Bridging the Discontinuity In Adolescent Literacy: Evidence of an Effective Middle Grades Intervention

Shaun M. Dougherty
Harvard University

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Abstract:

The development of strong literacy skills is crucial to ensuring an individual's future educational and economic success. Existing evidence suggests that the transition from elementary to middle school is a particularly crucial period for a child's literacy development and requires sustained support through this transition. In this paper I investigated the impact of a "double dose" of literacy instruction in a large suburban school district on subsequent measures of student literacy. I capitalize on the existence of a natural experiment born out of the district's use of an exogenously-determined cutoff in Iowa Test scores in 5th grade to assign students to an additional literacy course in middle school. My findings suggest that an additional semester of exposure to this instructional intervention generates notable increases in students' state standardized reading test scores (0.2 SD), and positive effects (0.1 SD) on their percentile ranking on the reading portion of the Iowa Test in 8th grade. Most research that uses student test score outcomes finds positive effects of intervention in mathematics, but often not in reading. My findings suggest that using a double dose of literacy instruction in middle school is an effective way of increasing student understanding in literacy for students in the middle of the 5th-grade distribution of literacy ability.

Literacy in Transition: Regression-Discontinuity Evidence of an Effective Literacy Intervention in Middle School

The capacity of school districts to support the ongoing development of their students' literacy skills plays a critical role in enhancing their academic and labor-market outcomes. Students who do not develop adequate literacy skills by the end of elementary school are at higher risk of dropping out of school and face inferior labor-market options (National Governor's Association, 2005; Vignoles, De Coulon, & Marcenaro-Gutierrez, 2011). Though fourth graders' reading scores on the National Assessment of Educational Progress have been trending higher, Snow and Moje (2010) point out that score trends are flat among 8th and 12th graders, (Lee, Grigg, & Donohue, 2007, p.3). These trends underscore the need for literacy support at the critical transition between elementary and secondary schooling (Chall & Jacobs, 2003).

Schools and districts seeking to improve their adolescent literacy outcomes face resource constraints. Recent budget crises and mounting pressure from the requirements of No Child Left Behind (NCLB) necessitate that schools find ways to leverage existing resources and generate results in short time frames. Prior work has documented the variety of strategies taken by districts to improve the academic performance of their students (Chamberlain, Daniels, Madden, & Slavin, 2007; Hong & Raudenbush, 2007; Jacob & Lefgren, 2004; Kemple, Herlihy, & Smith, 2005; Neal & Schanzenbach, 2009; Sims, 2008).

One widely-used though under-evaluated method for improving student outcomes is through providing a "double dose" of instruction in subject areas tested for the purposes of NCLB, most notably, reading and mathematics. Recent evidence from Chicago suggests that these double-dose strategies with algebra instruction can have positive short-term impacts on student's academic performance, as well as positive longer-run impacts on high-school graduation and post-secondary enrollment. (Nomi & Allensworth, 2009; Cortes, Goodman, & Nomi, 2012). Other recent work examining the effects of double dose strategies in mathematics have shown similarly positive effects (Taylor, unpublished). However, little is known about the effectiveness of the double dose strategy for boosting literacy outcomes despite evidence that double-dose strategies have been and are used throughout the country (Cavanagh, 2006; Mazzolini & Morley, 2006; Paglin, 2003; Wanzek & Vaughn, 2008; Durham Public Schools, n.d). The paucity of good evidence on the effectiveness of literacy interventions at the crucial transition from elementary to middle grades is particularly notable in that the little evidence that exists is not causal.

I fill this gap in the literature by providing causal evidence for the effectiveness of a double dose of literacy instruction in middle school. I focus on an intervention where the second dose of literacy instruction uses research-based instructional strategies, and I show that this instruction leads to systematic improvement in adolescent reading comprehension. Using a rich set of data from school districts that enrolls over 90,000 students, I estimate the impact of a district-developed, classroom-based literacy intervention in middle school on both immediate and medium-term student test scores. Specifically, I investigated whether — and by how much — participation in a supplementary reading class in middle school improved student test scores in reading.

