynarski 2008). It is more common for boys than girls, and for whites than African Americans.

The second mechanism is that students born just after the entry-eligibility cut date (hereafter designated as DEEs for "delayed entry eligibility") are less likely to complete high school than those born just before. Under the compulsory schooling laws of the states, students are eligible to leave school after reaching a threshold age, ranging from 16 to 18, and students who are old for their grade have a longer period during which they may legally drop out prior to graduation (Angrist and Krueger 1991). The lack of a high school diploma is a considerable handicap in the labor market (Heckman, Lochner, and Todd 2008).[2]

[2] Surprisingly, there is some question about whether the elevated dropout rate due to delayed school entry has an effect on subsequent employment and earnings. Angrist and Krueger (1991) report that delayed entrants have lower earnings in middle age. But Dobkin and Ferreira (2010), using a more fine-grained regression discontinuity analysis of Texas and California data, find that dropout induced by delayed entry to school has no effect on labor market outcomes. It should be noted that the "dose" in Texas and California is small because students are not allowed to drop out until age 18.

Our analyses are based on rich administrative data from the North Carolina public school system and other state agencies. In addition to detailed data on enrollment and academic performance, the dataset includes items from the youth's birth certificate, juvenile delinquency, and adult criminal records. Using the regression discontinuity (RD) framework (Thistlethwaite and Campbell 1960), we compare educational and criminal outcomes of children born just before and after the school entry cutoff date. Given that individual characteristics associated with educational and criminal outcomes are balanced at the cutoff date, the differences in outcomes provide estimates of the causal effect of school entry eligibility on education and crime. The dataset is large and of high quality—for example, exact birth dates and data on demographic characteristics are taken directly from the birth certificates, while education and crime data are taken from administrative records rather than self-reports.

The results reported here demonstrate that youths born just after the cutoff date for entry eligibility perform relatively well in school by a variety of measures through middle school and beyond, no doubt due to the advantages of being relatively mature for their grade. Nonetheless, in comparison with those born just before the cutoff date, they are more likely to drop out of school before graduation. With respect to crime, we find that youths born just after the cutoff have a significantly lower likelihood of criminal activity between age 13 and 15 (as measured by delinquent complaints), but a higher likelihood of committing a serious adult crime (as measured by felony conviction for crimes committed by age 19). Both these crime-related findings can be linked to school performance. Delayed-entry-eligibility (DEE) youths tend to be relatively successful in school through age 15 (measured by end-of-grade test scores and promotion rates), and so through that age have relatively favorable legitimate prospects. Just the fact that DEE youths are less likely to place at the bottom of the sixth grade end-of-grade reading test accounts for half of the reduction in delinquency. But this same group is more likely to drop out of high school, in which case their prospects are much diminished. Hence, it is reasonable to conclude that high school dropout enhances the likelihood of committing serious crimes. Indeed, the "extra" dropouts in the late-entry group account for almost all of the increase in criminal convictions that we observe. That this pattern is not due to the reverse sequence of events (in which criminal involvement leads to dropping out) is suggested by the fact that the elevated crime rate for the delayed-entry group is concentrated at age 19, by which time few youths are still in high school.

This interpretation of our results, linking crime to educational attainment, is actually reinforced by a recent study of Danish school children, even though at first glance it appears to have contradictory findings on the adult-crime effects of starting school late due to birth date (Landersø, Nielsen, and Simonsen 2013). In Denmark the late-entry children are *less* likely to become involved in crime than early-entry children. A unique feature of Denmark's compulsory schooling laws suggests the explanation—Danish students are not allowed to withdraw from school until they have completed ninth grade, regardless of age. Hence, late entry does not expand the legal "window" for dropping out, as it does in North Carolina and the rest of the states.[3]

The rest of the paper is organized as follows. Section I describes the institutional background and data used. Sections II and III introduce our empirical strategy and present the main results, with suitable checks on validity and robustness. Section IV explores the link between the time "exposure" to legal dropout and the probability of dropping out. Section V concludes with a discussion of the policy relevance of the findings.

I. Institutional Framework and Data Description

A. *Minimum Age Requirement for School Entry in North Carolina*

The compulsory schooling law in North Carolina specifies the minimum age of enrollment in public kindergarten.[4] While the law has been recently amended, prior to the 2009 school year children in North Carolina became eligible to enter kindergarten only if they reached the age of five by October 16 in the relevant year. Thus, the children born in September 1987 were eligible to enter school a year earlier than those born in November 1987, who were in turn slated to enter school at the same time as children born in September 1988. There are exceptions to this rule, but they do not prove important in practice.

The actual timeline for school entry and progression through the grades is to some extent a matter of choice. Some parents choose to delay their child's enrollment in school by a year, and other students are retained in primary school for an extra year by school officials. The prevalence of such delays is particularly large among children born just before the cutoff date. Thus, our findings are best interpreted as intention-to-treat (ITT) effects, namely, the effect on educational and criminal outcomes of receiving school entry eligibility nearly a year earlier than a comparable control group, rather than the effect of actually entering school a year earlier.

B. *Data Description*

Our main data source is individual-level administrative data from the North Carolina public school system, provided by the North Carolina Education Research Data Center (NCERDC). The student-level data from the NCERDC cover all students enrolled in the North Carolina public school system, and contain detailed information on students' schooling from grades 3 to 12.[5] Our measure of academic achievement comes from students' performance on state-wide End-of-Grade (EOG) reading and math tests that are administered from grades 3 to 8, which all students are required to take. Students' test performance across years can be tracked by unique individual identifiers assigned by the NCERDC. EOG test records specify

[3] Where our results are directly comparable to the Danish results is with respect to delinquency during age 13–15, prior to dropout eligibility. Both their study and ours find that late entry reduces delinquency.

[4] North Carolina General Statutes 115C–364.

[5] Unfortunately, we do not have information on students' actual age of kindergarten enrollment.

the grade in which they were administered; we identify students who take the EOG tests for a given grade level more than once as grade repeaters. Enrollment data in North Carolina public school system above grade 8 are available from the NCERDC "masterfile."

A potential difficulty in following students' academic progress over time is the movement of students between the public school system and private schools in North Carolina, or migration to and from other states. If the group of students leaving or entering the North Carolina public school system is systematically different from those initially enrolled and staying in the system with respect to characteristics related to their academic performance, it is not straightforward to track and understand students' academic progress over time. For instance, in comparing academic performance of students born before and after the school entry cutoff date, if students who were born just after the cutoff date and score high on EOGs are more likely to leave for private schools, the difference in academic achievement between those born before and after the cutoff who remain in the public schools will diminish over time even if the true effect of school entry eligibility remains constant. Alternatively, comparison of educational experience at the cutoff date over time may be obscured by the influx of new students into the public school system. For example, students entering North Carolina public schools after kindergarten years may include disproportionately many children from immigrant households with limited English proficiency. To avoid these potential complications, we restrict our main analyses to students who were born in North Carolina and enrolled in the North Carolina public school system for 5 consecutive years between ages 11 and 15.[6] This choice is further motivated by data availability and the compulsory schooling laws in North Carolina allowing students to leave school at age 16.[7]

We determine students' in-state birth status from North Carolina birth certificate data, which are merged with the educational data via the NCERDC individual identifiers. The birth certificate data also provide information on the exact date of birth, a key identifying variation in our empirical analyses below.[8] In addition, the birth certificate data contains other key demographic attributes measured at the time of birth, such as gender, birth weight, mother's race, parents' marital status, and mother's education attainment and age level. Our regression analyses focus on students born within 60 days of school entry cutoff dates in 1987, 1988, 1989, 1991, 1992, and 1993. Since the EOG tests are administered in late May to early June, students from a given birth cohort (e.g., those born within 60 days of the school entry cutoff date in 1987) are of the same age when taking the EOG tests, which makes it straightforward to construct and interpret some of our outcome measures, such as

[6] We also exclude students enrolled in charter schools from our analysis.

[7] We also ran alternative analyses based on all North Carolina public school students enrolled in the North Carolina public school system between ages 11 and 15 (regardless of their birthplace); and those who were born in North Carolina and attended the North Carolina public school system at some point of time between ages 11 and 15, and obtained similar results. Results are available on request from the authors.

[8] The EOG test score files from the NCERDC data also contain students' date of birth, but aggregated up to each calendar month. For example, all students who were born in October 1987 are assigned October 15, 1987 as their birthdates. Since the school entry cutoff date in North Carolina we use is in the middle of a calendar month (October 17), the EOG test score files do not allow us to distinguish students born just before and after the cutoff date.

grade level distribution at a given age. We run a robustness check on the RD analysis by shortening the time window to 30 days of the cutoff date. Discontinuity estimates for key educational and criminal outcomes are not much affected by the use of the narrower window.

