Published in final edited form as:

Econ Educ Rev. 2016 February ; 50: 45–62. doi:10.1016/j.econedurev.2015.11.004.

The Effects of Changes in Kindergarten Entry Age Policies on Educational Achievement

Jason Fletcher^{*,a} and Taehoon Kim^b

^aLa Follette School of Public Affairs, University of Wisconsin-Madison, 1225 Observatory Drive, Madison, WI 53706, United States

^bDepartment of Economics, University of Wisconsin-Madison, 1180 Observatory Drive, Madison, WI 53706, United States

Abstract

This study explores the effects of state kindergarten-entry-age policies on students' outcomes by exploiting variation in the kindergarten entry cutoff dates enacted by states in the United States over the last 40 years. Using the state average and standard deviation in NAEP test scores in 4th, 8th and 12th grades, we estimate the impacts of state entry-age policies on educational achievement and test score dispersion in the state. The estimation results from the baseline state and time fixed effects model show that a one month earlier cutoff increases average state reading and math scores of 4th graders by 21.7 and 13.6 percent of a standard deviation, respectively. Eighth graders' average score increases in math and science are 12.4 and 24.3 percent of a standard deviation, respectively, while the effect on reading score significantly decreases. We find no effect of kindergarten entry date on educational outcomes in 12th grade. We also find that an earlier kindergarten entry date generally reduces the standard deviation of state test scores. Robustness checks support these findings and suggest no evidence of endogeneity of the policy changes. Our findings provide novel evidence that early school start cutoffs have improved state-level achievement measures over the past 40 years.

Keywords

State kindergarten-entry cutoff; Educational achievement

JEL classification

I20; I21; I24; I28

1 Introduction

Is it a good policy for states to change their kindergarten-entry cutoff to an earlier date? Many states have moved their kindergarten-entry cutoff date earlier in the school year during the last 40 years. An earlier state kindergarten-entry cutoff date increases the minimum age

*Corresponding author: Tel.: +608-263-6010; Fax: +608-265-3233.

of children as they start school in the state so that it can increase the average age of students at school entry, and therefore at the date of state achievement tests. If these ages are positively associated with educational achievement, an earlier school-entry cutoff may be able to increase educational achievement of students in the state. In addition, increased school or class average age also may enhance educational achievement, as it can cause positive peer effects and make teachers use advanced teaching materials (Elder & Lubotsky, 2009). School accountability metrics may also be improved by an earlier cutoff date, and these factors may contribute to states' considering and adopting earlier kindergarten-entry cutoff dates. As an earlier kindergarten-entry cutoff can lead to greater childcare cost and later labor market entry of students, however, the policy that changes a kindergarten-entry cutoff date to an earlier date should have enough impacts on educational achievement to be justified. As a component of a larger attempt to evaluate the kindergarten-entry age policy, this study explores the effect of kindergarten-entry-cutoff date on educational achievement.

There is a large literature that investigates the effect of school-entry age on educational achievement. Most of the literature estimate the combined effect of age at school entry and age at test on educational performance among students in the same grade, as there is perfect collinearity among school-entry age, age-at-test and schooling. A common finding is that the combined effect is large and significant in the lower grades and weakens over time (e.g., Bedard & Dhuey, 2006; Crawford, Dearden, & Meghir, 2007; Elder & Lubotsky, 2009; Datar, 2006; Kim, 2015; McEwan & Shapiro, 2008). Whether the effect is still persistent at college enrollment and in the labor market is not conclusive (Bedard & Dhuey, 2006; Black, Devereux, & Salvanes, 2011; Dobkin & Ferreira, 2010; Fredriksson & Öckert, 2005; Kim, 2015).¹ A smaller set of studies estimate average or relative age effects.² For example, Fredriksson and Öckert (2005) find that the relative age effect is positive but small and statistically insignificant for 9th graders in Sweden. Crawford, Dearden, and Meghir (2007) report that the relative age effect is small in England. Elder and Lubotsky (2009) find that the average age of the school-cohort is likely to affect educational achievement positively until 8th grade in the U.S.. This literature implies that the state entry cutoff can affect students' educational achievement through these channels. It also predicts that an earlier cutoff can have a positive effect on educational achievement, and it decreases over time. We test this prediction by directly estimating the overall impacts of the cutoff and discuss the policy implications of our findings.

To the best of our knowledge, this is the first study that explores the relationship between state kindergarten-entry-cutoff policies and state standardized test results. Bedard and Dhuey (2012) is the only paper that is directly related to this study in the sense that they explore the effect of kindergarten-cutoff date on human capital accumulation. Specifically, they estimate the overall impacts of state kindergarten-entry cutoff on wage and educational attainment

¹It is important to estimate school-entry age effect separately for evaluating the kindergarten-entry age policy. There are a few studies that separate the impacts of age-at-testing and school-entry age and find that the effect of age-at-testing is more important (Black, Devereux, & Salvanes, 2011; Crawford, Dearden, & Meghir, 2007). These findings may have significant implications, as it is possible that the significant combined effect of school entry age and age-at-testing in the previous literature may not be driven by school entry age, thus having an earlier cutoff itself may not be effective for improving educational achievement of children.

²In some cases, the term "average age effect" is mingled with the term "relative age effect". School (or class) average age is the mean age of students in school (class). Relative age can be thought of as the percentile rank in the age distribution (Fredriksson & Öckert, 2005) or the individual age relative to the school average age (Elder & Lubotsky, 2009).

and find that an earlier state kindergarten-entry-cutoff date increases the hourly wage of males and has no significant effect on (final) educational attainment. This study focuses on the effect of state kindergarten-entry date on educational achievement for students and how the effect changes as students advance through school. This study also investigates the possible problem of kindergarten-entry-cutoff changes that Stipeck (2002) points out. She suggests that children from higher socioeconomic families can accumulate more human capital outside of school so that an earlier cutoff date can increase the educational achievement gap across students. We indirectly evaluate this point by estimating the effect of kindergarten-cutoff date on the *standard deviation* of students' test scores in the state.

We use state NAEP scores for 4th and 8th graders and ACT and SAT results for high school students for this study. We exploit the variations in the state kindergarten cutoffs over the last 40 years to estimate the effect of an earlier cutoff date on the educational achievement of students. This allows us to use standard difference-in-differences estimation techniques. We provide several new findings to the evaluation of state-level entry age policies. First, a one month earlier entry cutoff increases the state average score of 4th grade NAEP by 21.7 and 13.6 percent of a standard deviation in reading and math, respectively. The estimation results for the standard deviations of test scores show that there is no evidence that an earlier entry cutoff increases the degree of dispersion of test scores in the state, rather it is more likely to reduce the degree of the dispersion. Second, we find some evidence of fade-out. A one month earlier cutoff increases state average score of 8th grade NAEP in math by 12.9 percent of a standard deviation and the effect on reading in 8th grade is 5.1 percent of a standard deviation. The earlier cutoff also decreases the standard deviations of test scores in math and science in 8th grade. Third, the effect of a one month earlier cutoff on ACT and SAT scores is small and statistically insignificant.

To check the validity of econometric assumptions used in this study, we indirectly test if the cutoff changes were endogenously determined. We find no evidence that state kindergarten cutoff changes are related to changes in demographic variables or economic conditions, which is consistent with the assumptions in the econometric model. We also conduct several robustness tests for the econometric model. First, we estimate the model using various specifications. Second, we estimate placebo tests. Third, we test the model using the sample that excludes states that have changed their cutoff by more than or less than one month. Fourth, we test the fade-out of cutoff date effect using a restricted sample that includes state-entry year cohort that took both 4th and 8th grade NAEP tests. Finally, we use alternative functional forms of the cutoff effect in the econometric model. In general, the estimation results from our baseline model are quite robust to these different models.

The rest of this paper consists of the following sections. Section 2 explains the data and the trends of the state kindergarten-cutoff changes. The econometric model is described in section 3. Section 4 reports the estimation results. Section 5 discusses and concludes.

2 Background

This section briefly introduces the trends in the changes of state kindergarten-entry cutoff during the past 40 years. We then provide motivations for this study by showing that state kindergarten-entry cutoff can be related to educational achievement in the state.

Figure 1 depicts the time trend of the number of states by the kindergarten entry cutoff month from 1975 to 2008.³ We can see that the secular trend of kindergarten cutoff changes to earlier dates of the school year. The number of states that have September or August cutoffs has increased while the number of states that have October, November, December or January cutoffs has decreased during the period. For example, 10 states had a September cutoff and 11 states had a December cutoff in 1975. In 1985, however, 18 states had a September cutoff and 9 states had a December cutoff. The number of September cutoffs was increased to 25 in 1995 and 29 in 2005 while that of December cutoffs was 7 in 1995 and 4 in 2005.

Figure 2 presents the frequency of cutoff changes from 1975–2008 according to magnitude of the differences in start date. A positive sign means the cutoff was moved to an earlier date while a negative sign means the change was to a later date. During this period, 28 states changed their kindergarten entry cutoff and there were 58 total changes. Among the 58 changes, 49 were to an earlier time of the academic year and 36 were towards an earlier date by approximately one month. The cutoff changes to a later date happened only 9 times during the period.

Figure 3 shows the standardized state average reading score and cutoff dates in Delaware, Rhode Island (chosen for expositional purposes) and states that did not change the cutoff in the sample period. The cutoff date is the date that is applied to the 4th graders in the state and test year in the sample. Panel (a) and (b) in Figure 3 show that there are jumps in average reading score at the time of cutoff change to an earlier date in the states. Panel (c) of Figure 3 shows that average reading scores weighted by state cohort size in states that have not changed kindergarten entry cutoff and participated in all reading tests. The graph shows that state average reading scores generally have increased between 1992 and 2013. The average reading score trend is also quite similar to those in Delaware and Rhode Island. We focus on the periods from 1998–2002 in Delaware and from 2007–2009 in Rhode Island when 4th graders in each state faced the cutoff changes when they entered kindergarten, respectively. There was also a sharp increase in average reading scores between 1998 and 2002 in states that had not changed the cutoff although there was not much change between 2007 and 2009. These graphs intimate that state kindergarten entry cutoff may be related to educational achievement in the state and suggest that we need to control time trends of the score to estimate the effect of kindergarten entry cutoff.