The site for my study provided an ideal setting to evaluate the impact of a research-based and district-designed literacy intervention. In the district, student assignment to the supplemental reading class was made using a cutoff rule based on a student's 5th grade test score, allowing me to use a regression-discontinuity approach to obtain an unbiased estimate of the causal impact of the intervention on student outcomes. The student's position relative to this cutoff provided an indicator of intent-to-treat, which I used to instrument for their "take-up" of the supplementary reading intervention. Thus, I was able to identify the causal impact of enrollment in the program for students near, but on opposite sides of the cutoff.

I find that there was a positive and statistically significant improvement in student reading state test scores in 6^{th} grade, for students in the immediate vicinity of the cut-off, with smaller effects in 7^{th} grade, and complete fade out of the effect by 8^{th} grade. In addition, I find that the intervention had a small positive impact on student percentile rank on the reading portion of the Iowa Test of Basic Skills in grade 8, indicating that the measured learning gains suggest real learning and not an artifact of potential teaching to the test.

I have laid out the rest of the paper in four sections. In the next section, I consider the district's theory of action with respect to the extant literature on effective instructional strategies that promote adolescent literacy, and describe the school district setting and their implementation of the supplementary reading program itself. In section three, I present my research design, including a description of my data collection and data-analytic strategy, followed by my results in section four. In the final section of the paper, I discuss potential threats to both the internal and external validity of my findings and review the implications of my findings for practice and future research.

2. Background and Context

2.1 Background on the Intervention:

For the last twenty years, the Hampton County Public School (HCPS) district has adapted its approach to meeting the instructional needs of its students in literacy, as the policy environment has shifted around it.[1] Initially, the district employed the use of a supplementary reading program as a means to improve the literacy skills of its students as they transition from primary to secondary schooling. The district-maintained reading lab was designed to provide instructional support in literacy for students in the late elementary and early secondary grades. This lab supported students outside of their regular course of instruction, but in the 1990s the district moved to embed literacy support within an established course of instruction. Some of this change was motivated by standards-based reforms that changed the way that instructional targets, or standards, were defined (Darling-Hammond, 2004; McLaughlin & Shepard, 1995). The importance of the course was further underscored when the policy landscape was modified again in 2001 by the passage of the federal *No Child Left Behind* (NCLB) act and the implementation of high-stakes, standards-based testing that began in the 2002-2003 school year. In response to these changes, HCPS has revised its instructional strategy to meet the needs of its students and to ensure that its schools satisfy, among other things, the adequate yearly progress (AYP) provision of NCLB.

Each of the district's twenty middle schools serves students in grades 6 through 8. In all district middle schools, students must earn a passing grade in a language-arts course to fulfill their annual English requirement. Language-arts courses address all of the state standards' domains: reading, writing, literary conventions, listening, speaking, and viewing. To address these domains, the language-arts classes use a literature anthology, a grammar text, and selected novels assigned specifically by grade level. The supplementary reading course was designed to complement a student's language arts curriculum, and to improve the development student's literacy skills to levels that are consistent with grade-level expectations by focusing only on the

[1] Per my agreement with the district I have replaced the actual district and program names with pseudonyms when referring to them in print.

reading standards, and the standards for writing in response to reading. Teachers address the reading standards in the supplementary reading classes using grade-level-appropriate non-fiction texts and novels.

2.2 Theory of Change and Recent Literature

The theory of change employed by HCPS is that enrolling students who have demonstrated a need for additional literacy support in a course that was designed to employ research-proven strategies is likely to improve literacy outcomes for those students. Specifically, this district drew on research from Dole, Duffy, Roehler, and Pearson (1991), and designed the supplementary reading class to explicitly dwell on seven "basic" reading strategies: activating background knowledge, questioning the text, drawing inferences, determining importance, creating mental images, repairing understanding when meaning breaks down, and synthesizing information. In addition, the district also encouraged the use of writing activities to support each of these seven reading strategies.