We use the following measures of students' educational experience: students' EOG reading and math test score percentiles in grades 6 through 8, grade retention between ages 11 and 15, grade at age 11 and age 15, and school enrollment 4 years after grade 8. Students who took the EOG for the same grade in two consecutive years are designated as "repeaters." We do not have direct information on high school graduation for our sample of students, but for the 1987–1989 cohorts we do know whether they persisted in public school. In particular, we consider whether students remain enrolled in North Carolina public schools four years after eighth grade (henceforth, "Year 12"). Year 12 is equivalent to grade 12 if they did not repeat grades between grades 8 and 12. Students who transfer out of state or to a private school after age 15 are, unfortunately, indistinguishable from dropouts by this measure, and so are students who start attending community colleges and/or four-year universities early. It is also true that some students who are enrolled in Year 12 never graduate. The net effect is that Year 12 enrollment appears to overstate the graduation rate: Year 12 enrollment for our sample is 79 percent, while the official four-year high school graduation rate in North Carolina during School Year 2007–2008 was 70 percent (North Carolina Department of Instruction 2008).

Our measures of criminal activity are based on the official-juvenile-complaint data[9] and adult-felony-conviction data in North Carolina, provided by the North Carolina Department of Juvenile Justice and Delinquency Prevention (NCDJJDP) and North Carolina Department of Corrections (NCDOC), respectively. We examine whether individuals receive a juvenile complaint between ages 13 and 15 and whether they are convicted of a serious crime committed between ages 17 and 19.[10] The prevalence of juvenile complaints between ages 13 and 15 in our 1991–1993 sample is 9 percent, and that of convictions for adult criminal activity between ages 17 and 19 is 6 percent. While the official complaint and felony conviction records are reliable indicators of involvement in crime, they are far from comprehensive. For example, for a youth to be convicted of a serious crime requires that the crime is known to the police and results in an arrest, and that the resulting case works its way through the court system to conviction at the felony level. It is fair to say that our indicator tends to signal the high end of the crime-involvement spectrum.

II. Empirical Strategy

Our empirical strategy exploits the sharp discontinuity in grade level configuration between children born before and after the school entry cutoff date in North Carolina. Figure 1 illustrates the extent of this grade level variation among sample

[9] A complaint filed by a law enforcement officer, teacher, or citizen against a youth suspected of committing a crime/delinquency is the first step of the juvenile justice system. After evaluating the complaint and evidence, a NCDJJDP counselor determines whether the case should go to court and makes referral to other resources if necessary.

[10] The choice of crime outcome measures is driven by data availability.

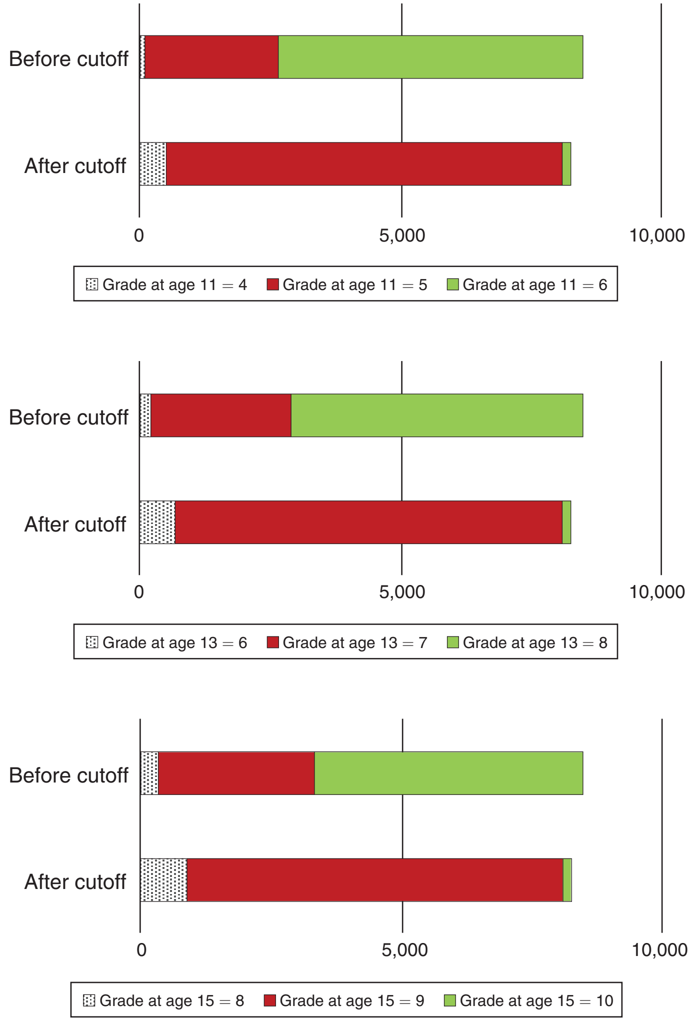


Figure 1. Grade Level Distribution across Age Levels, 1987 Cohort

Note: Figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987 (October 17) and attended North Carolina public schools between ages 11 and 15.

students born within 60 days of the cutoff date in 1987. Each panel shows the age at which students take the EOG tests and the corresponding grade level distribution, computed separately for students born before and after the cutoff date. For example, our 1987 cohort was 11 years old when taking their EOG tests in school year 1998–1999; 75 percent of students born before the cutoff were enrolled in grade 6, while more than 90 percent of those born after were in grade 5. Similarly, large differences in grade level configuration between students born before and after the cutoff date are also observed in subsequent years, as shown.

The grade level variation at the cutoff date enables an estimate of the causal effects of school entry eligibility on children's subsequent educational and criminal outcomes. Given that other characteristics associated with these outcomes remain similar and continuous at the cutoff date, the outcomes of children born just before the cutoff provide reasonable estimates of the counterfactual outcomes of those born just after the cutoff had they been eligible to enter school a year earlier. This interpretation of regression discontinuity estimates using the potential outcomes framework is formalized in Hahn, Todd, and Van der Klaauw (2001). Moreover, as long as individuals do not have precise control over their children's birthdates, the variation in school entry eligibility can be considered as good as randomized near the cutoff date (Lee and Lemieux 2010). Below, we formally introduce our regression specification and describe our estimation procedure in more detail.

The discontinuity in educational and criminal outcomes at the cutoff date can be estimated in several ways. Here we use the local-linear-regression technique which estimates the discontinuity nonparametrically, assigning more weight to data points closer to the cutoff date than points further away.[11] Local-linear-regression estimates can be obtained by solving the following method-of-moment specification:

$$(1) \qquad \min \sum_{i=1}^{Ni} (Y_i - \alpha_1 D_i - \alpha_2 R_i - \alpha_3 D_i R_i)^2 K_h(D_i, R_i),$$

where $K_h(D_i, R_i)$ represents a weighting kernel function with bandwidth h. We use the following triangular kernel in our analyses, as it is known to be optimal for local-linear regression at the boundary (Fan and Gijbels 1992):

$$(2) \qquad K_h(D_i, R_i) = \max\left(0, 1 - \left|\frac{R_i}{h}\right|\right).$$

The vector of individual covariates $\mathbf{X}$ is included in the specification to improve the precision, as follows

$$(3) \qquad \min \sum_{i=1}^{Ni} (Y_i - \alpha_1 D_i - \alpha_2 R_i - \alpha_3 D_i R_i - \mathbf{X}_i \beta)^2 K_h(D_i, R_i).$$

From equation (3) it is clear that the local linear regression estimates are affected by the choices of the kernel and bandwidth. The consensus in the technical literature is that the choice of the kernel has little impact on the estimates, but the choice of bandwidth is more influential. Motivated by the optimal bandwidth proposed by Imbens and Kalyanaraman (2012), we present our main results using a 60-day bandwidth. In Section IIIE, we describe in more detail the optimal bandwidth for our data, and examine the robustness of our findings across an alternative bandwidth choice.

[11] We also ran the regression analyses using the global parametric specification and obtained very similar results. For brevity, we only report point estimates obtained from local linear regression.