Figure 1 shows that there have been many changes in the state kindergarten-entry-cutoff date and Figure 2 shows that there is enough variation in the dates at the times of the changes. We

³We do not include June, July and February cutoffs in the graph because only at most one state had any one of these cutoffs for each year.

use these variations to estimate the effect of state kindergarten entry cutoff on educational attainment in the state, controlling for state characteristics and time effects.

3 Empirical Strategy

We use standard program evaluation techniques to examine the impacts of changes in the state-level kindergarten-entry-age cutoff on state-level achievement outcomes pooling data between 1990 and 2013, through the window differs across outcomes of interest. Our preferred regression analysis uses state and time (year) fixed effects to control for differences across states in their educational policies and programs and to control for secular changes in test scores across the cohorts of interest. Samples are weighted by the square root of the expected cohort size of kindergarten entrants by state and entry year to account for heteroskedasticity in grouped data. Specifically, we estimate the effect of kindergarten-entry cutoff using the following regression model.

$$Y_{st}^k = \beta_0 + \beta_1 C_{st}^k + X_{st}^k \beta_2 + \beta_3 D_t + \beta_4 D_{t-1} + \zeta_s + \zeta_t + \epsilon_{st} \quad (1)$$

Y_{st}^k is an average educational outcome of k-th graders in state s and time t. C_{st}^k is a monthly measure of state kindergarten entry cutoff in the year when k-th graders in state s who take achievement test in year t entered kindergarten. If state A has a September 15 cutoff and state B has an October 30 cutoff, then C_{st}^k of state A is greater than that of state B by 1.5. X_{st}^k is a vector of other regressors including demographic characteristics of the students and state school policy in state s and time t. D_t is a dummy variable that indicates 1 if a cutoff change occurs in time t and 0 otherwise. D_{t-1} is a one-year lagged variable of D_t . There variables are further included to control other possible unobservable changes at the time of cutoff change. ζ_s represents state fixed effects and ζ_t is time fixed effects. ϵ_{st} is an error term.⁴

To motivate model(1), we explain how the change of state kindergarten-entry cutoff affects school entry age, age-at-testing and school average age, and how these affect educational achievement in the state. As noted in Bedard and Dhuey (2012), there are two types of students affected by kindergarten cutoff changes. The first type are the students whose absolute school entry age and age at the time of test increase by the policy, and the second type are those whose absolute age does not change. For example, students who were born between September 2, 1990, and September 1, 1991, in states with a September 1 cutoff are eligible to enter kindergarten in 1996, as are students between December 2, 1990, and December 1, 1991, in states with a December 1 cutoff. If a state with a December 1 cutoff changed it to September 1, then students who were born between September 1 and December 2 (first type) would be one year older at school entry in the new regime, while the

⁴We ignore grade retention in the derivation of the regression model from the structural equations in appendix 1 for simplicity. Previous literature shows that being older at school entry decreases the probability of grade retention (Elder & Lubotsky, 2009; McEwan & Shapiro, 2008) so that a kindergarten-entry-cutoff change to an earlier date would decrease the grade retention rate in the state. In this case, students in states that have not changed kindergarten-entry-cutoff may be more selected students in 4th or upper grades so that our model could underestimate β_1 .

entry age of other students (second type) would not be affected. The cutoff change could affect educational achievement of the first type since they become older at school entry and testing. However, the second type could be affected by the cutoff change as well. Two channels can be considered. First, the average age of students increases by the cutoff change to an earlier date, and this could have spillover effects on both types of students (Elder & Lubotsky, 2009). Second, the relative age of students is changed by the cutoff change. The percentile of the “first type” students in the age distribution in school increases while that of the “second type” students decreases. If teachers support less matured students more, then being relatively older in class would have a negative effect on educational performance. The effect could be the opposite if teachers support students with high performance more. The overall effect of the cutoff change to an earlier date on state-level educational outcome is the combination of the effect of absolute age increase on the first type and the effect of average age increase on both types of students, since it is expected that the effects of relative age change are canceled out. In this study, we focus on the aggregate impacts of the cutoff change on state-level educational achievement rather than investigate the possible asymmetric effects on the two types of students.

The parameter β_1 in model (1) represents the overall policy impact on educational outcomes, and therefore the object of this paper is to estimate the parameter β_1 . We provide an appendix section that formally explores the parameter we uncover (“reduced form parameter”) in comparison to the structural parameters of interest, which can be considered as underlying mechanisms that kindergarten-entry cutoff affects educational achievement. These include an effect of (1) an individual’s entry age on achievement, (2) an individual’s age at the test date on achievement, and (3) the average age of classmates on individual performance. These effects mix the impacts of peers and how schooling interacts with the biological age of children. Also important in interpreting the policy impacts are the potential responses to law changes, such as non-compliance. The larger the age effects and the less children who enroll in kindergarten earlier than they are supposed to enter, the greater effect state kindergarten cutoff has on state-level educational performance.

Most previous studies estimate the combined effects of (1) school entry age, and (2) age at the test date, since school entry age, age-at test and schooling are collinear in typical data. Exceptions are Black, Devereux, and Salvanes (2011) and Crawford, Dearden, and Meghir (2007) who decompose (1) school-entry-age effect and (2) age-at-test effect.⁵ Elder and Lubotsky (2008) estimate (3) school-average-age effect. This study cannot disentangle the multiple mechanisms of kindergarten-entry-age policy effects. Instead, we directly estimate the overall impact of kindergarten entry cutoff on educational achievement using variations in state kindergarten-entry cutoffs. We think that it is also important to test if the change of kindergarten-entry cutoff actually leads to the results that are consistent with the prediction. This can give a lower bound for a positive policy effect, since it is difficult to support the policy of a cutoff change to an earlier date if it does not have an effect or it decreases state educational achievement. An earlier cutoff date is likely to generate additional childcare

⁵However, Crawford, Dearden, and Meghir (2007) could not separate the effect of school entry age from schooling effect.

costs and to delay labor market entry of students so that it should have enough impacts on educational performance to be outweigh potential costs of the policy change.

4 Data

This study uses multiple state-level data sets to construct our variables. Many states have a single school-entry cutoff but there are states that do not have an explicit entry cutoff, allowing the local education authority to determine it or the cutoff date is the first day of school. We include only state-year units in the sample in which a state has an explicit single school-entry date in the year. We exclude from our sample state-year pairs without an explicit state-entry cutoff, those that allow a local education authority to decide the cutoff, or the cutoff date is the first day of school. For example, Georgia did not have an explicit school entry cutoff until 1984 and has had a September 1 cutoff since 1985. For Georgia, students who entered kindergarten in 1985 and after are included in our sample.

Table 1 summarizes the data sources for educational achievement. The first data set for educational achievement is the National Assessment of Educational Progress (NAEP). We use 4th grade reading and math test results and 8th grade reading, math and science test results from 1990 to 2013. The NAEP is not held every year and the years of the test differ by the grades and the subjects. Detailed information on the years of tests for each grade-subject is described in Table 1. The average test score and the standard deviation by state are used as outcome measures. An earlier state kindergarten-entry-cutoff date, which increases time span at home before school entry, can increase an educational achievement gap among different socio-economic groups since children from a higher socio-economic family can accumulate human capital more out of school (Stipek, 2002). We use the standard deviation as an additional outcome variable to examine if the state cutoff date affects the degree of dispersion of test scores in state.

The educational performance of high school seniors is measured by both ACT and SAT participation and scores. The results are for graduating seniors in the year who took the exams during the high school years. Since students can take these exams at different times and they also can take them multiple times, the date of the test and the number of participations are not the same across the students.⁶

Demographic variables, variables that represent economic conditions, and education policy variables are used as independent variables. First, we create measures of the sex ratio, average age of parents at birth, average gestation, racial composition of parents, and mother's education years using the Vital Statistics Birth Data. We identify the kindergarten entry cohort for each state and school year using the birth date information in the Vital Statistics and state-kindergarten-cutoff-policy information.⁷ We collapse the above demographic variables for each school cohort by state and school year. We exploit real

⁶The Digest of Education Statistics specifies that the most recent scores until March of the senior year are reported. For the ACT, it is not specified. We use the state average composite score which is the average of English, math, reading and science scores and participation rate from 1994 to 2013 for ACT. For the SAT, each average score of critical reading, mathematics and writing, and participation rate by state from 1990 to 2011 are used. We get ACT data from the official ACT website: <http://www.act.org/>. We obtain SAT data from the Digest of Education Statistics. The 1995 SAT participation rate is not included in analysis since it is omitted in the Digest of Education Statistics.

personal income per capita and unemployment rate by state and year by controlling the economic conditions at the test year. Real personal income per capita is obtained from the U.S. Bureau of Economic Analysis and the unemployment rate is from the U.S. Bureau of Labor Statistics. From the U.S. Department of Education, *Digest of Education Statistics*, we collect information on average sizes of elementary and secondary schools, the number of teachers per pupil, the number of staff per pupil, average salary of teacher, and current expenditures per pupil in public elementary and secondary schools by state and year.⁸

5 Inspection of the Possibility of Endogenous Cutoff Changes

A crucial assumption for fixed effects models is that the policy is not related to the time varying unobservable component of the state-level error term. It is not possible to test this directly, but we test the assumption indirectly by checking if there is any relationship between state kindergarten cutoff policy changes (within-states) and demographic characteristics, economic conditions and education policy in the state. We implement these checks in two ways. First, we check if demographic characteristics, economic conditions and education policies in the state change significantly when the state cutoff change occurs. Second, we test if there is any correlation between the magnitude of state cutoff changes and demographic characteristics, economic conditions, and education policy variables in the state. In model (1), economic conditions and education policy variables in the year of test are controlled. Here, those in the year of kindergarten entry are used as dependent variables.