Though the research from Dole and colleagues is more than twenty years old, more recent research continues to substantiate the use of these strategies, particularly with adolescents. A meta-analysis on the effectiveness of reading interventions for struggling readers in grades six through twelve revealed that many of the same strategies suggested by Dole and colleagues were used across the thirteen studies that could be included in that meta-analysis (Edmonds, Vaughn, Wexler, Reutebuch, Cable, Klinger Tackett, Schnakenberg, 2009). This meta-analysis found a large effect size of 0.89 SD for reading comprehension outcomes. Evidence from another recent meta-analysis on writing to read, further supports the strategies employed by HCPS. Graham & Hebert (2012) found that writing to read strategies improve student reading comprehension by about 0.37 SD. In yet another teacher-delivered intervention, Vaughn, Klingner, Swanson, Boardman, Roberts, Mohammed, & Stillman-Spisak (2011) performed an experimental evaluation of collaborative strategic reading (CSR) with middle school students, where English-language arts teachers provided a multicomponent reading comprehension instruction twice a week for 18 weeks, and found modest positive effects on reading comprehension. All of this more recent evidence suggests that the research used to design the supplementary reading class continues to be valid and relevant.

2.3 Assignment to the Supplementary Reading Program

Students in HCPS were assigned to receive supplementary reading instruction in middle school based on how they scored on the Iowa Test of Basic Skills (ITBS) in reading during their 5th grade year. Students who scored below the nationally-defined 60th percentile on ITBS in reading were assigned, by rule, to complete the supplementary reading program in middle school. The HCPS policy was designed to enroll students in the supplementary reading course for all three (grades 6, 7, and 8) years of middle school, with the goal of preparing students to meet proficiency requirements on the criterion-referenced 8th grade state test in reading (used in making decisions about grade promotion), and on the norm-referenced 8th grade administration of the ITBS in reading. Students not identified to participate in the reading intervention could elect to take a reading course or enrolled in an exploratory foreign-language course.

Prior to this study, HCPS had never explored whether participating in a supplementary reading course in middle school actually improved students' literacy outcomes. The program's perceived low cost and the knowledge of the importance of literacy skills were sufficient justification for offering the supplementary reading course. The potential effectiveness of the HSPC reading intervention has implications beyond the district's own interests. Understanding how and whether similar literacy interventions improve student outcomes is important for making both local and state-level decisions regarding literacy instruction. In particular, there are a growing number of computer-based forms of literacy interventions that schools may choose to purchase and implement, some of which have been shown to produce learning gains (Rouse & Krueger, 2004). By knowing the impact of a district-developed, teacher-delivered literacy intervention, schools and districts will have some means for deciding whether existing human capital can produce results comparable to those possible through programs available for purchase.

3. Research Design:

3.1 Site, Dataset, and Sample:

My study is situated in a large (over 80,000 students Pre-K through grade 12) suburban school district in the southeastern United States. My data are drawn from a comprehensive administrative data set covering all students enrolled in the district during the school years of 1999-2000 through 2009-2010. This dataset contains test scores and enrollment data for students in middle school and follows them longitudinally within the district into high school. The data include course enrollment data, mandated state accountability test scores in reading, literature and mathematics, ITBS scores from grades five and eight, high school end-of-course examinations, and SAT scores. HCPS resembles the changing demographic structure of many suburban settings, with substantial racial and socioeconomic variation. The student population is 43% white, 36% African American, 10% Latino/a, 8% Asian, and 3% other race. Forty-three percent of students receive free- or reduced-price lunch, 8% are English-Language Learners, and 18% have an Individualized Education Program.

The district is comprised of schools classified as traditional, charter, converted charter, and alternative schools. Both traditional and conversion charter schools are subject to district policies while alternative and other charters are exempt. I restrict my analysis to students who go through one of the 20 traditional or conversion charter middle schools that serve HCPS students in grades 6 through 8. My sample includes all students from the seven cohorts who took the 5^{th} grade ITBS reading test in the school years 2002-2003 through 2008-2009. The students I retain in my sample are representative of the students in both the traditional and conversion charter schools.