Table 1—Descriptive Statistics

Cohort	1987–1989		1991–1993	
Date of birth	Before cutoff (percent)	After cutoff (percent)	Before cutoff (percent)	After cutoff (percent)
Male	49.1	49.4	48.9	48.5
Black	30.6	31.7	31.5	32.2
Unwed mother	26.4	27.5	32.7	33.4
Born to teenage mother	10.1	10.7	10.5	10.7
Mother's education < high school	12.0	12.5	11.5	11.9
Birth weight < 2,500 grams	7.2	7.3	7.5	7.9
Free/reduced price lunch, age 11			43.2	44.0
Observations	28,023	26,054	28,282	26,642

Notes: Sample is composed of students born within 60 days of the school entry cutoff dates in 1987–1989 and 1991–1993. Each cohort is defined by students born between August 18 and December 16 of the relevant year (60 days before and after the cutoff date of October 17). The sample is further restricted to students who attended North Carolina public schools between ages 11 and 15, and whose North Carolina birth certificate information is available.

III. Results

We begin by documenting that for students born within 60 days on either side of the cutoff date, the "before" group is similar to the "after" group. Table 1 provides prevalence statistics for seven indicator variables used as individual covariates in the analysis to follow: sex (male), race (black), unwed mother, teenage mother, mother's education less than high school at time of birth, birth weight less than 2500 grams, and eligible for free or reduced price lunch at age 11. For each of these variables, and for both samples (1987–1989 and 1991–1993), the prevalence for the "before" group is close to the prevalence of the "after" group, as would be expected if students were assigned at random to the two groups. Below, we show regression results that confirm continuity of these variables at the cutoff date (Table 7).

That most students complied with the state law governing minimum age eligibility is demonstrated by a sharp discontinuity in the grade level around October 17th. The grade level distribution at age 11 is depicted in Figure 2. The horizontal axis corresponds to students' birth dates relative to the school entry cutoff date (day 0 = October 17). The discontinuity is clear: those who were born just before the cutoff average 0.6 grade level higher than those born just after. That the difference is less than a full year indicates the fact that a share of students born before the cutoff date either entered kindergarten after their eligibility year or repeated a grade prior to age 11.

Table 2 presents point estimates of the grade level discontinuity at the cutoff date. The first column reports a baseline specification in which grade level at age 11 is regressed on an indicator of birth date after the cutoff (D), the birthdate (R), their interaction (DR) and a constant (equation (1)). Consistent with the graphical evidence, we find a sizable discontinuity at the cutoff date in the grade levels at age 11. The specification reported in the second column includes the seven individual covariates (equation (3)). In support of the assumption that the timing of birth near the cutoff date is independent of sociodemographic characteristics, we find little change in the key coefficient estimates, but a considerable increase in explanatory

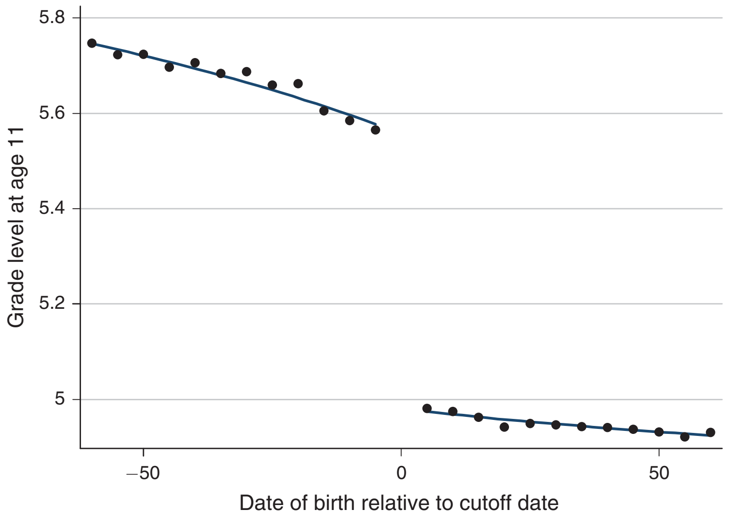


Figure 2. Grade Level Distribution at Age 11, 1987–1989 Cohort

Notes: Figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987, 1988, and 1989 (October 17) and attended North Carolina public schools between ages 11 and 15. Horizontal axis represents the date of birth relative to the cutoff date. Dots represent 5-day averages of students' grade level at age 11. Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth.

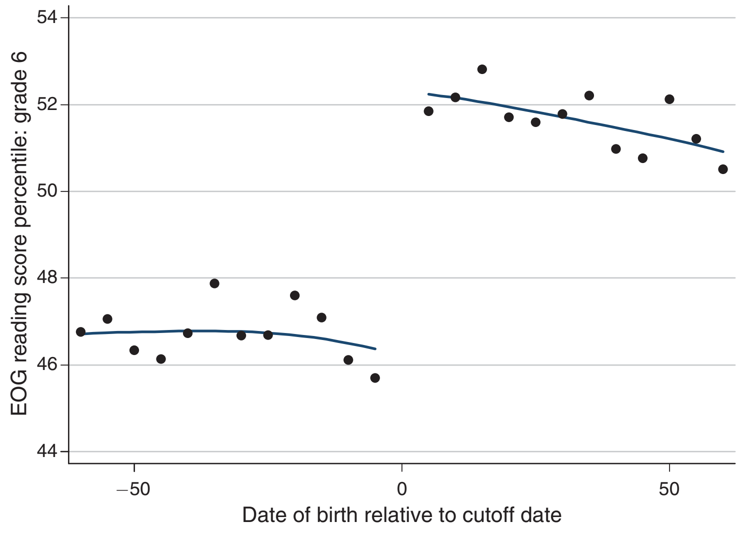
Table 2—Effect of Delayed School Entry Eligibility on Grade Level at Ages 11 and 15: 1987–1989 Cohorts

Outcome: grade level at	Age 11		Age 15	
D	−0.59***	−0.59***	−0.52***	−0.53***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	5.57***	5.67***	9.46***	9.62***
	(0.01)	(0.01)	(0.01)	(0.01)
Covariates	No	Yes	No	Yes
R^2	0.40	0.42	0.29	0.34
Observations	53,523	53,523	53,523	53,523

Notes: All estimates are from local linear regression specifications, which include birthdays (*R*), post-cutoff indicator (*D*), their interaction term (*DR*), and cohort fixed effects. A triangular kernel with bandwidth of 60 days is used. Two of the regressions also control for the following individual covariates in the form of binary indicators for gender (1 if male), race (1 if black), mother's marital status at birth (1 if unwed), mother's age at birth (1 if under 19), mother's education level at birth (1 if mother is more than 19 years old and has less than 12 years of schooling), low birth weight (1 if less than 2,500 grams), and free or reduced price lunch eligibility at age 11 (available only for 1991–1993 cohorts), as well as cohort fixed effects. Robust standard errors clustered at the birthday level are in parentheses.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

power and some improvement in estimate precision. Results at age 15 are presented in the next two columns, and tell a similar story. The discontinuity in the grade level is slightly smaller, reflecting the differential retention rates between early-entry and late-entry students.



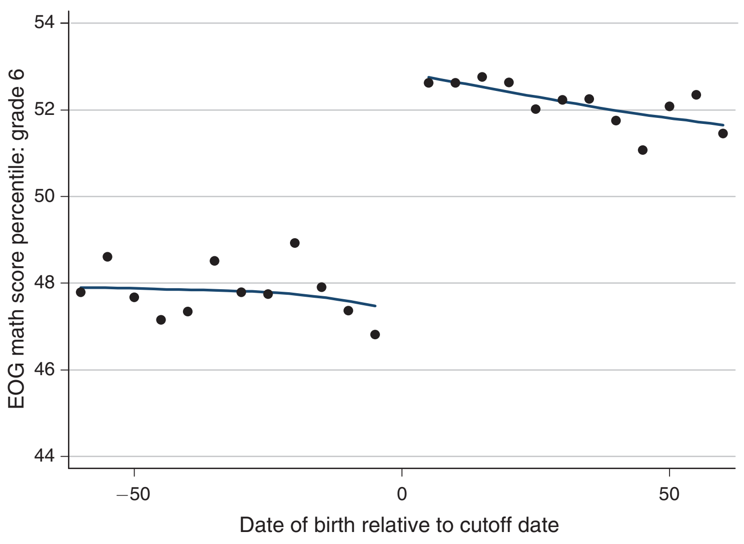


Figure 3. EOG Reading and Math Score Percentiles in Grade 6, 1987–1989 Cohort

Notes: Figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987, 1988, and 1989 (October 17) and attended North Carolina public schools between ages 11 and 15. Horizontal axis represents the date of birth relative to the cutoff date. Dots represent EOG reading and math score percentiles (normalized with respect to each grade level and test year) averaged over 5-day blocks. Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth.