Table 2 reports the estimation results for the effect of a state cutoff change on demographic, economic condition and education policy variables. Here, the independent variable is a dummy variable that is 1 if the kindergarten-entry cutoff change occurs in the state in the year and 0 otherwise. Therefore the estimate of the coefficient represents the effect of a state cutoff change on state-level characteristics, which is zero if the cutoff change is exogenous. We use a fixed effects model with and without state-specific linear time trends and weighted and unweighted fixed effects models for estimation. Table 2 shows no evidence of jumps in demographic or education policy variables coincident with the state policy change in all specifications. With the number of tests we run, we consider a very limited number of statistically significant associations. This is consistent with the argument in Bedard and Dhuey (2012) that there is no clear evidence that state cutoff change accompanies the change of other education policies. The estimation results are consistent with our assumption that the state kindergarten policy changes are not endogenous to time varying unobservable state characteristics that may also affect educational achievement.

Table 3 presents the estimates for the effect of a one month earlier state kindergarten entry cutoff on state demographic, economic condition and educational policy variables. The monthly measure of kindergarten entry cutoff, C_{st} , is the main independent variable of

⁷Birth day information has not been available in public use Vital Statistics data since 1989. For births since 1989, we randomly assign a birth day to people born in the cutoff month. We believe that this does not cause significant problems since the number of people affected by this assignment, which is the number of people born in the cutoff month, is relatively small. The number is especially small when the cutoff date is close to beginning or end of the month. In addition, Dickert-Conlin and Elder (2010) find no evidence of birth selection around the cutoff.

⁸Most education policy variables since 2011 are also not reported yet. We use personal income information until 2012. We use extrapolated variables in missing years.

interest in this second test and the estimation results are reported in Table 3. The estimation results show that an earlier cutoff date is not related to state demographic and economic conditions at the time of kindergarten entry. It is, however, related to education policy variables. The earlier kindergarten entry cutoff is correlated with higher expenditure per pupil and average salary of teachers and lower elementary school size and the number of pupils per teacher and staff. We interpret that these relationships are from reductions in cohort size after a cutoff change to earlier in the year. We estimate cohort size decreases in the year of the cutoff change in Table 2 and 3. Since the measures of education policy variables depend on the cohort size, the significant relationships are observed when the state kindergarten cutoff changes to an earlier date. We include these education policy variables in the regression model (1), and therefore the effects of changes of education policy variables at the time of cutoff change can be controlled. In addition, a dummy variable that indicates a cutoff change and its lagged variable are included to control unobservable changes that a cutoff change can accompany.

Finally, we further check if states that have ever changed their kindergarten cutoff are systematically different from those that have not changed it in terms of observable variables. If states with certain characteristics can achieve greater improvement in educational achievement from earlier kindergarten cutoff, they may prefer to change their cutoffs to earlier dates. In this case, the estimates from our state fixed effects model may be greater than the average treatment effect. We compare observable variables by conducting OLS and WLS regressions. Dependent variables are demographic characteristics, economic conditions and education policy variables. A dummy variable that indicates 1 if a state has changed kindergarten cutoff during the years 1975–2008 and 0 otherwise is used as the main independent variable of interest. Time fixed effects are further controlled in the model. Table 4 reports the results and no estimate is statistically significant at 5% in both regressions. Table 4 shows that no estimate is statistically significant in both regressions, which we interpret as providing no evidence of systematic differences in observable characteristics between states according to decisions about this education policy.

6 Results

6.1 4th Grade NAEP

Table 5 presents the estimation results for the effect of a one month earlier kindergarten entry cutoff on state average NAEP scores for reading, math and science in 4th grade. The estimation results from the state and time fixed effects model weighted by the square root of cohort size are reported in Table 5. Regressors used in the estimations are reported in the notes of Table 5. For the reading test, a one month earlier kindergarten-entry cutoff increases the state average score by 1.492 points, which is 21.7 percent of the standard deviation. It also increases by 1.353 points the state math average score, which is 13.6 percent of the standard deviation.⁹

⁹These effects are relatively modest, but also likely reasonable and important—because for many states, an increase in their NAEP scores of only 1–1.5 points would increase their US ranking by several places. For example, Kentucky has an October 1 cutoff (as of 2008) and is ranked 10th. An increase of 1.5 points (by switching to a September 1st cutoff) would be predicted to increase the state rank to between 5th and 8th. For test score ranks, see: <http://www.kansasopengov.org/SchoolDistricts/StudentAchievement/NAEPRankingsbyState/4thGradeReadingScaleScore/tabid/2168/>

Table 5 also presents an examination of potential changes in the standard deviation of the test scores in a state related to the state's entrance age policy changes. Each unit of the dependent variable is the standard deviation of test scores of students in each state and test year. We take the state standard deviation of test scores as a measure of the degree of inequality in educational achievement in a state.¹⁰ The average of the standard deviation of reading test score is 35.88, and its standard deviation across state and year is 2.77. A one month earlier school entry cutoff reduces the standard deviation of reading scores in the state by -0.468 and it is not statistically significant (p-value: 0.134). The estimate is -0.338 for math test and it is statistically significant at 5% level. The estimation results in Table 5 show that earlier school-entry cutoff increases state average scores and reduces the standard deviations in both reading and math tests.

6.2 8th Grade NAEP

The estimation results for 8th grade NAEP scores are presented in Table 6. We generally find some evidence of fade-out relative to the 4th grade effects in Table 6, especially for reading. Indeed our preferred point estimate is for reading test scores is 0.471 (approximately 5.1% of a standard deviation) and statistically significant at 10 percent level. The estimated effect of a one month earlier school-entry cutoff on state average math score is 1.264 (approximately 12.9% of a standard deviation), and this is slightly lower than the results for 4th grade. We find large effects on science scores-our preferred estimate is 1.51 (nearly 18.9% of a standard deviation).

Table 6 also reports the estimation results for the effect of state kindergarten cutoff on the standard deviation of the state NAEP scores in 8th grade. For reading, the estimated effect of a one month earlier cutoff on the standard deviation is -0.23 and it is not statistically significant. The findings are of similar magnitude across specification but typically not statistically different from zero. In contrast, we find more robust evidence of reductions in the standard deviation of math and science test scores, approximately 0.348 and 0.467 points, respectively.

6.3 ACT and SAT

Table 7 presents the estimation results for the ACT average composite score and participation rate and the SAT scores and participation rate. The ACT results suggest small increases in participation rates, 2.6% off of a base of 48.4%. We estimate small increases in scores-neither set of results is statistically significant. Similarly, the results for the SAT participation rate are small and not statistically significant and the impacts on sub-component scores are small for critical reading and math. The results for writing are relatively large and negative but are sensitive to specification, especially when state-specific linear time trends are controlled.

These are many previous studies that show a fade-out of the combined effects of school entry age and age at test as children transition through school. The reason why earlier school entry cutoff has no effect on test scores in 12th grade may be that the combined effects of

¹⁰The standard deviation in panel (a) in Table 5 is the standard deviation of state average scores.

school entry age and age at test decreases over time. The interpretation should be made with caution, however, since the monthly kindergarten cutoff variable is less precise here because of the large time gap between time at kindergarten entry and time of taking the ACT or SAT. For some students, the current state of residence could be different from that at kindergarten entry because of inter-state migrations. It is well known that attenuation bias could be large in fixed effects models with measurement error, and consequently underestimate the policy impact. In addition, the fact that students could take the ACT or SAT many times makes it difficult to interpret the estimation results clearly. While we have chosen to provide the results for ACT and SAT, we do so with the caveats mentioned above and suggest that further research is required to investigate the long-term effect of kindergarten cutoff on educational achievement.

7 Sensitivity Test

7.1 Econometric Specification

We estimate the effect of kindergarten-entry-cutoff date on educational achievement using various econometric models to check if the estimation results from the baseline model are robust to different specifications. This test can help us evaluate if the previous estimation results are derived from particular econometric assumptions or not. We report the results from (1) a naive pooled OLS (without fixed effects) model, (2) the inclusion of state-specific linear time trends, (3) unweighted fixed effects models with and without state-specific linear time trends, (4) first difference models, (5) fixed effects models allowing an AR(1) error process (Baltagi and Wu 1999) and (6) two types of dynamic panel models (Allerano and Bover (1995) and Blundell and Bond (1998), respectively).

We show estimation results from (2) fixed effects model with state-specific linear time trends to check that changes of state kindergarten-entry-age policies are correlated with upward or downward trends of educational achievement in the state. We also show the estimation results from (3) unweighted fixed effect model and (4) unweighted fixed effect model with linear time trend. Solon et al. (2015) discuss the weighting problem in regression using grouped variables. Their recommendation is to report both weighted and unweighted estimation results. The (5) First difference model and (6) AR(1) model allows for AR(1) serial correlation of error term in the baseline model. Dynamic panel models are also estimated for a robustness test that allow for the possibility that a change of state kindergarten-entry-cutoff is related to educational achievement in previous years in the state.

Table 8 reports the estimation results for 4th grade NAEP. For reading average score, all the estimation results suggest a significant and positive effect of earlier cutoff date and the magnitudes of the estimates are comparable. The results for standard deviation show quite robust results and only the results from pooled OLS and unweighted fixed effects model with linear time trend are not statistically significant. The estimation results for math average score are generally not sensitive to econometric models except dynamic panel models. Those for math standard deviation consistently show that a one month earlier cutoff decreases standard deviation of math score while some are not precisely estimated. We may be able to conclude that the estimation results are quite robust to different econometric specifications for 4th grade NAEP.

The estimation results for 8th grade NAEP are presented in Table 9. In most specifications, the cutoff date does not have a significant effect on state reading average score. The estimates for standard deviation of reading scores are also insignificant in most models while the signs of the estimates are consistently negative. For state average score and standard deviation of math test, the estimates from first difference model and dynamic panel models are not statistically significant. All estimates for average score and standard deviation of science are significant and the size of them are also comparable.

We can find in Table 10 that the estimation results are robust to econometric models for ACT and SAT results in the sense that the effect of kindergarten cutoff is not statistically different from zero in most models. Although there are some exceptions, those exceptions do not appear consistently in the specific model, and therefore they are likely to occur by chance so that it is difficult to designate particular econometric assumptions that we need to care about.