3.2 Measures

My academic outcomes of interest are state test scores in reading in grades six through eight (*READ6*, *READ7*, *READ8*). For each of these outcomes I wish to estimate the effect of participating in the supplementary reading intervention which I measure as the number of semesters of enrollment in the supplementary course (*SUPREAD*). This variable has a minimum at zero for students who enroll in no semesters of the supplementary reading course, and a maximum of six for those who participate for all six semesters of their three years in middle school. Because student eligibility for the reading intervention is conditional on their 5^{th} grade ITBS percentile score, I also include this measure (*ITBS5*) as the forcing variable – or the variable used to dictate the offer of intervention - , as well as a binary indicator (*ELIG*) equal to one if a student scored at or below the 60^{th} percentile on the 5^{th} grade ITBS, and is therefore eligible to receive the supplementary reading instruction. To improve the precision of my estimates I also include a vector of student covariates, $\boldsymbol{X_{ij}}$. This vector includes student state test scores in reading and mathematics from 5^{th} grade (*READ5*, *MATH5*), as well as indicators for sex, race, free and reduced lunch status, special education status, and English Language Learner status. Despite designing the literacy intervention as a district-level policy, the application of the policy may vary based on the individual behavior of school administrators. For instance, individual schools may be more or less stringent in their requirement that students who are eligible for supplementary reading take-up the treatment. Likewise, adherence to a long-standing policy may experience drift over time. To control for potential differences in the implementation of the literacy intervention across schools and cohorts of students, I additionally include fixed-effects for school (γ_j)and cohort (γ_c).

3.3 Statistical Model:

I employ a two-stage least squares (2SLS) approach to estimate the causal effect of participating in an additional semester of supplementary reading while in middle school. Because take up of the supplementary reading instruction is potentially endogenous, I use the random offer of eligibility in the program, generated by a student's position relative to the 60^{th}-percentile cutoff, to isolate the exogenous variation in participation. In my first stage, I fit the following statistical model:

$$SUPREAD_{ijgs} = \beta_0 + \beta_1(ITBS5_{ijs} - c) + \beta_2 ELIG_{ijs} + \beta_3\big((ITBS5_{ijs} - c) \times ELIG_{ijs}\big)$$
$$+\beta_4 \boldsymbol{X_{ijgs}} + \gamma_j + \gamma_s + \varepsilon_{ij} \qquad (1)$$

I model the number of semesters that a student is enrolled in the supplementary reading course ($SUPREAD_{ijgs}$), for student i in school j in grade g and cohort s. I estimate this participation variable as a function of students' 5^{th}-grade ITBS score re-centered at the 60^{th} percentile cutoff score ($(ITBS5_{ijs} - c)$), the exogenous instrument, $ELIG_{ijs}$, the vector of student-level covariates ($\boldsymbol{X_{ijgs}}$), and fixed effects for school and cohort. To allow the relationship between supplementary reading score and 5th grade ITBS score to vary on either side of the exogenous cutoff, I also include the interaction term $((ITBS5_{ijs} - c) \times ELIG_{ijs})$. Following the example of Dee (2004) and the suggestion of Murnane and Willett (2011), I also interact pretreatment indicators for whether a student is black and whether they had an individualized educational program (IEP) with the indicator for supplementary reading eligibility, to create two additional instrumental variables $((AFAM \times ELIG_{ijs}\ ,\ IEP \times ELIG_{ijs}\ )$ which I include in my preferred model specification. I model the error structure to account for the clustering of students within schools and use Huber-White adjusted standard errors to account for potential deviations from normality assumptions.