Next, we consider the discontinuity in students' academic achievement levels at the cutoff date. Children born just after the cutoff are likely to score higher in both reading and math across all three grade levels. Table 3 presents local linear regression estimates of the reading achievement percentile discontinuity at the cutoff date. (The discontinuity estimates obtained from a baseline specification, equation (1), and an extended specification, equation (3), are very similar, and only the latter

Table 3—Effect of Delayed School Entry Eligibility on EOG Reading and Math Achievement in Grades 6, 7, and 8: 1987–1989 Cohorts

	(A) EOG reading	(B) EOG math
Grade 6	5.70***	5.11***
	(0.41)	(0.39)
Grade 7	5.58***	4.79***
	(0.39)	(0.38)
Grade 8	4.62***	4.01***
	(0.45)	(0.43)
Observations	53,523	53,523

Notes: Each entry represents the coefficient on the post-cutoff indicator (D). All estimates are from local linear regression specifications, which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), and cohort fixed effects. A triangular kernel with bandwidth of 60 days is used. Regressions also control for the following individual covariates in the form of binary indicators for gender (1 if male), race (1 if black), mother's marital status at birth (1 if unwed), mother's age at birth (1 if under 19), mother's education level at birth (1 if mother is more than 19 years old and has less than 12 years of schooling), low birth weight (1 if less than 2,500 grams), and free or reduced price lunch eligibility at age 11 (available only for 1991–1993 cohorts), as well as cohort fixed effects. Robust standard errors clustered at the birthday level are in parentheses.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

are reported here.) We find that individuals born just after the cutoff score substantially higher on EOG reading and math tests across grades 6–8 than those born just before. The magnitude of the discontinuity decreases somewhat with grade level, yet remains large: for example, the sixth grade reading effect is approximately 75 percent of that on out-of-wedlock birth, and more than twice as large as that on underweight birth. Our results are consonant with those reported by Bedard and Dhuey (2006), who also find a persistent advantage in math test scores through middle school.

A. *Promotion and Persistence*

The school entry eligibility age influences whether students successfully advance through the grade levels on time between ages 11 and 15 and remain enrolled through senior year on the way to graduation. The seeming paradox is that delayed entry eligibility (DEE) students are less likely to be held back in school through age 15, but more likely to drop out. The North Carolina compulsory schooling law allows students to drop out from school at age 16. A student born just after the cutoff will be exposed to the legal possibility of dropping out prior to graduation for almost a year longer than a student born just before, assuming neither has been delayed. Table 4 presents the corresponding regression estimates. DEE students are 6 percentage points less likely to repeat a grade between ages 11 and 15. On the other hand, we find a 3 percentage point drop in the Year 12 enrollment for DEE students. (Figure 4 depicts the discontinuity.) Table 4 also presents the results for Year 11, defined as enrollment three years following eighth grade.

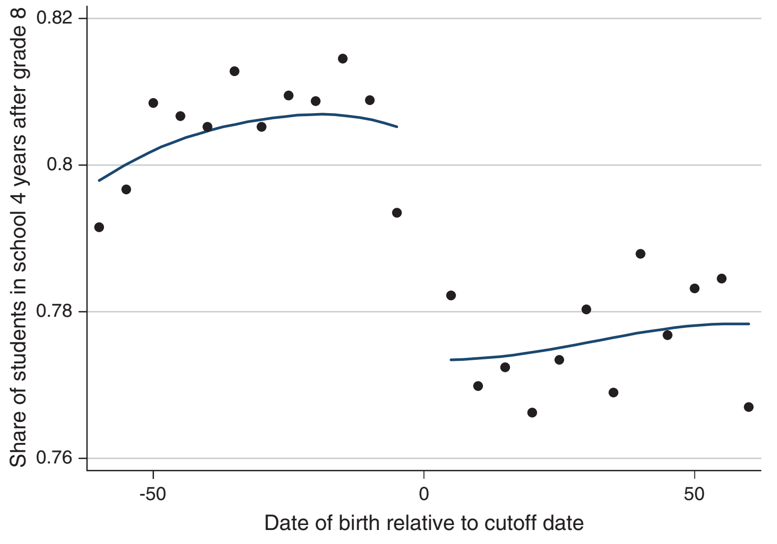


Figure 4. Share of Students Enrolled in School in Year 12, 1987–1989 Cohort

Notes: Figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987, 1988, and 1989 (October 17) and attended North Carolina public schools between ages 11 and 15. Horizontal axis represents the date of birth relative to the cutoff date. Dots represent 5-day averages of the share of students who remain enrolled in North Carolina public school 4 years after grade 8 ("Year 12"). Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth.

Table 4—Effect of Delayed School Entry Eligibility on Likelihood of Grade Retention and High School Attainment: 1987–1989 Cohorts

Outcome	Grade retention ages 11–15	Enrollment year 11	Enrollment year 12
D	−6.42***	−2.79***	−3.14***
	(0.37)	(0.69)	(0.86)
Constant	5.06***	94.62***	87.82***
	(0.51)	(0.54)	(0.72)
R^2	0.05	0.04	0.04
Observations	53,523	53,523	53,523

Notes: All estimates are from local linear regression specifications, which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), and cohort fixed effects. A triangular kernel with bandwidth of 60 days is used. Regressions also control for the following individual covariates in the form of binary indicators for gender (1 if male), race (1 if black), mother's marital status at birth (1 if unwed), mother's age at birth (1 if under 19), mother's education level at birth (1 if mother is more than 19 years old and has less than 12 years of schooling), low birth weight (1 if less than 2,500 grams), and free or reduced price lunch eligibility at age 11 (available only for 1991–1993 cohorts), as well as cohort fixed effects. Robust standard errors clustered at the birthday level are in parentheses.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Again, coefficients on the individual covariates (not shown in the table) take expected signs. Children who were born out of wedlock, whose mothers were underage or had low education attainment, and who had low birth weight are significantly more likely to repeat grades and are less likely to remain enrolled in high school

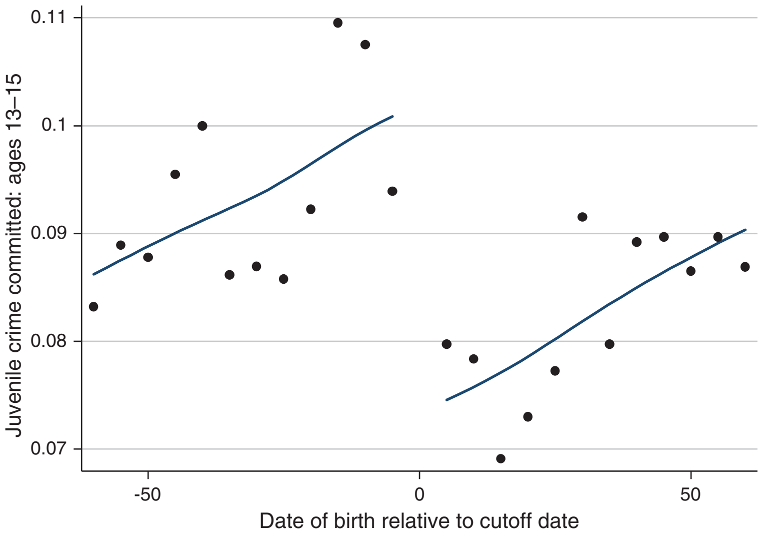


Figure 5. Share of Students with Juvenile Delinquency between Ages 13–15, 1991–1993 Cohort

Notes: The figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987, 1988, and 1989 (October 17) and attended North Carolina public schools between ages 11 and 15. Horizontal axis represents the date of birth relative to the cutoff date. Dots represent 5-day averages of the share of students who commit juvenile delinquency between ages 13 and 15. Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth.

before graduation. A free/reduced price lunch eligibility indicator is available for the 1991–1993 cohorts, and is a significant and positive predictor of grade retention outcome. We take a closer look at the potential heterogeneity in educational experience and the magnitude of the discontinuity at the cutoff date across different socioeconomic groups below.

B. *Juvenile Delinquency*

Our main objective is to explore how the differences in educational experience, driven by the variation in the timing of birth with respect to the school entry cutoff date, influence individuals' risks in delinquency and crime. We begin with an analysis of juvenile delinquency committed between ages 13 and 15, measured by the NCDJJDP complaint records for the 1991–93 cohorts. (Recall that youths are treated as adults beginning at age 16 in the North Carolina criminal justice system.) There is a sharp, precisely measured drop in the delinquency rate associated with the cutoff date. The estimated discontinuity using the equation (3) specification is -2.8 percentage points (SE $=$ 0.6), compared with the overall delinquency prevalence of 8.8 percent. Thus the likelihood of a delinquent complaint is nearly one-third less for DEE students.