7.2 Placebo Test

As another robustness check, we conduct placebo tests. We code the kindergarten entry cutoff changes so that they occurred in the years before the actual cutoff change and check the estimates on these placebo treatments. Specifically, we estimate the following regression model:

$$Y_{st}^k = \theta_0^k + \theta_1^k D_{kst}^0 + \theta_2^k D_{kst}^1 + \theta_3^k D_{kst}^2 + \theta_4^k D_{kst}^3 + \theta_5^k D_{kst}^4 + \theta_6^k D_{kst}^5 + X_{st}^k \theta_7 + \vartheta_s + \vartheta_t + \varsigma_{st} \quad (2)$$

where D_{kst}^0 is a dummy variable which is 1 if kindergarten-entry-cutoff change to earlier date occurred at the time of kindergarten entry or before for k-th graders in time t in state s and 0 otherwise. θ_1^k represents an average effect of the cutoff change on test scores. D_{kst}^τ is a dummy variable which is 1 if cutoff change to earlier date occurred τ years before school entry time of k-th graders in time t and state s and 0 otherwise.

Table 11 reports estimation results for the 4th grade NAEP scores. The effect of the actual cutoff change to an earlier date is 2.227 points increase in state average reading score. The estimates are 3.088 for math. All the lagged variables (i.e. placebo treatments) of cutoff changes are not statistically significant. The estimation results for 8th grade NAEP scores are reported in Table 12. For 8th grade NAEP, a cutoff change to an earlier date increases average reading, math, and science scores by 1.854, 3.369, and 4.438, respectively. State reading and science average scores, however, are significantly higher in 2 and 3 years before the cutoff change. For ACT and SAT, a cutoff change to an earlier date has no effect on all outcome variables. Only several lagged variables of the cutoff change have significant effect on verbal and writing scores.

Even though we find some significant effects of the placebo treatments on 8th grade state average reading and science scores, most estimates of the lagged variables are not statistically significant. We further conduct robustness checks using the model (1) adding these five lagged variables of cutoff change to earlier date and find comparable estimates to those in Tables 5 and 6. We conclude that it is less likely that the effects of earlier school

entry cutoff are completely driven by different trends in the states that have changed the cutoff.

7.3 Sample Restriction I: Cutoff Change by One Month

As a third robustness test, we estimate the model (1) in the sample that excludes states that have changed their cutoff by more than or less one month.¹¹ Since a big change of cutoff date can accompany a significant change of cohort composition and education policy variables, we estimate the model using the relatively homogeneous variations in cutoff date.

Table 14 presents the estimation results for the NAEP in the sample that includes states that have experienced cutoff change by one month or have not changed their cutoff during the sample periods. The results are very similar to those for the whole sample except that the effect on state average math score for 8th graders is not statistically significant. The effect of cutoff date on the reading average score becomes greater both in 4th and 8th grades in the restricted sample. The results for ACT and SAT are also reported in Table 15, and they are also similar to the results for the whole sample.

7.4 Sample Restriction II: Common State-Entry Year Cohort

We find some evidence in Tables 5–7 that the effect of kindergarten cutoff fades out as students advance through school. Since it is possible that this result might be driven in part by the differences in subjects who took the tests by test year, we construct state-entry year cohorts that took the tests both in 4th and 8th grades for each subject and estimate the model using this matched sample.¹² For example, states that participated in 4th grade NAEP for reading in 1994 and took part in 8th grade NAEP for reading in 1998 are included in the sample for the analysis of the cutoff date effect on reading test results because they are the same state-entry year cohort. 4th grade reading in 1992, however, is not included in the sample since 8th grade reading test was not held in 1996. More specific explanation for the sample construction is described in note 4 of Table 16.

Table 16 reports the estimation results, showing that it is not likely that the fade-out of the cutoff date effect on reading average score is due to differences in subjects who took the tests. A one month earlier cutoff increases state average reading score by 2.056 points in 4th grade and there is no significant effect in 8th grade. The effect on math average score, however, becomes greater in 8th grade. A one month earlier cutoff reduces standard deviation of test scores in both reading and math in 4th grade while the significant effect is not observed in 8th grade.

7.5 Functional Form

We have estimated model (1) and other models based upon a linearity assumption of the cutoff effect. As we find in Figure 1, many states have changed their cutoff to September and the number of states that have an earlier cutoff than September is relatively small. The linearity assumption of the cutoff effect may imply that even earlier cutoff can increase state

¹¹Here, one month means 29–31 days.

¹²The regression is not conducted for ACT and SAT since the sample becomes small if the sample is confined to cohorts that took the tests in all the three grades.

average test scores and reduce the degree of dispersion of the scores among students. We relax this assumption and estimate model (1) with quadratic functional form of the cutoff effect. Specifically, we estimate the following model. We normalize the cutoff variable C_{st}^k to be zero for the latest cutoff date in the sample, February 1.

$$Y_{st}^k = \gamma_0 + \gamma_1 C_{st}^k + \gamma_2 C_{st}^{k2} + X_{st}^k \gamma_3 + \gamma_4 D_t + \gamma_5 D_{t-1} + \zeta_s + \zeta_t + \varsigma_{st} \quad (3)$$

Table 17 reports the estimation results for 4th grade and 8th grade NAEP. Panel (a) of Table 17 presents the results for 4th grade NAEP and panel (b) is for 8th grade NAEP. Although not all results are precisely estimated, the estimation results generally show that the effect of cutoff date decreases as the cutoff changes to an earlier date of the year. The partial effect of cutoff date is $\gamma_1 + 2\gamma_2 C_{st}^k$ and we can examine how the effect of cutoff date varies according to an initial cutoff date using it. For example, the effect of a one month earlier cutoff on state reading average score is 3.395 for states with February 1 cutoff while it is approximately zero for states with an August cutoff. For 8th grade math, a one month earlier cutoff increases state average score by 4.751 for states with a February 1 cutoff while it does not have an effect for states with a September cutoff. These results have an important implication that a further cutoff change from a September cutoff may not lead to sufficient improvement in state educational achievement. Table 18 shows the results for ACT and SAT. A one month earlier cutoff increases participation rates of ACT and SAT and the effect decreases as the cutoff changes to earlier cutoff dates. For SAT scores, the results are opposite to other ones. A one month earlier cutoff decreases state average scores of SAT and the effect increases as the cutoff moves to earlier dates.

8 Discussion and Conclusion

This paper analyzes the effects of state policies on kindergarten entry dates on educational achievement as students progress through school. An earlier state kindergarten entry cutoff, which increases the average age of students at entry in the state, increases state average scores in reading and math in the 4th grade. It increases state average scores in math and science in 8th grade, while the effect is less clear for reading. The effect of state kindergarten entry cutoff date on ACT and SAT results is small and statistically insignificant in most specifications. These results are quite robust to various specifications. We also find no evidence of endogenous cutoff changes with respect to the test score processes we are interested in. Placebo tests are also conducted and suggest that it is not likely that the effect of cutoff date is derived from different trends between states that have changed the cutoff and those that did not.

As noted in Section 3, the effect of the state kindergarten-entry-cutoff date depends on the sum of the effects of school entry age, age at test, and class average age and the degree of compliance with the school-entry law. Most previous literature finds that the combined effect of school entry age and age at test is large and significant in earlier grades and the effect decreases over time. This generates a prediction that earlier state kindergarten-entry

date increases educational achievement in the state and the effect decreases as students advance through school. The estimation results in this study are consistent with the prediction. An earlier cutoff positively affects average test scores in 4th and 8th grades but the effect on reading scores decreases between 4th grade and 8th grade. We also find a negligible effect in 12th grade, even though the interpretation of the result is limited because students can take the tests in 12th grade multiple times and there is measurement error issues for the cutoff date variable.

Another important finding in this study is that state kindergarten entry date policy does not increase the degree of the dispersion of test scores in the state. Rather, most estimation results show a reduction in the dispersion of test scores in 4th and 8th grades. This is in conflict with the expectation in Stipek (2002) that an earlier kindergarten-entry cutoff may increase the gap in educational achievement, since children from higher socio-economic status families can accumulate human capital more out of school. One possible explanation is that the change of the cutoff to an earlier date could increase average age at kindergarten entry more, or that the returns to a school entry age increase is higher, for children from lower socio-economic status families. Some recent studies report that poor children tend to conform with the school entry rule more than non-poor children and that the ratio of delayed enrollment is higher for White and high-income children (Bassok & Reardon, 2013). If earlier cutoff rules decrease the proportion of delayed entrants by increasing entry age and reducing the number of delayed entrants from higher socioeconomic status families, it would reduce the entry age gap among children.¹³

Is it a good policy for states to change their kindergarten entry cutoff to an earlier date? As we can see in Figure 1 and as noted in Bedard and Dhuey (2012), most previous cutoff changes have moved earlier in the academic year, towards September. State education policy-makers may be interested in improving the educational achievement of students in the state from the policy. The results in this paper show that earlier kindergarten-entry cutoff date increases state average test scores in 4th and 8th grades, which suggests a motivation for many state cutoff changes that have been made over the last 40 years.

This study can help explain the motivation and incentives that may have led many states to change their cutoff to earlier dates and can provide evidence for future considerations by states that have not yet made the change. It is difficult, however, to conclude that moving the cutoff to an earlier date is socially desirable. First, if the positive effect of an earlier cutoff on test scores is mostly from an age-at-test effect, then it is difficult for earlier cutoff date policies to be shown to be useful. Indeed, this study could not separate age-at-test effects from the overall cutoff effect. Second, there needs to be a greater consensus on understanding the potential long-term effects of kindergarten-entry cutoff or school-entry age. If the effect of kindergarten entry date dissipates, this can weaken the grounds for advocating for earlier cutoff policies. Finally, moving the cutoff to a date earlier than September may not be beneficial for improving test scores in states. Our analysis using a

¹³Even if there is no change in the ratio of delayed entrants according to the cutoff change, the change could reduce the gap in educational achievement if the education production function is concave in school entry age and age-at-test. In this case, the returns to school-entry-age and age-at-test increases are lower for children from high socio-economic status families since their entry age and age-at-test before the change are likely to be higher.

quadratic functional form of the cutoff date effect find some evidence that the positive effect of an earlier cutoff decreases as the cutoff moves to earlier dates. Especially, in some subjects, the effect of moving the cutoff to earlier dates becomes zero around an August or September cutoff.