In the second stage of my estimation, I use the following statistical model:

$$Y_{ijgs} = \theta_0 + \theta_1(ITBS5_{ijs} - c) + \theta_2 SUPREAD_{ijgs} + \theta_3((ITBS5_{ijs} - c) \times ELIG_{ijs})$$
$$+\theta_4 \boldsymbol{X_{ij}} + \gamma_j + \gamma_s + \mu_{ij} \qquad (2)$$

In this model I estimate Y_{ijgs}, a generic placeholder for my several outcomes of interest, as a function of the re-centered 5th-grade ITBS score, student exposure to the supplementary reading course, as well as a vector of student covariates and fixed effects for school and cohort. As in my first stage, I also allow the slope of relationship between ITBS score and the outcome to vary on either side of the cutoff. Importantly, because the take-up of supplementary reading is endogenous, I use the fitted values of $SUPREAD_{ijgs}$ from my first-stage model to isolate that the variation in this treatment that is exogenous, to estimate the causal effect of an additional semester of supplemental reading on the student outcome, Y_{ijgs}. As in the first stage, I also cluster standard errors at the school level, and apply a Huber-White adjustment for violations of homoskedasticity assumptions.

The coefficient that answers my research question is θ_2, which represents the causal effect of experiencing an additional semester of the literacy intervention for a student who fell just shy of the required passing score on the 5^{th}-grade ITBS compared to students who scored just above this score threshold on the 5^{th} grade test.

Following the suggestion of Imbens & Lemiux (2008), I model the relationship between 5^{th} grade ITBS score and the outcome in each stage as “locally linear”. I chose an optimal bandwidth according to their suggestion of minimizing the mean square error of models fit across analytic windows of varying width. The results of this process suggest a symmetric window of 10 percentile points for fitting all models. To verify the robustness of my results, I also fit these models across multiple bandwidths.

3.4 Verifying Assumptions for Regression-Discontinuity

All regression discontinuities have the potential to be undermined by failures of important assumptions, most notably discontinuities in other variables, or discontinuities in the forcing variables at unexpected locations. In my study, it is crucial to establish that my findings are not driven by discontinuities in control variables, that the instrument is working the way that it was intended, and that the only discontinuity in student exposure to the treatment is at the point of the cutoff designated by the school district.

To verify the soundness of my regression discontinuity design, I employ several checks on my model. Following the example of McCrary (2008), I first investigated whether any evidence existed to suggest manipulation of the forcing variable.[1] Manipulation of student’s position relative to the district-defined cutoff is highly implausible. For instance, students can not manipulate their position relative to the cutoff since the percentile rank is generated from a nationally-normed sample. And district administrators may likewise not manipulate the eligibility of students with respect to the exogenously-chosen cutoff, which lessens the potential threat to the RD design. Despite absence of a real threat to the validity of my forcing variable, in Figure 1, I present the empirical distribution of the forcing variable, 5th-grade ITBS score, to illustrate that it is smooth across the whole distribution, and in particular around the discontinuity used for assigning students to the supplementary reading (denoted by the vertical red line). The empirical distribution that I present in Figure 1 does not show evidence of particularly high densities of individuals on either side of the cutoff which might suggest evidence of manipulation.

To further attest to the validity of the RD approach, I display in Figure 2 evidence of a discontinuity in exposure to treatment at the exogenously-determined cutoff in ITBS score. Each of the three graphs depicts evidence of a modest discontinuity in the number of semesters of the reading support that students on either side of the eligibility cutoff received. The gap shown between the trends at the cutoff score suggests that exposure to treatment does change discontinuously at this ITBS score. The smaller magnitude in the discontinuity motivated my choice (above) to use multiple instruments in the first stage of my estimation.

As a final check on the appropriateness of my RD approach, I examined the distributions of covariates that I used as control variables to ensure that no other discontinuities existed which might have generated my results. To examine potential discontinuities, I fit the model: $W_{ij} = \alpha_0 + \alpha_1 ITBS_{ij} + \alpha_2 ELIG_{ij} + \alpha_3 ITBSxELIG_{ij} + \delta_{ij}$. I fit this model across multiple bandwidths to confirm that, near the cutoff, there are no discontinuities in the covariates and that students who are eligible for assignment to supplementary reading are equal in expectation to those who are not eligible based on their 5th grade ITBS score. Evidence that this assumption is upheld is demonstrated by my failing to reject the null hypothesis that α_2 is equal 0 for each of the covariates. I display the results of this specification check in Table 1. These results suggest that there is no evidence of discontinuities in the conditional distributions of these covariates in any of the eight panels, which suggests that there is no reason to believe that any effects found in my regression analyses would be driven by discontinuities in these other variables.