The delinquency patterns provide suggestive evidence that the effect is mediated in part by academic performance, as measured, for example, by the EOGs. Almost half of the delinquents from the group of youths born during the 60-day interval before the cutoff date scored in the bottom quartile (Q1) of the sixth grade

EOG reading test. The "yield" of delinquents from Q1 was 16.1 percent, compared with just a 6.6 percent yield for the remaining students. For youths born in the 60 days following the cut date, the reduction in delinquency resulted from both a sharp reduction in the prevalence of Q1 students (from 28.9 percent to 23.0 percent) and a reduction in the delinquency "yields" for both Q1 (16.1 percent to 15.5 percent) and for the rest (6.6 percent to 6.1 percent). A simple decomposition suggests that improved test scores and lower delinquency yields (conditioned on test score) get about equal credit for delinquency reduction.[12] This decomposition is based on a single rather narrow measure of academic performance, and it is quite possible that a broader measure would capture still more of the delinquency reduction.

One potential explanation for the association of delinquency with academic achievement is that children who do well in the classroom are likely to enjoy school more and hence resist the temptation to play truant with delinquent friends. A more Beckerian explanation would be that those with little success in schoolwork may anticipate low potential earnings from the legitimate labor market, where academic success and educational attainment are valued, and instead "invest" more on building crime capital.

C. *Adult Crime*

Participation in criminal activity as an adult may compete with licit opportunities, which are influenced by the quality and quantity of schooling. In the contrast analyzed here, quality and quantity tend to push in opposite directions. On the one hand, children born just after the cutoff date show higher academic achievement and lower risks of juvenile delinquency, which are associated with lower likelihood of committing crime as adults. On the other hand, they are also more likely to drop out, which has an adverse impact on their subsequent risk of criminal activity. The sign and magnitude of the discontinuity in the adult criminal risks at the cutoff should then depend on the relative magnitudes of these two opposing factors.

Table 5 reports regression estimates for adult crime committed between ages 17 and 19. The first column of Table 5 shows that DEE youths are 0.80 percentage points more likely to commit a crime between ages 17 and 19 (SE $= 0.40$), significantly greater than zero ($p < 0.05$). To place this finding in context, 5.68 percent of all youths in the 1987–1989 cohorts were convicted of a serious crime by age 19; overall, then, DEE reduced involvement in serious crime by 14 percent (0.80/5.68). The increase in adult crime at the cutoff is particularly noteworthy, given that the DEE group had much lower rates of juvenile delinquency. A likely explanation is that the adverse effect of high school dropout on crime is large enough to outweigh the crime-reducing effects of early academic advantage and low juvenile delinquency. Indeed, the fact that the eligibility effect on crime between 17 and 19 is concentrated at age 19 (fourth column of Table 5) suggests that high school dropout,

[12] The percentile distribution for the state EOGs is established by the North Carolina Department of Public Instruction. The percentage of sample youths in Q1 dropped from 28.9 percent for the "before" group to 23.0 percent in the "after" group. If yields had remained the same, there would have been 140.7 fewer delinquents in the DEE group. The drop in yields accounts for an additional 142.4 fewer delinquents.

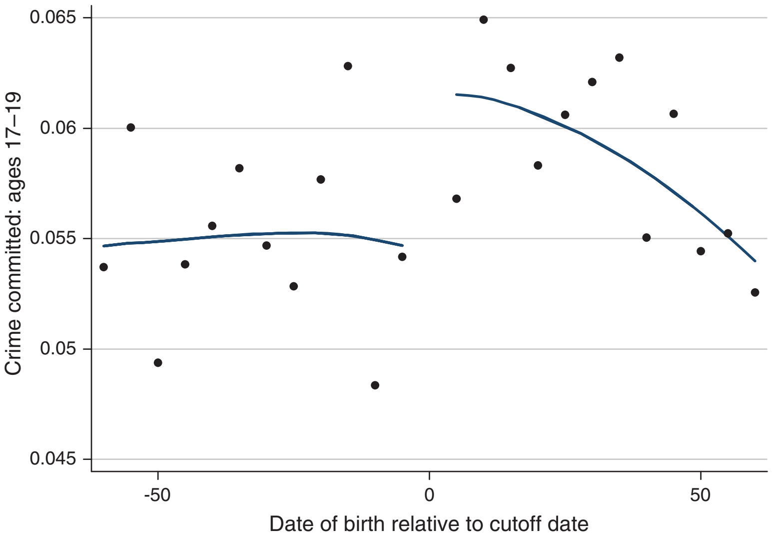


Figure 6. Share of Students with Adult Criminal Conviction between Ages 17–19, 1987–1989 Cohort

Notes: The figure is based on cohorts of students who were born in North Carolina within 60 days of the school entry cutoff date in 1987, 1988, and 1989 (October 17) and attended North Carolina public schools between ages 11 and 15. Horizontal axis represents the date of birth relative to the cutoff date. Dots represent 5-day averages of the share of students who received a criminal conviction for crimes committed between ages 17 and 19. Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth.

Table 5—Effect of Delayed School Entry Eligibility on Likelihood of Adult Criminal Conviction for Crimes Committed between Ages 17 and 19: 1987–1989 Cohorts

Outcome: crime committed at	Ages 17–19	Age 17	Age 18	Age 19
D	0.80**	0.13	0.02	0.69**
	(0.40)	(0.26)	(0.30)	(0.28)
Constant	−0.60*	−0.44**	−0.38	−0.31
	(0.34)	(0.18)	(0.26)	(0.22)
R^2	0.04	0.02	0.02	0.02
Observations	53,523	53,523	53,523	53,523

Notes: All estimates are from local linear regression specifications, which include birthdays (*R*), post-cutoff indicator (*D*), their interaction term (*DR*), and cohort fixed effects. A triangular kernel with bandwidth of 60 days is used. Regressions also control for the following individual covariates in the form of binary indicators for gender (1 if male), race (1 if black), mother's marital status at birth (1 if unwed), mother's age at birth (1 if under 19), mother's education level at birth (1 if mother is more than 19 years old and has less than 12 years of schooling), low birth weight (1 if less than 2,500 grams), and free or reduced price lunch eligibility at age 11 (available only for 1991–1993 cohorts), as well as cohort fixed effects. Robust standard errors clustered at the birthday level are in parentheses.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

which almost always occurs before age 19, may be an important mechanism through which the variation in school entry eligibility influences adult crime.

As with our analysis of delinquency (above), a simple decomposition provides suggestive evidence of the role of schooling in adult crime. In this case, almost all of the increase in crime is associated with the increased dropout rate. For youths born 60 days before the cutoff point, 13.4 percent of the dropouts were convicted, compared with just 3.6 percent of the persisters.[13] For the DEE youths born within 60 days after the cutoff point, the dropout rate increases from 19.5 percent to 22.4 percent, while the crime rates for dropouts and persisters remain close to the same. (The crime rate for the DEE dropouts increases slightly to 13.7 percent, and for persisters remains the same at 3.6 percent.) As a result, 82 percent of the crime increase for DEEs can be attributed to the increased dropout rate.

D. *Heterogeneity across Disadvantaged Groups*

The estimated magnitudes of the various academic and crime effects of DEE differ among demographic and socioeconomic subgroups. Here we focus on disadvantaged subgroups, finding that these effects tend to be larger for these youths than for the overall population. Table 6 reports results for three demographic groups traditionally considered to be disadvantaged: children born to unwed mothers; children whose mothers had less than high school education; and children who were eligible for a free/reduced price lunch program at age 11. As shown, both the levels and the RD effects on grade retention, high school dropout, juvenile delinquency and adult crime are much larger than those obtained from the general population. For crime in particular, the *proportional* effects of DEE are larger for the two subgroups shown than for the population at large. In other words, the crime effects associated with delayed entry to school are concentrated among students whose mothers were teenagers at their birth, or high school dropouts.

E. *Validity and Robustness*

An attractive property of the regression-discontinuity framework is that, as long as individuals do not have precise control over the running variable, which assigns individuals to a treatment or control group, the variation in the treatment is "as good as randomized in a neighborhood around the discontinuity threshold" (Lee and Lemieux 2010). The phenomenon of academic redshirting indicates that some parents prefer to have their children enter school older rather than younger. But, since children who were born just before the cutoff can readily delay school entry for a year, there is little incentive for parents to manipulate children's birthdates near the cutoff date. A related possibility is that age eligibility for entering a public kindergarten may influence parents' decision to send their children to private schools instead of public. For example, our RD estimates will be muted if wealthier parents are more likely to send their children to private kindergarten when born just after the cutoff dates and then keep them there from age 11 to 15. (Recall that if they are in private school during that period, they will not be included in our sample.)