References

1. Angrist JD, Krueger AB. The Effect of Age at School Entry on Educational Attainment: An Application of Instrumental Variables With Moments From Two Samples. *Journal of American Statistical Association*. 1992; 87(418):328–36.
2. Bassok D, Reardon SF. Academic Redshirting” in Kindergarten: Prevalence, Patterns, and Implications. *Educational Evaluation and Policy Analysis*. 2013; 35(3):283–297.
3. Bedard K, Dhuey E. The Persistence of Early Maturity: International Evidence of Long-Run Age Effects. *The Quarterly Journal of Economics*. 2006; 106(4):1737–72.
4. Bedard K, Dhuey E. School-Entry Policies and Skill Accumulation Across Directly and Indirectly Affected Individuals. *The Journal of Human Resources*. 2012; 47(3):643–683.
5. Black SE, Devereux PJ, Salvanes KG. Too Young to Leave the Nest? The Effects of School Starting Age. *Review of Economics and Statistics*. 2011; 93(2):455–67.
6. Crawford C, Dearden L, Meghir C. When You Are Born Matters: The Impact of Date of Birth on Child Cognitive Outcomes in England. *Institute for Fiscal Studies Report*. 2007
7. Datar A. Does delaying kindergarten entrance give children a head start? *Economics of Education Review*. 2006; 25(1):43–62.
8. Dhuey E, Lipscomb S. What Makes a Leader? Relative Age and High School Leadership. *Economics of Education Review*. 2008; 27(2):173–183.
9. Dickert-Conlin S, Elder TE. Suburban Legend: School Cutoff Dates and the Timing of Births. *Economics of Education Review*. 2010; 29(5):826–841.
10. Dobkin C, Ferreira F. Do School Entry Laws Affect Educational Attainment and Labor Market Outcomes? *Economics of Education Review*. 2010; 29(1):40–54.
11. Elder TE, Lubotsky DH. Kindergarten Entrance Age and Children’s Achievement: Impacts of State Policies, Family Background and Peers. *The Journal of Human Resources*. 2009; 44(3):641–83.
12. Fredriksson P, Öckert B. Is Early Learning Really More Productive? The Effect of Schooling Starting Age on School and Labour Market Performance. *IZA Discussion Paper No. 2055*. 2005
13. Fredriksson P, Öckert B. Life-cycle Effects of Age at School Start. *The Economic Journal*. 2013; 124:977–1004.
14. Kim T. The Effect of Age at School Entry on Long-term Educational Attainment in Korea. *The Korean Journal of Labor Economics*. 2011; 34(1):1–32.
15. Kim T. Age Culture, School-Entry Cutoff and the Choices of Birth Month and School-Entry Timing in South Korea. *Working Paper*. 2015
16. McEwan PJ, Shapiro JS. The Benefits of Delayed Primary School Enrollment: Discontinuity Estimates Using Exact Birth Dates. *The Journal of Human Resources*. 2008; 43(1):1–29.
17. Mühlenweg A, Blomeyer D, Stichnoth H, Laucht M. Effects of Age at School Entry (ASE) on the Development of Non-Cognitive Skills: Evidence from psychometric data. *Economics of Education Review*. 2012; 31(3):68–76.
18. Solon G, Haider SJ, Wooldridge J. What Are We Weighting For? *The Journal of Human Resources*. 2015; 50(2):301–316.
19. Stipek D. At What age Should Children Enter Kindergarten? A Question for Policy Makers and Parents. *Social Policy Report*. 2002; 16(2):1–16.

Appendix 1 Derivation of Reduced Form Equation from Structural Equation

We start from the individual level education production function. The structural equation for educational outcome can be represented by the following equation:

$$Y_{ist}^k = \alpha_0 + \alpha_1 EA_{ist}^k + \alpha_2 A_{ist}^k + \alpha_3 A_{c(i)st}^k + X_{ist}^k \alpha_4 + \alpha_5 (A_{ist}^k - A_{c(i)st}^k) + u_s + \epsilon_{ist}^k \quad (4)$$

where Y_{ist}^k is an educational outcome, EA_{ist}^k is a kindergarten entry age and A_{ist}^k is the current age of individual i in grade k in state s in time t . $A_{c(i)st}^k$ is the average age of students in class c individual i attends in grade k in state s in time t . X_{ist}^k is a vector of other regressors, u_s is a state fixed effect and ϵ_{ist}^k is an error term. α_1 , α_2 , α_3 and α_5 represent kindergarten entry age effect, age at test effect, average class age effect and relative age effect respectively.

Since $A_{ist}^k = EA_{ist}^k + k$, which means current age, schooling years and kindergarten entry age are perfect multicollinear, the prior equation can be rewritten by the following equation:

$$Y_{ist}^k = \alpha_0 + \alpha_2 k + (\alpha_1 + \alpha_2) EA_{ist}^k + \alpha_3 A_{c(i)st}^k + X_{ist}^k \alpha_4 + \alpha_5 (A_{ist}^k - A_{c(i)st}^k) + u_s + \epsilon_{ist}^k \quad (5)$$

We can derive the equation for the state average educational outcome from the individual level education function represented in equation (2) by averaging the individual outcomes by state and year:

$$\begin{aligned} Y_{st}^k &= \alpha_0 + (\alpha_2 + \alpha_3)k + (\alpha_1 + \alpha_2 + \alpha_3) EA_{st}^k + X_{st}^k \alpha_4 + u_s + \epsilon_{st}^k \\ &= \gamma_0 + \gamma_1 EA_{st}^k + X_{st}^k \gamma_3 + u_s + \epsilon_{st}^k \end{aligned} \quad (6)$$

where $\gamma_0 = \alpha_0 + \alpha_2 k$, $\gamma_1 = \alpha_1 + \alpha_2 + \alpha_3$, $\gamma_3 = \alpha_4$,

$Y_{st}^k = \sum_{i_s=1}^{N_{st}^k} Y_{ist}^k / N_{st}^k$, $EA_{st}^k = \sum_{i_s=1}^{N_{st}^k} EA_{ist}^k / N_{st}^k = \sum_{i_s=1}^{N_{st}^k} EA_{c(i)st}^k / N_{st}^k$, $X_{st}^k = \sum_{i_s=1}^{N_{st}^k} X_{ist}^k / N_{st}^k$ and

$\epsilon_{st}^k = \sum_{i_s=1}^{N_{st}^k} \epsilon_{ist}^k / N_{st}^k$. N_{st}^k is the number of students in grade k in state s in year t . The relative

age effect term is erased since $A_{st}^k = \sum_{i_s=1}^{N_{st}^k} A_{ist}^k / N_{st}^k = \sum_{i_s=1}^{N_{st}^k} A_{c(i)st}^k / N_{st}^k$

The structural equation for actual kindergarten entry age is

$$EA_{ist}^k = \delta_0 + \delta_1 AEA_{ist}^k + X_{ist}^k \delta_2 + \kappa_s + \mu_{ist}^k \quad (7)$$

where AEA_{ist}^k is an assigned kindergarten entry age of individual i in grade k in state s in time t and κ_s is a state fixed effect for kindergarten entry age, and μ_{ist}^k is an idiosyncratic error.

By averaging equation (4) by state and year, we can have an equation for state average of actual kindergarten entry age.

$$EA_{st}^k = \delta_0 + \delta_1 AEA_{st}^k + X_{st}^k \delta_2 + \kappa_s + \mu_{st}^k \quad (8)$$

where AEA_{st}^k is an average age of assigned entry age in state s in time t and

$$\mu_{st}^k = \sum_{i=1}^{N_{st}} \mu_{ist}^k / N_{st}.$$

The state average of assigned school entry age AEA_{st}^k is a function of state kindergarten entry cutoff and birth distribution of children. If all states have the same birth date distribution, the state average assigned entry age will be a deterministic function of the state kindergarten entry cutoff. We assume that birth date is randomly distributed across states and time periods.

$$AEA_{st}^k = \pi_0 + \pi_1 C_{st}^k + \xi_{st}^k \quad (9)$$

where C_{st}^k is a measure of state kindergarten entry cutoff for k -th graders in state s in time t . Bedard and Dhuey (2012) interprets it as a minimum age at which the youngest student in the school cohort is eligible for kindergarten entry. ξ_{st}^k is an error term capturing the randomness of birth date distribution by state and time.

By replacing the average assigned entry age AEA_{st} in equation (5) with the right hand side of equation (6), state average age at kindergarten entry becomes an equation of kindergarten entry cutoff and other regressors.

$$\begin{aligned} EA_{st}^k &= \delta_0 + \delta_1 \pi_0 + \delta_1 \pi_1 C_{st}^k + X_{st}^k \delta_2 + \kappa_s + \mu_{st} + \delta_1 \xi_{st}^k \\ &= \lambda_0 + \lambda_1 C_{st}^k + X_{st}^k \lambda_2 + \kappa_s + \eta_{st}^k \end{aligned} \quad (10)$$

where $\lambda_0 = \delta_0 + \delta_1 \pi_0$, $\lambda_1 = \delta_1 \pi_1$, $\lambda_2 = \delta_2$ and $\eta_{st}^k = \mu_{st} + \delta_1 \xi_{st}^k$

Finally, we replace average of actual kindergarten entry age in equation (3) with the right hand side of equation (7). Now state level educational outcome is an equation of state kindergarten entry cutoff and other regressors.

$$\begin{aligned}
Y_{st}^k &= \gamma_0 + \gamma_1 EA_{st}^k + X_{st}^k \gamma_3 + u_s + \varepsilon_{st}^k \\
&= \gamma_0 + \gamma_1 (\lambda_0 + \lambda_1 C_{st}^k + X_{st}^k \lambda_2 + \kappa_s + \eta_{st}) + X_{st}^k \gamma_3 + u_s + \varepsilon_{st}^k \\
&= \gamma_0 + \gamma_1 \lambda_0 + \gamma_1 \lambda_1 C_{st}^k + X_{st}^k (\gamma_1 + \gamma_3) \lambda_1 + u_s + \gamma_1 \kappa_s + \varepsilon_{st}^k + \gamma_1 \eta_{st}^k \\
&= \beta_0 + \beta_1 C_{st}^k + X_{st}^k \beta_2 + \zeta_s + \zeta_{st}^k
\end{aligned} \tag{11}$$

where $\beta_0 = \gamma_0 + \gamma_1 \lambda_0$, $\beta_1 = \gamma_1 \lambda_1$, $\beta_2 = (\gamma_1 + \gamma_3) \lambda_1$, $\zeta_s = u_s + \gamma_1 \kappa_s$ and $\zeta_{st}^k = \varepsilon_{st}^k + \gamma_1 \eta_{st}^k$

The equation in the last line is the final equation that will be used in this study. The main reduced form parameter of interest is β_1 where $\beta_1 = \gamma_1 \lambda_1 = (a_1 + a_2 + a_3) \delta_1 \pi_1$. The reduced form parameter β_1 captures the aggregate effect of state kindergarten cutoff on state level educational outcome. It is interpreted as the multiplication of the sum of the effect of kindergarten entry age, age at test effect and the effect of average age in class ($a_1 + a_2 + a_3$), the degree of conforming to kindergarten entry rule (δ_1), and the parameter that determines the relationship between assigned entry age and kindergarten cutoff (π_1). The larger age effects are and the less children enroll kindergarten earlier than when they are supposed to enter, the state kindergarten cutoff would have a greater effect on state level educational performance.

Figure 1.
The number of states by kindergarten entry cutoff month (August–January): 1975–2008

Figure 2.
The number of cutoff changes by the amount of variation in the cutoff: 1975–2008

(a) Standardized Average Score and Cutoff Date in Delaware

(b) Standardized Average Score and Cutoff Date in Rhode Island

(c) Standardized Average Reading Score for States that Have Not Changed the Cutoff

Figure 3.

Standardized State Reading Score and Corresponding Kindergarten Cutoff for 4th Graders

Table 1

The Data for test scores

Data	Grade	Subject	Measure	Test year
NAEP	4th grade	Reading	Average score, Standard deviation	1992, 1994, 1998, 2002, 2003, 2005, 2007, 2009, 2011, 2013
		Math	"	1992, 1996, 2000, 2003, 2005, 2007, 2009, 2011, 2013
NAEP	8th grade	Reading	"	1998, 2002, 2003, 2005, 2007, 2009, 2011, 2013
		Math	"	1990, 1992, 1996, 2000, 2003, 2005, 2007, 2009, 2011, 2013
		Science	"	1996, 2000, 2005, 2009, 2011
ACT	12th grade	English, math, reading and science	Average composite score, participation rate	1994–2013
SAT	12th grade	Critical reading, math, writing	Average score for each subject, participation rate	1990–2011

Table 2
The effect of cutoff change on demographic, economic condition and education policy variables

	Mean	(1)FE	(2)FE	(3)FE	(4)FE	N
Sex ratio	0.512 (0.004)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0002 (0.0004)	-0.0002 (0.0004)	1,451
Father's age at birth	29.19 (1.11)	0.142 (0.088)	0.044 (0.044)	0.124 (0.095)	0.035 (0.042)	1,451
Mother's age at birth	27.73 (9.67)	0.400 (0.309)	-0.201 (0.127)	0.577 (0.487)	-0.241 (0.203)	1,451
Average birth weight (grams)	3329.3 (47.91)	4.171 (3.218)	-0.472 (2.209)	2.202 (2.370)	-1.804 (1.556)	1,451
Average gestation (weeks)	39.16 (0.336)	0.014 (0.009)	0.004 (0.010)	0.010 (0.009)	0.004 (0.010)	1,451
Ratio of white father	0.844 (0.082)	-0.010*** (0.003)	-0.003 (0.002)	-0.012*** (0.004)	-0.003 (0.002)	1,451
Ratio of black father	0.126 (0.078)	0.008** (0.003)	0.001 (0.002)	0.010** (0.004)	0.002 (0.002)	1,451
Ratio of white mother	0.807 (0.102)	-0.010** (0.004)	-0.002 (0.002)	-0.012** (0.005)	-0.003 (0.002)	1,451
Ratio of black mother	0.160 (0.106)	0.007* (0.004)	0.001 (0.001)	0.009* (0.005)	0.002 (0.001)	1,451
Mother's years of education	12.49 (0.475)	0.016 (0.032)	0.015 (0.014)	0.024 (0.031)	0.010 (0.016)	1,451
Unemployment rate	0.061 (0.019)	-0.126 (0.172)	-0.174 (0.191)	-0.216 (0.195)	-0.259 (0.199)	1,331
Personal income per capita	33057.2 (6084.7)	259.6 (416.7)	-12.44 (208.2)	427.7 (493.5)	97.7 (248.8)	1,042
Expenditures per pupil in public elementary and secondary schools	8992.2 (2180.3)	3.184 (111.8)	-91.093 (81.37)	2.838 (114.7)	-103.2 (118.0)	958
Elementary school size	506.3 (117.1)	-4.946 (3.228)	-1.428 (2.561)	-4.529 (2.756)	0.435 (3.118)	829

	Mean	(1)FE	(2)FE	(3)FE	(4)FE	N
Secondary school size	795.3 (232.4)	6.782 (12.225)	11.6** (5.508)	14.62 (13.49)	15.0** (5.866)	829
The number of pupils per staff	8.90 (1.59)	0.033 (0.191)	0.121 (0.190)	0.022 (0.220)	0.136 (0.187)	829
The number of pupils per teacher	17.19 (2.777)	0.118 (0.190)	0.149 (0.140)	0.127 (0.247)	0.164 (0.174)	829
Average salary of teachers	52264.7 (8215.7)	-760.9 (653.6)	-192.0 (317.4)	-561.7 (504.4)	-173.4 (319.5)	829
Cohort size	64700.3 (81310.4)	-7,094.2* (3,791.6)	-3,683.3 (2,570.3)	-12,232.4* (6,217.9)	-13,651.7* (7,081.1)	1,451
Weight		N	N	Y	Y	
Linear Time Trend		N	Y	N	Y	

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

The cutoff change variable is defined by a dummy variable that is 1 if cutoff change occurs in school entry year and 0 otherwise.

Specification (1)–(4) include state and time fixed effects and specification (2) and (4) add state-specific linear time trends. Specification (3) and (4) are weighted by square root of state population by year.

Table 3
The effect of cutoff date on demographic, economic condition and education policy variables

	Mean	(1)FE	(2)FE	(3)FE	(4)FE	N
Sex ratio	0.512 (0.004)	0.0002* (0.0001)	0.00001 (0.0002)	0.0002 (0.0001)	-0.00002 (0.0001)	1,451
Father's age at birth	29.19 (1.11)	0.015 (0.043)	0.018 (0.024)	-0.004 (0.039)	0.008 (0.027)	1,451
Mother's age at birth	27.73 (9.67)	0.061 (0.165)	-0.018 (0.072)	-0.073 (0.155)	0.009 (0.076)	1,451
Average birth weight (grams)	3329.3 (47.91)	-2.289 (1.43)	-0.900 (0.615)	-2.737** (1.199)	-0.919 (0.605)	1,451
Average gestation (weeks)	39.16 (0.336)	-0.007 (0.009)	0.002 (0.006)	-0.006 (0.006)	0.003 (0.006)	1,451
Ratio of white father	0.844 (0.082)	0.002 (0.003)	0.001 (0.002)	0.004 (0.003)	-0.0002 (0.003)	1,451
Ratio of black father	0.126 (0.078)	-0.001 (0.002)	0.0004 (0.002)	-0.002 (0.003)	0.002 (0.003)	1,451
Ratio of white mother	0.807 (0.102)	-0.00001 (0.002)	0.0005 (0.001)	0.001 (0.002)	0.001 (0.001)	1,451
Ratio of black mother	0.160 (0.106)	0.001 (0.001)	0.0002 (0.001)	0.0001 (0.002)	0.0005 (0.001)	1,451
Mother's years of education	12.49 (0.475)	0.007 (0.017)	0.013 (0.010)	0.028 (0.029)	0.010 (0.009)	1,451
Unemployment rate	0.061 (0.019)	-0.079 (0.081)	0.0002 (0.103)	-0.115 (0.095)	-0.069 (0.082)	1,331
Personal income per capita	33057.2 (6084.7)	34.8 (163.1)	139.2 (139.798)	173.8 (218.4)	186.9 (167.5)	1,042
Expenditure per pupil in public elementary and secondary schools	8992.2 (2180.3)	314.7*** (58.1)	216.7*** (72.238)	323.6*** (58.6)	227.6** (101.3)	958
Elementary school size	506.3 (117.1)	-8.220*** (1.91)	-6.408*** (1.942)	-8.309*** (2.324)	-7.167*** (2.074)	829

	Mean	(1)FE	(2)FE	(3)FE	(4)FE	N
Secondary school size	795.3 (232.4)	-3.672 (6.16)	-3.279 (6.847)	-3.477 (6.956)	-3.763 (6.336)	829
The number of pupils per staff	8.90 (1.59)	-0.139** (0.052)	-0.177** (0.069)	-0.180*** (0.054)	-0.216*** (0.077)	829
The number of pupils per teacher	17.19 (2.777)	-0.082 (0.059)	-0.166** (0.074)	-0.067 (0.084)	-0.182** (0.076)	829
Average salary of teachers	52264.7 (8215.7)	566.4*** (181.0)	353.7 (302.9)	628.4*** (190.587)	437.1 (315.9)	829
Cohort size	64700.3 (81310.4)	-3,830.8 (3,425.4)	-1,782.5 (1,125.4)	-9,421.5 (7,526.0)	-3,926.9** (1,794.3)	1,451
Weight		N	N	Y	Y	
Linear Time Trend		N	Y	N	Y	

Notes:

* p<0.1;

** p<0.05;

*** p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

The cutoff change variable is defined by a dummy variable that is 1 if cutoff change occurs in school entry year and 0 otherwise.