Figure 7 displays the rate of sample attrition, defined as one minus the ratio of the number of individuals included in our sample to the number of observed births

[13] Recall that we do not have an indicator of graduation per se, but do know which students stay in school. The group that is still in school four years after their eighth grade, and hence most likely in their senior year, is identified here as "persisters."

Table 6—Effect of Delayed School Entry Eligibility on Various Outcomes for Two Cohorts, by Demographic Characteristics

	All	Unwed mother	Mother's education < HS	Free/reduced price lunch
Panel A. 1987–1989 cohort				
Grade retention, ages 11–15	−6.42***	−10.83***	−12.40***	
	(0.37)	(1.09)	(1.74)	
	[8.06]	[13.66]	[14.90]	
School enrollment, year 12	−3.14***	−3.47*	−5.87**	
	(0.86)	(1.87)	(2.42)	
	[79.11]	[72.71]	[64.19]	
Crime, ages 17–19	0.80**	2.73***	2.16*	
	(0.40)	(0.93)	(1.10)	
	[5.69]	[10.25]	[8.71]	
Observations	53,523	14,414	6,545	
Panel B. 1991–1993 cohort				
Grade retention, ages 11–15	−5.59***	−9.06***	−9.75***	−8.62***
	(0.40)	(1.03)	(1.52)	(0.75)
	[5.37]	[8.77]	[10.00]	[8.67]
Juvenile offense, ages 13–15	−2.80***	−3.74**	−5.00**	−4.01***
	(0.57)	(1.70)	(2.06)	(1.20)
	[8.79]	[14.53]	[16.23]	[14.40]
Observations	54,416	17,997	6,351	23,715

Notes: Each cell is taken from a different multiple regression for the given outcome (rows) and subgroup (column). Robust standard errors clustered at the birthday level are in parentheses. Sample means are reported in square brackets. All estimates are obtained from local linear regression specifications (with a triangle kernel and bandwidth of 60 days), which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), other individual covariates, and cohort fixed effects.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

in the North Carolina birth certificate data;[14] the lack of discontinuity at the cutoff date suggests that variation in school entry eligibility is unlikely to be obscured by a systematic manipulation of the timing of birth or use of private schools relative to the cutoff date. The visual impression of continuity is confirmed by regression analysis. Using our main regression specification (equation (1)), we find that the discontinuity at the cutoff is equal to 0.005 (SE = 0.005).

To further explore the extent to which a child's enrollment in public schools is influenced by his timing of birth, we also performed McCrary's density test to see whether there was a significant discontinuity in the sample density at the cutoff date (McCrary 2008). Within our estimating sample of 1987–1989 and 1991–1993

[14] About half of the attrition is due to death or moving out of state following birth. Based on the American Community Survey data, we find that in 2000, 20 percent of 10–14 year olds born in North Carolina were no longer living in North Carolina. Another source of attrition between ages 11–15 is enrollment in a private school. About 6 percent of natives are enrolled in private school at age 11, and 1 percent are enrolled in charter schools (which, although they are public schools, are not included in our calculations). Approximately 7 percent of those enrolled in public school miss at least 1 year by age 15 for various reasons. Remaining attrition may be due in part to matching problems between birth certificates and public school records.

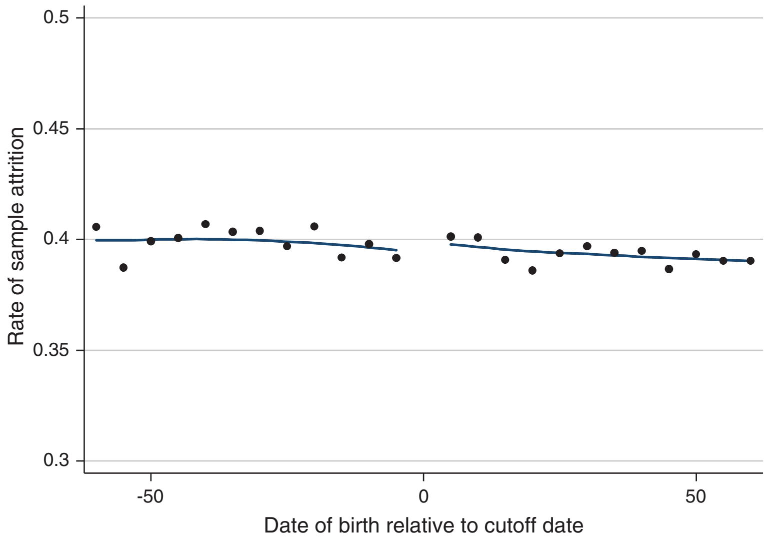


Figure 7. Sample Attrition Rate, 1987–1989 and 1991–1993 Cohorts

Notes: Horizontal axis represents the date of birth relative to the cutoff date. Dots represent 5-day averages of sample attrition rates (the number of students in the estimating sample divided by the number of observed births) across 6 cohorts (1987, 1988, 1989, 1991, 1992, and 1993). Solid curves represent local linear smoother using a triangle kernel and 60-day bandwidth. The discontinuity at the cutoff is equal to 0.005 (SE = 0.005), based on the main local linear regression specification with a 60-day bandwidth and triangle kernel.

cohorts, the difference in density is small and insignificant (log density = 0.019, SE = 0.018).

Another way to examine the internal validity of our research design is to test whether individuals' observed characteristics are continuous at the cutoff date. If the variation in individuals' timing of birth near the cutoff date is effectively random, we expect that those born just before the cutoff are similar to those born just after. We test for the continuity of observable characteristics at the cutoff using our preferred local linear regression specification (3) and report the results in Table 7. The results show that the discontinuity at the cutoff is small and insignificant for all covariates considered for both 1987–1989 and 1991–1993 samples, with one exception in out-of-wedlock birth for the 1987–1989 sample (significant at the 10 percent level).

Another possible concern is whether the choice of bandwidth in our regression analyses preserves the RD "experiment." It is apparent from equation (3) that RD estimates are potentially sensitive to the choice of bandwidth. A larger bandwidth brings in more observations in the analyses, and hence greater apparent precision of the estimates. On the other hand, if the bandwidth is too wide, local linear approximation may not be a good fit for the data in hand. The optimal bandwidth choice should then depend on the sample size and the extent to which the sample distribution is approximated by a linear function near the cutoff point. Although researchers have proposed various techniques for optimal bandwidth choice in recent years (Fan and Gijbels 1992; Ludwig and Miller 2007; Imbens and Lemieux 2008; Imbens and Kalyanaraman 2012; Calonico, Cattaneo, and Titiunik 2014), there does not appear to be a clear consensus. Therefore, to examine the degree to which our estimates are

Table 7—Continuity of Covariates at the Cutoff

	Male	Black	Unwed mother	Teenage mother	Mother education < HS	Low birth weight	Free/reduced price lunch
Panel A. 1987–1989 cohorts							
D	−1.32	−0.07	−1.25*	−0.41	0.13	−0.61	
	(0.89)	(0.76)	(0.73)	(0.69)	(0.57)	(0.54)	
Constant	49.84***	30.27***	26.94***	10.46***	12.28***	7.94***	
	(0.68)	(0.50)	(0.48)	(0.46)	(0.48)	(0.40)	
R^2	0.000	0.000	0.000	0.000	0.000	0.000	
Observations	53,523	53,523	53,523	53,523	53,523	53,523	
Panel B. 1991–1993 cohorts							
D	−1.26	0.82	0.72	0.66	0.36	−0.28	0.73
	(1.03)	(1.04)	(1.07)	(0.64)	(0.76)	(0.41)	(1.08)
Constant	49.06***	31.21***	32.24***	10.30***	11.83***	7.64***	43.63***
	(0.84)	(0.86)	(0.82)	(0.50)	(0.64)	(0.31)	(0.93)
R^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	54,416	54,416	54,416	54,416	54,416	54,416	54,416

Notes: Presented in each column is the discontinuity estimate of the given variable at the cutoff date. Robust standard errors clustered at the birthday level are in parentheses. All estimates are obtained from local linear regression specifications (with a triangle kernel and bandwidth of 60 days), which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), other individual covariates, and cohort fixed effects.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

sensitive to the choice of bandwidth, we replicate the regression analyses with alternative choices of bandwidths. We computed optimal bandwidth for each outcome measure following Imbens and Kalyanaraman (2012) and Calonico, Cattaneo, and Titiunik (2014), and found that the optimal bandwidth mostly lies within the range of 30 to 60 days (Appendix Table A1). In Table 8 we present results for a bandwidth of 30 days from the cutoff point, which conform quite well to our preferred findings based on 60 days.

IV. Exposure to Legal Dropout, High School Attainment, and Crime

The accepted explanation for the lower rate of high school attainment for children born after the cutoff date, in spite of their earlier academic advantage on standardized tests and on-time promotion, is that children who are relatively old for their grades have a longer time window during which they are eligible to drop out from high school. For instance, in North Carolina where students may leave school at age 16 or above, children who were born on the cutoff date and did not delay school entry or repeat grades have approximately 19 months between their 16th birthday and high school graduation, compared to 31 months for children born the day after the cutoff.

The RD analysis reported above is in the spirit of the "intention to treat" approach, recognizing that the "treatment" is attenuated by relatively high rates of redshirting and grade retention for the younger group. To estimate the "effect of the treatment

Table 8—Effect of Delayed School Entry Eligibility by Alternative Bandwidth

Bandwidth =	30	60
Panel A. 1987–1989 cohorts		
Grade 6 reading percentile	5.84***	5.70***
	(0.47)	(0.41)
Grade 7 reading percentile	5.93***	5.58***
	(0.54)	(0.39)
Grade 8 reading percentile	4.87***	4.62***
	(0.57)	(0.45)
Grade 6 math percentile	5.33***	5.11***
	(0.49)	(0.39)
Grade 7 math percentile	5.24***	4.79***
	(0.48)	(0.38)
Grade 8 math percentile	4.42***	4.01***
	(0.58)	(0.43)
Grade retention, ages 11–15	−5.85***	−6.42***
	(0.49)	(0.37)
School enrollment, year 12	−1.76	−3.14***
	(1.09)	(0.86)
Crime, ages 17–19	0.92*	0.80**
	(0.51)	(0.40)
Observations	26,465	53,523
Panel B. 1991–1993 cohorts		
Grade 6 reading percentile	4.80***	5.49***
	(0.56)	(0.45)
Grade 7 reading percentile	4.19***	4.70***
	(0.64)	(0.50)
Grade 8 reading percentile	3.52***	4.18***
	(0.74)	(0.58)
Grade 6 math percentile	4.89***	5.03***
	(0.52)	(0.39)
Grade 7 math percentile	4.36***	4.44***
	(0.46)	(0.40)
Grade 8 math percentile	4.13***	4.36***
	(0.58)	(0.45)
Grade retention, ages 11–15	−4.98***	−5.59***
	(0.44)	(0.40)
Juvenile offense, ages 13–15	−2.32***	−2.80***
	(0.85)	(0.57)
Observations	26,922	54,416

Notes: Presented in each column is the discontinuity estimate of the given variable (rows) at the cutoff date. Robust standard errors clustered at the birthday level are in parentheses. All estimates are obtained from local linear regression specifications (with a triangle kernel), which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), other individual covariates, and cohort fixed effects.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

on the treated" in this case, we re-estimate the Year 12 and crime RD equations for the subsample that stayed on time at least through age 11, and hence were fully exposed to the "treatment." The problem, of course, is that for this selected sample,

Table 9—Exposure to Legal Dropout, High School Attainment, and Crime

Cohort	1987–1989			1991–1993		
Sample	"On-time"		Full	"On-time"		Full
Enrollment, year 12	−6.24***	−6.27***	−3.14***			
	(0.87)	(0.86)	(0.86)			
Crime, ages 17–19	1.07**	1.08**	0.80**			
	(0.44)	(0.44)	(0.40)			
Delinquency, ages 13–15				−2.37***	−2.51***	−2.80***
				(0.69)	(0.67)	(0.57)
Reading score, age 11	No	Yes	No	No	Yes	No
Observations	42,199	42,199	53,523	41,188	41,188	54,416

Notes: Each cell is taken from a different multiple regression for the given outcome (rows), birth cohort (columns), and sample group (columns). "On-time" sample restricts the main sample to those who were placed in the predicted grade level at age 11. Robust standard errors clustered at the birthday level are in parentheses. All estimates are obtained from local linear regression specifications (with a triangle kernel and bandwidth of 60 days), which include birthdays (R), post-cutoff indicator (D), their interaction term (DR), other individual covariates, and cohort fixed effects.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

the treatment is not orthogonal to student characteristics. In particular, the younger students who stay on time are more "selected"—mature for their grade and academically gifted (relative to their peer group)—than is true for the older students. Our usual covariates may not fully account for this difference. The new estimates reported here include the students' standardized EOG reading score from age 11 to control for the academic disparity between pre-cutoff and post-cutoff students.[15]

Table 9 presents the estimation results. Consider the first three columns, which pertain to the 1987–1989 cohorts. The outcomes of students who entered school and experienced on-time progress to the appropriate grade level exhibit strong discontinuities in the Year 12 enrollment and criminal conviction at the cutoff date (first and second columns). Among on-timers, DEE youths are over 6 percentage points less likely to remain enrolled in school in Year 12 and about 1 percentage point more likely to be convicted of a serious crime, even after the academic disparity is controlled for by inclusion of the EOG score. When these estimates are compared with the "ITT" estimates obtained from the full sample (third column), the Year 12 effects appear over twice as large for the "on time" sample as for the full sample. The crime coefficients obtained from the on-timers are also about 20 percent larger than the corresponding ITT estimate.

On the other hand, when considering the juvenile delinquency outcome from the 1991–1993 cohorts, there is little difference in results between the on-time sample and the full sample. We conclude that the selection process by which some youths

[15] We normalize the EOG reading score with respect to the score distribution from a given school year, instead of a given school year *and* grade level. For example, when constructing the standardized EOG reading score at age 11 for the 1987 cohort, we normalize students' test scores to mean 0 and variance 1, with respect to all EOG reading scores from grades 3 to 8, recorded in school year 1998–1999. This across-grade normalization process is made possible by a unique feature of the North Carolina EOG tests, in which its "developmentally-scaled scores are intended to be interpreted much like measurements of heights in inches" (Pommerich et al. 1993; North Carolina State Board of Education 1996), enabling researchers to compare test scores across different grades.

are redshirted or otherwise held back by age 11 is not strongly correlated with crime (or delinquent) propensity. If correct, then the adult-crime results for the "on time" sample would be a reasonable estimate of the effect of the "treatment on the treated." But this conclusion is speculative.

V. Discussion

One important justification for investing in public education is the belief that improved educational opportunities, especially for at-risk youths, will reduce their involvement in criminal activity. For example, a large share of the social benefit from the Perry Preschool stemmed from the reduction in criminal involvement of the treatment group (Heckman et al. 2010). At the other end of the spectrum, there is strong quasi-experimental evidence that extending the age of mandatory school attendance reduces lifetime crime involvement. Given the complex terrain of rules and resources for public education in the United States, it is useful to consider whether crime would also be affected by other reforms that might improve the quality or quantity of schooling.

One peculiarity of mandatory attendance rules in the states is that all students are permitted to withdraw from school at the same age, regardless of how long they have been in school or how far they have advanced through the grades. In interaction with the rules governing minimum age of school eligibility, the result is that students born just after the cutoff date are permitted to quit school a full school year earlier than students born just before. This study documents the fact that youths who have a longer time to contemplate dropout prior to graduation are in fact more likely to drop out, and that one result is a higher involvement in crime, especially for those who come from disadvantaged at-risk households. An alternative mandatory attendance rule that specified a minimum grade attainment (as in Denmark) rather than a minimum age requirement for dropping out would better reflect the social justification for mandatory schooling.

This paper is also of interest in contributing to the broader discussion of schooling and crime. We document suggestive evidence for two mechanisms of interest. First, youths who are relatively old for their grade (due to DEE) perform better academically than their grade peers and are substantially less likely to get involved in delinquency while in school. The large estimated effect is closely linked to performance on the EOG test, and hence is not simply a matter of relative maturity. Second, DEE youths are more likely to drop out prior to graduation and get convicted of a serious crime. While the crime effect is somewhat smaller than the delinquency effect, it is noteworthy that they are in opposite directions—but that set of results turns out to be reasonable, given the opposing effects on the quality and quantity of school that we believe are driving these results. Overall, then, this paper affirms a set of causal links between schooling and crime, and supports the view that crime outcomes should be considered in evaluating school reform.