Specification (1)–(4) include state and time fixed effects and specification (2) and (4) add state-specific linear time trends. Specification (3) and (4) are weighted by square root of state population by year.

Table 4

The comparison of regressors between states that have changed cutoff and those that have not changed it

	(1) OLS	(2) WLS	N
Sex ratio	−0.00004 (0.0004)	−0.00003 (0.0003)	1,451
Father's age at birth	−0.1552 (0.1882)	−0.1962 (0.2295)	1,451
Mother's age at birth	−0.3689 (0.3035)	−0.3764 (0.3246)	1,451
Average birth weight	0.7560 (17.7316)	−0.5568 (15.0495)	1,451
Average gestation	−0.0335 (0.0468)	−0.0192 (0.0447)	1,451
Ratio of white father	−0.0562 * (0.0307)	−0.0390 (0.0258)	1,451
Ratio of black father	0.0280 (0.0252)	0.0187 (0.0252)	1,451
Ratio of white mother	−0.0750 ** (0.0371)	−0.0487 (0.0330)	1,451
Ratio of black mother	0.0415 (0.0353)	0.0250 (0.0349)	1,451
Mother's years of education	−0.1884 * (0.1061)	−0.1903 * (0.1061)	1,451
Unemployment rate	0.2800 (0.3534)	0.1566 (0.3311)	1,331
Personal income per capita	−1,478.5 (1,338.0)	−1,442.3 (1,390.8)	1,042
Expenditure per pupil in public elementary and secondary schools	−629.5 (565.6)	−977.6 (654.3)	958
Elementary school size	20.7 (42.1)	8.5 (41.1)	829
Secondary school size	20.9 (79.9)	5.2 (78.6)	829
The number of pupils per staff	0.459 (0.4010)	0.6467 (0.4516)	829
The number of pupils per teacher	0.3146 (0.7098)	0.7467 (0.8507)	829
Average salary of teachers	−1,824.9 (2,283.5)	−2,453.5 (2,790.1)	829
Cohort size	−15,220.2 (21,957.1)	−8,348.2 (43,945.7)	1,451
Weight	N	Y	

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

Independent variable is a dummy variable which is 1 if a state has ever changed kindergarten cutoff during the sample period and 0 otherwise. Year dummies are also controlled.

Table 5

The effect of one month earlier cutoff on the average and standard deviation of test scores in 4th grade

	Mean (SD)	FE	N
(1)Average Score			
Reading	217.0 (6.89)	1.492*** (0.511)	402
R^2		0.904	
Mathematics	233.2 (9.97)	1.353*** (0.241)	368
R^2		0.963	
(2)Standard Deviation			
Reading	35.88 (2.77)	-0.468 (0.307)	402
R^2		0.747	
Mathematics	28.72 (2.14)	-0.338** (0.146)	368
R^2		0.834	

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 6

The effect of one month earlier cutoff on the average and standard deviation of test scores in 8th grade

	Mean (SD)	FE	N
(1)Average Score			
Reading	264.5 (9.22)	0.471 * (0.255)	330
R^2		0.964	
Mathematics	275.9 (9.77)	1.256 ** (0.540)	396
R^2		0.945	
Science	148.5 (8.00)	1.510 *** (0.396)	191
R^2		0.966	
(2)Standard Deviation			
Reading	33.92 (2.11)	-0.230 (0.216)	330
R^2		0.750	
Mathematics	35.13 (2.24)	-0.356 ** (0.134)	396
R^2		0.826	
Science	33.59 (2.62)	-0.467 ** (0.211)	191
R^2		0.922	

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 7

The effect of one month earlier cutoff on the average scores and participation rate in ACT and SAT

	Mean (SD)	FE	Observations
(1)ACT			
Average Score	21.20 (1.04)	0.048 (0.099)	859
R^2		0.873	
Participation Rate	0.484 (0.293)	0.026** (0.013)	859
R^2		0.964	
(2)SAT			
Reading	534.3 (36.12)	0.884 (1.641)	930
R^2		0.975	
Mathematics	537.6 (36.26)	0.319 (1.730)	930
R^2		0.971	
Writing	522.2 (40.13)	-4.026*** (1.336)	303
R^2		0.989	
Participation Rate	0.353 (0.283)	-0.001 (0.006)	888
R^2		0.991	

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 8

The effect of one month earlier cutoff on the average and standard deviation of test scores in 4th grade

	(1)POLS	(2)FE	(3)FE	(4)FE	(5)FD	(6)GLS	(7)AB	(8)BB	N
(1)Average Score									
Reading	0.727** (0.296)	1.571*** (0.466)	1.278** (0.489)	1.032** (0.475)	1.238*** (0.466)	1.392*** (0.280)	1.465*** (0.432)	1.393*** (0.438)	402
R^2	0.754	0.898	0.950	0.951	0.409				
Math	0.711** (0.343)	1.442*** (0.213)	1.171*** (0.348)	1.013*** (0.355)	0.509** (0.204)	0.870*** (0.261)	0.311 (0.351)	0.172 (0.363)	368
R^2	0.756	0.898	0.949	0.951	0.404				
(2)Standard Deviation									
Reading	-0.243 (0.148)	-0.642* (0.350)	-0.615* (0.319)	-0.404 (0.311)	-0.607** (0.256)	-0.591*** (0.195)	-0.776*** (0.258)	-0.736*** (0.259)	402
R^2	0.564	0.762	0.854	0.846	0.569				
Math	-0.135 (0.105)	-0.397** (0.192)	-0.080 (0.221)	0.003 (0.217)	0.076 (0.166)	-0.343** (0.134)	0.083 (0.173)	0.069 (0.162)	368
R^2	0.639	0.828	0.881	0.887	0.422				

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

The number of observations is the full number of observations. The number of observations is smaller for specifications (5)–(8).

(1)POLS: pooled OLS, (2)FE: weighted fixed effects model with state-specific linear time trends, (3) unweighted fixed effects model with state-specific linear time trends, (4) unweighted fixed effects model allowing an AR(1) error process (Baltagi and Wu (1999)), (7)AB: dynamic panel model (Allerano and Bover (1995)), (8)BB: dynamic panel model (Blundell and Bond (1998)). All models except specification (1) include state and time fixed effects.

Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size and dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 9

The effect of one month earlier cutoff on the average and standard deviation of test scores in 8th grade

	(1)POLS	(2)FE	(3)FE	(4)FE	(5)FD	(6)GLS	(7)AB	(8)BB	N
(1)Average Score									
Reading	0.774 *** (0.282)	0.556 (0.336)	0.457 (0.345)	0.335 (0.387)	-0.055 (0.307)	-0.436 (0.406)	-0.087 (0.324)	-0.382 (0.304)	330
R^2	0.892	0.963	0.976	0.977	0.920				
Math	1.194 *** (0.338)	1.437 *** (0.439)	0.967 (0.730)	0.612 (0.827)	0.655 (0.531)	1.023 *** (0.346)	0.302 (0.597)	0.030 (0.477)	396
R^2	0.828	0.948	0.976	0.976	0.590				
Science	1.169 *** (0.416)	1.430 *** (0.345)	2.374 *** (1.165)	2.147 *** (1.033)	1.476 *** (0.509)	1.262 * (0.636)	1.826 *** (0.776)	1.825 *** (0.769)	191
R^2	0.791	0.967	0.989	0.990	0.469				
(2)Standard Deviation									
Reading	-0.202 *** (0.075)	-0.275 (0.252)	-0.544 (0.340)	-0.551 * (0.326)	-0.193 (0.348)	-0.158 (0.245)	-0.183 (0.307)	-0.162 (0.307)	330
R^2		0.49	0.57	0.73	0.22				
Math	-0.292 *** (0.085)	-0.411 *** (0.153)	-0.409 * (0.229)	-0.283 (0.204)	-0.248 (0.222)	-0.377 *** (0.169)	-0.155 (0.282)	-0.142 (0.265)	396
R^2	0.643	0.819	0.860	0.869		0.313			
Science	-0.379 *** (0.113)	-0.520 *** (0.222)	-1.261 *** (0.413)	-1.251 *** (0.378)	-0.906 *** (0.246)	-0.932 *** (0.358)	-0.951 *** (0.342)	-1.032 *** (0.339)	191
R^2	0.800	0.924	0.966	0.962	0.644				

Notes:

* p<0.1;

** p<0.05;

*** p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

The number of observations is the full number of observations. The number of observations is smaller for specifications (5)–(8).

(1)POLS: pooled OLS, (2)FE: weighted fixed effects model with state-specific linear time trends, (3) unweighted fixed effects model with state-specific linear time trends, (4) unweighted fixed effects model with state-specific linear time trends, (5)FD: first difference model, (6)GLS: fixed effects model allowing an AR(1) error process (Baltagi and Wu (1999), (7)AB: dynamic panel model (Allerano and Bover (1995), (8)BB: dynamic panel model (Blundell and Bond (1998). All models except specification (1) include state and time fixed effects.

Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size and dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 10
The effect of one month earlier cutoff on the average scores and participation rate in ACT and SAT

	(1)POLS	(2)FE	(3)FE	(4)FE	(5)FD	(6)GLS	(7)AB	(8)BB	N
(1)ACT									
Average	0.028 (0.050)	0.111 (0.085)	0.096 (0.080)	0.027 (0.057)	0.073 (0.036)	0.128*** (0.047)	0.124** (0.056)	0.049 (0.044)	859
R^2	0.796	0.874	0.932	0.934	0.094				
Participation Rate	0.072*** (0.023)	0.014 (0.011)	0.013 (0.009)	0.019** (0.010)	0.005 (0.008)	0.008 (0.007)	-0.001 (0.008)	0.005 (0.006)	859
R^2	0.635	0.966	0.980	0.976	0.127				
(2)SAT									
Reading	6.743*** (2.386)	0.192 (1.529)	-0.300 (0.672)	-0.425 (0.757)	0.112 (0.346)	-0.855 (0.621)	-0.507 (0.518)	1.057 (0.811)	930
R^2	0.67	0.67	0.75	0.98	0.22				
Math	7.360*** (2.629)	0.017 (1.586)	-0.998 (0.805)	-1.098 (0.892)	0.188 (0.594)	-0.813 (0.639)	-0.266 (0.623)	0.500 (0.673)	930
R^2	0.639	0.967	0.987	0.989		0.183			
Writing	7.281*** (2.645)	-3.742*** (1.740)	4.502 (3.318)	3.498 (2.323)	0.187 (1.202)	-0.438 (1.604)	0.019 (0.985)	1.630 (1.121)	303
R^2	0.719	0.987	0.995	0.996		0.218			
Participation Rate	-0.044*** (0.016)	0.001 (0.006)	0.006* (0.003)	0.003 (0.004)	-0.001 (0.002)	0.001 (0.003)	0.008*** (0.003)	0.005** (0.003)	888
R^2	0.707	0.989	0.995	0.996	0.211				

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

The number of observations is the full number of observations. The number of observations is smaller for specifications (5)–(8).

(1)POLS: pooled OLS, (2)FE: weighted fixed effects model with state-specific linear time trends, (3) unweighted fixed effects model with state-specific linear time trends, (4) unweighted fixed effects model with state-specific linear time trends, (5)FD: first difference model, (6)GLS: fixed effects model allowing an AR(1) error process (Baltagi and Wu (1999), (7)AB: dynamic panel model (Allerano and Bover (1995), (8)BB: dynamic panel model (Blundell and Bond (1998). All models except specification (1) include state and time fixed effects.

Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size and dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 11

The effect of kindergarten entry cut-off change and its lag variables on 4th Grade NAEP

	(1) Reading	(2) Mathematics
Change (θ_1^4)	2.227 (1.459)	3.088*** (1.069)
Change t-1 (θ_2^4)	-1.018 (1.241)	0.906 (1.156)
Change t-2 (θ_3^4)	0.491 (1.425)	0.008 (1.204)
Change t-3 (θ_4^4)	-0.758 (1.071)	0.481 (1.461)
Change t-4 (θ_5^4)	-0.474 (1.052)	-0.683 (1.200)
Change t-5 (θ_6^4)	-2.131 (1.549)	-0.541 (0.980)
Observations	402	368
R^2	0.898	0.962

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income and cohort size by state and test year are used as regressors.

Table 12

The effect of kindergarten entry cutoff change and its lag variables on 8th Grade NAEP

	(1) Reading	(2) Mathematics	(3) Science
Change (θ_1^8)	1.854 ** (0.740)	3.369 ** (1.374)	4.438 *** (1.631)
Change t-1 (θ_2^8)	2.015 (1.318)	1.382 (1.216)	-0.192 (2.821)
Change t-2 (θ_3^8)	1.628 * (0.960)	1.442 (1.510)	2.576 * (1.405)
Change t-3 (θ_4^8)	2.865 *** (0.741)	3.154 (1.936)	2.790 ** (1.382)
Change t-4 (θ_5^8)	-1.218 (1.377)	1.523 (1.944)	-1.255 (1.689)
Change t-5 (θ_6^8)	1.464 (1.715)	2.050 (1.587)	0.094 (1.732)
Observations	330	396	191
R^2	0.966	0.946	0.966

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income and cohort size by state and test year are used as regressors.

Table 13
The effect of kindergarten entry cutoff change and its lag variables on ACT and SAT results

	ACT			SAT		
	(1) Average score	(2) Participation rate	(3) Verbal	(4) Mathematics	(5) Writing	(6) Participation rate
Change (θ_1^{12})	0.291 (0.176)	0.023 (0.029)	-1.815 (3.208)	-0.728 (3.601)	-1.712 (4.414)	-0.037 (1.046)
Change t-1 (θ_2^{12})	0.156 (0.166)	-0.032 (0.034)	-1.030 (1.363)	1.298 (1.234)	4.289 (2.814)	-0.259 (0.788)
Change t-2 (θ_3^{12})	0.121 (0.146)	-0.013 (0.021)	-2.276** (0.972)	-0.274 (1.093)	2.886 (3.712)	0.617 (0.606)
Change t-3 (θ_4^{12})	0.131 (0.123)	-0.008 (0.020)	-1.593 (0.966)	-0.236 (0.955)	7.221* (3.691)	0.151 (0.476)
Change t-4 (θ_5^{12})	0.187 (0.154)	-0.006 (0.032)	-0.928 (1.110)	0.771 (1.220)	9.277*** (2.582)	-0.165 (0.547)
Change t-5 (θ_6^{12})	0.048 (0.170)	-0.007 (0.028)	-4.041*** (1.235)	-2.576 (1.697)	10.621*** (2.930)	0.287 (0.754)
Observations	859	859	890	890	303	848
R^2	0.875	0.963	0.977	0.974	0.989	0.991

Notes:

* p<0.1;

** p<0.05;

*** p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income and cohort size by state and test year are used as regressors.

Table 14

The effect of one month earlier cutoff on the average and standard deviation of test scores in 4th grade: one month cutoff change

	Cutoff Date	Observations
<u>(a) 4th Grade NAEP</u>		
(1) Average Score		
Reading	2.682 *** (0.533)	293
Mathematics	1.352 *** (0.280)	266
(2) Standard Deviation		
Reading	-1.182 *** (0.414)	293
Mathematics	-0.551 * (0.301)	266
<u>(b) 8th Grade NAEP</u>		
(1) Average Score		
Reading	0.900 ** (0.422)	217
Mathematics	0.761 (0.876)	261
Science	1.111 ** (0.483)	128
(2) Standard Deviation		
Reading	-0.638 (0.421)	217
Mathematics	-0.523 ** (0.200)	261
Science	-0.408 * (0.213)	128

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

States that have had a cutoff change by more than or less than one month are excluded in the sample.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 15

The effect of one month earlier cutoff in ACT and SAT: one month cutoff change

	Cutoff Date	Observations
<u>ACT</u>		
Average Score	-0.009 (0.162)	578
Participation Rate	0.034 (0.023)	578
<u>SAT</u>		
Verbal	2.835 (2.210)	598
Math	2.454 (2.309)	598
Writing	3.358 (2.441)	205
Participation Rate	-0.007 (0.008)	570

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

States that have had a cutoff change by more than or less than one month are excluded in the sample.

Table 16

The effect of one month earlier cutoff on the average and standard deviation of test scores in the common cohort sample

	Cutoff Date	Observations
<u>(a) 4th Grade NAEP</u>		
(1) Average Score		
Reading	2.056 *** (0.516)	235
Mathematics	1.386 *** (0.448)	236
(2) Standard Deviation		
Reading	-0.963 * (0.518)	235
Mathematics	-0.336 * (0.184)	236
<u>(b) 8th Grade NAEP</u>		
(1) Average Score		
Reading	0.387 (0.316)	235
Mathematics	2.030 *** (0.527)	236
(2) Standard Deviation		
Reading	-0.083 (0.278)	235
Mathematics	-0.201 (0.218)	236

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

The following test results are included in the sample. 4th grade reading: 1994, 1998, 2003, 2005, 2007, 2009. 8th grade reading: 1998, 2002, 2007, 2009, 2011, 2013. 4th grade math: 1992, 1996, 2003, 2005, 2007, 2009. 8th grade math: 1996, 2000, 2007, 2009, 2011, 2013.

Table 17

The effects of cutoff date and its square on the average and standard deviation of test scores in 4th and 8th Grade NAEP

	Cutoff	Cutoff Square	Observations
<u>(a)4th Grade NAEP</u>			
(1)Average Score			
Reading	3.395 *** (1.255)	-0.282 * (0.152)	402
Mathematics	1.764 (1.195)	-0.061 (0.185)	368
(2)Standard Deviation			
Reading	-1.784 ** (0.777)	0.195 ** (0.091)	402
Mathematics	-0.965 (0.643)	0.093 (0.094)	368
<u>(b)8th Grade NAEP</u>			
(1)Average Score			
Reading	-0.322 (0.819)	0.119 (0.105)	330
Mathematics	4.751 *** (0.893)	-0.492 *** (0.143)	396
Science	2.237 * (1.189)	-0.103 (0.169)	191
(2)Standard Deviation			
Reading	1.113 (0.669)	-0.202 ** (0.086)	330
Mathematics	-0.792 ** (0.643)	0.061 (0.040)	396
Science	-1.469 ** (0.555)	0.142 * (0.081)	191

Notes:

*
p<0.1;

**
p<0.05;

p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.

Table 18

The effects of cutoff date and its square on the ACT and SAT Results

	Cutoff	Cutoff Square	Observations
<u>ACT</u>			
Average Score	0.090 (0.243)	−0.006 (0.023)	859
Participation Rate	0.072 ** (0.028)	−0.006 ** (0.003)	859
<u>SAT</u>			
Verbal	−6.221 * (3.416)	0.947 *** (0.304)	930
Mathematics	−7.282 ** (3.524)	1.013 *** (0.315)	930
Writing	−13.957 ** (5.742)	1.504 * (0.887)	303
Participation Rate	0.018 * (0.010)	−0.003 *** (0.001)	888

Notes:

*
p<0.1;**
p<0.05;***
p<0.01.

Standard errors are in parentheses. Standard errors are clustered by state.

State and time fixed effects are controlled. Sex ratio, average ages of parents at birth, average birth weight, average gestation, the ratios of white parents, the ratios of black parents, average of mother's years of education for each school cohort by state and school entry year, expenditure per student, average elementary school size, average secondary school size, the number of teachers per pupil, the number of staff per pupil, average teacher's salary, unemployment rate, average personal income, cohort size, dummy variables indicating cutoff change year and previous year by state and test year are used as regressors.