Appendix

Appendix Table A1—Optimal Bandwidth

	Bandwidth choice	
	IK	CCT
Panel A. 1987–1989 cohort		
EOG reading, grade 6	75	36
EOG reading, grade 7	61	31
EOG reading, grade 8	56	32
EOG math, grade 6	66	32
EOG math, grade 7	62	30
EOG math, grade 8	54	29
Grade retention, ages 11–15	92	43
Enrollment, year 12	58	21
Crime, ages 17–19	59	48
Panel B. 1991–1993 cohort		
EOG reading, grade 6	44	30
EOG reading, grade 7	71	36
EOG reading, grade 8	52	30
EOG math, grade 6	43	36
EOG math, grade 7	54	35
EOG math, grade 8	41	34
Grade retention, ages 11–15	85	36
Enrollment, year 12	72	33

Notes: IK represents optimal bandwidth suggested by Imbens and Kalyanaraman (2011). CCT represents optimal bandwidth suggested by Calonico, Cattaneo, and Titiunik (2014). Optimal bandwidth is computed using STATA software rdrobust.

REFERENCES

Anderson, D. Mark. 2014. "In School and Out of Trouble? The Minimum Dropout Age and Juvenile Crime." *Review of Economics and Statistics* 96 (2): 318–31.

Anderson, D. Mark, Benjamin Hansen, and Mary B. Walker. 2013. "The minimum dropout age and student victimization." *Economics of Education Review* 35: 66–74.

Angrist, Joshua D., and Alan B. Krueger. 1991. "Does Compulsory School Attendance Affect Schooling and Earnings?" *Quarterly Journal of Economics* 106 (4): 979–1014.

Becker, Gary S. 1968. "Crime and Punishment: An Economic Approach." *Journal of Political Economy* 76 (2): 169–217.

Bedard, Kelly, and Elizabeth Dhuey. 2006. "The Persistence of Early Maturity: International Evidence of Long-Run Age Effects." *Quarterly Journal of Economics* 121 (4): 1437–72.

Black, Sandra E., Paul J. Devereux, and Kjell G. Salvanes. 2011. "Too Young to Leave the Nest? The Effects of School Starting Age." *Review of Economics and Statistics* 93 (2): 455–67.

Calonico, Sebastian, Matias D. Cattaneo, and Rocio Titiunik. 2014. "Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs." *Econometrica* 82 (6): 2295–2326.

Clay, Karen, Jeff Lingwall, and Melvin Stephens, Jr. 2012. "Do Schooling Laws Matter? Evidence from the Introduction of Compulsory Attendance Laws in the United States." National Bureau of Economic Research (NBER) Working Paper 18477.

Cook, Philip J., and Songman Kang. 2016. "Birthdays, Schooling, and Crime: Regression-Discontinuity Analysis of School Performance, Delinquency, Dropout, and Crime Initiation: Dataset." *American Economic Journal: Applied Economics*. http://dx.doi.org/10.1257/app.20140323.

Crawford, Claire, Lorraine Dearden, and Costas Meghir. 2010. "When You Are Born Matters: The Impact of Date of Birth on Educational Outcomes in England." Institute of Education University of London Quantitative Social Science Working Paper 10-09.

Datar, Ashlesha. 2006. "Does Delaying Kindergarten Entrance Give Children a Head Start?" *Economics of Education Review* 25 (1): 43–62.

Deming, David, and Susan Dynarski. 2008. "The Lengthening of Childhood." *Journal of Economic Perspectives* 22 (3): 71–92.

Dobkin, Carlos, and Fernando Ferreira. 2010. "Do School Entry Laws Affect Educational Attainment and Labor Market Outcomes?" *Economics of Education Review* 29 (1): 40–54.

Elder, Todd E., and Darren H. Lubotsky. 2009. "Kindergarten Entrance Age and Children's Achievement: Impacts of State Policies, Family Background, and Peers." *Journal of Human Resources* 44 (3): 641–83.

Fan, Jianqing, and Irene Gijbels. 1992. "Variable Bandwidth and Local Linear Regression Smoothers." *Annals of Statistics* 20 (4): 2008–36.

Freeman, Richard. 1999. "The Economics of Crime." In *Handbook of Labor Economics*, Vol. 3, edited by Orley Ashenfelter and David Card, 3529–71. Amsterdam: North Holland.

Hahn, Jinyong, Petra Todd, and Wilbert Van der Klaauw. 2001. "Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design." *Econometrica* 69 (1): 201–09.

Harlow, Caroline Wolf. 2003. *Education and Correctional Populations*. Bureau of Justice Statistics Special Report. Washington, DC, January.

Heckman, James J., Lance J. Lochner, and Petra E. Todd. 2008. "Earnings Functions and Rates of Return." *Journal of Human Capital* 2 (1): 1–31.

Heckman, James J., Seong Hyeok Moon, Rodrigo Pinto, Peter A. Savelyev, and Adam Yavitz. 2010. "The rate of return to the HighScope Perry Preschool Program." *Journal of Public Economics* 94 (1–2): 114–28.

Hjalmarsson, Randi, Helena Holmlund, and Matthew J. Lindquist. 2015. "The Effect of Education on Criminal Convictions and Incarceration: Causal Evidence from Micro-Data." *Economic Journal* 125 (587): 1290–1326.

Imbens, Guido, and Karthik Kalyanaraman. 2012. "Optimal Bandwidth Choice for the Regression Discontinuity Estimator." *Review of Economic Studies* 79 (3): 933–59.

Imbens, Guido W., and Thomas Lemieux. 2008. "Regression Discontinuity Designs: A Guide to Practice." *Journal of Econometrics* 142 (2): 615–35.

Jacob, Bryan A., and Lars Lefgren. 2003. "Are Idle Hands the Devil's Workshop? Incapacitation, Concentration, and Juvenile Crime." *American Economic Review* 93 (5): 1560–77.

Landersø, Rasmus, Helena Skyt Nielsen, and Marianne Simonsen. 2013. "Schooling Starting Age and Crime." Institute for the Study of Labor (IZA) Discussion Paper 7228.

Lee, David S., and Thomas Lemieux. 2010. "Regression Discontinuity Designs in Economics." *Journal of Economic Literature* 48 (2): 281–355.

Lochner, Lance. 2011. "Education Policy and Crime." In *Controlling Crime: Strategies and Tradeoffs*, edited by Philip J. Cook, Jens Ludwig, and Justin McCrary, 465–515. Chicago: University of Chicago Press.

Lochner, Lance, and Enrico Moretti. 2004. "The Effect of Education on Crime: Evidence from Prison Inmates, Arrests, and Self-Reports." *American Economic Review* 94 (1): 155–89.

Luallen, Jeremy. 2006. "School's out…forever: A study of juvenile crime, at-risk youths and teacher strikes." *Journal of Urban Economics* 59 (1): 75–103.

Ludwig, Jens, and Douglas L. Miller. 2007. "Does Head Start Improve Children's Life Chances? Evidence from a Regression Discontinuity Design." *Quarterly Journal of Economics* 122 (1): 159–208.

Machin, Stephen, Olivier Marie, and Suncica Vujić. 2011. "The Crime Reducing Effect of Education." *Economic Journal* 121 (552): 463–84.

McCrary, Justin. 2008. "Manipulation of the Running Variable in the Regression Discontinuity Design: A Density Test." *Journal of Econometrics* 142 (2): 698–714.

McEwan, Patrick, and Joseph S. Shapiro. 2008. "The Benefits of Delayed Primary School Enrollment: Discontinuity Estimates using Exact Birth Dates." *Journal of Human Resources* 43 (1): 1–29.

North Carolina Department of Public Instruction. 2008. *North Carolina Public Schools: Statistical Profile 2008*. Raleigh: Public Schools of North Carolina.

North Carolina State Board of Education. 1996. *End of Grade Tests*. Raleigh: Public Schools of North Carolina.

Pommerich, Mary, Kathleen Billeaud, Valerie Williams, and David Thissen. 1993. "User's Guide for the North Carolina End of Grade Tests." Unpublished.

Puhani, Patrick A., and Andrea M. Weber. 2007. "Does the Early Bird Catch the Worm? Instrumental Variable Estimates of Educational Effects of Age at School Entry in Germany." *Empirical Economics* 32 (2): 359–86.

Raphael, Steven, and Melissa Sills. 2008. "Urban Crime, Race and the Criminal Justice System in the United States." In *Companion to Urban Economics*, edited by Richard Arnott, and Daniel P. McMillen, 515–35. Malden, MA: Blackwell Publishing.

Stephens, Melvin, Jr., and Dou-Yan Yang. 2014. "Compulsory Education and the Benefits of Schooling." *American Economic Review* 104 (6): 1777–92.

Thistlethwaite, Donald L., and Donald T. Campbell. 1960. "Regression-discontinuity analysis: An alternative to the ex post facto experiment." *Journal of Educational Psychology* 51 (6): 309–17.

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