4. Results:

I find evidence that the reading intervention appears to boost reading performance as measured by both the state standardized test and the percentile score of the 8th grade ITBS. The effect sizes for an additional semester of reading get smaller across successive grades, and become statistically insignificant by 8th grade.

4.1 Reduced-form OLS results

In Table 2 I present my reduced-form estimates of the effect of supplementary reading exposure on subsequent student test scores. To fit the reduced-form models, I used all available data in my sample and regressed the outcome on the forcing variable, 5th-grade ITBS scores, the measure of exposure to supplementary reading, demographic controls, and fixed-effects for cohort and school. To avoid having to make strong assumptions about the functional form of the relationship between my forcing variables and the outcomes of interest, I allow the relationship between the forcing variable and the outcome to be a flexible polynomial and include terms up to a quartic in 5th-grade ITBS scores.[2] For the purposes of illustration, and I include the reduced-form estimates for two of my outcomes of interest, standardized reading scores in 6th and 8th

[2] I also modeled the relationship as linear, quadratic, and cubic with no substantive change in the results

grade. The results were similar for the other outcome. In the first row of each column of Table 2, I present the respective reduced-form estimates for 6^{th}- grade state reading scores, and 8^{th}-grade ITBS percentile. The coefficients in the first row represent the estimated effect of receiving the offer of a spot in a supplementary reading course on the respective outcomes. I interpret the coefficient in row one of column (1), 0.03, as suggesting that receiving the random offer to participate in supplementary reading in 6^{th} grade, on average, is associated with a three-hundredths of a standard deviation increase in scores on the 6^{th}-grade state reading test, though this relationship is not statistically significant. In fact, the coefficients on *ELIG* in each of these two reduced-form models is not significant, and therefore these estimates suggest that the offer of supplementary reading alone has no effect on these later measures of reading performance.

My reduced-form estimates constitute the intent-to-treat (ITT) estimates of the offer of eligibility for supplementary reading. If take up of the supplementary reading program was perfectly predicted by eligibility for the program these estimates would be the estimates of greatest policy interest, since they apply to the whole distribution of reading ability. However, because take-up of the treatment, conditional on eligibility, is not perfect I contrast my ITT estimates with the instrumental-variable estimates from my regression-discontinuity analysis below, and emphasize in the discussion the implications this has for research and practice. These IV estimates constitute the treatment-on-the-treated (TOT) effects of supplementary reading, which are of arguably larger importance in answering the question of whether those who experienced the treatment actually benefited from it.

4.2 TOT Estimates of Supplementary Reading

I find that exposure to an additional semester of supplementary reading has positive and statistically-significant effects on student test scores in 6th and 7th grade, with the marginal effects fading out by 8th grade. In column (1) of Table 3 the coefficient of 0.265 (p=0.03) in the first row of column (1) suggests that for 6th graders, experiencing an additional semester of supplementary reading increases student's 6th-grade state reading test scores by just over a quarter of a standard deviation. If the effect of each semester of exposure is equal, then the maximum positive effect of participating in supplementary reading for both semesters of 6th grade is just over 0.5 standard deviations. In 7th grade I estimate the effect of an additional semester of supplementary reading on 7th-grade state reading scores. The coefficient of 0.103 (p=0.03) suggests that an additional semester of supplementary reading increases reading test scores in 7th-grade by just over a tenth of standard deviation. If the effect of the intervention is additive and linear, then the maxmimum exposure (all four semesters) to the reading intervention by the end of 7th grade is about 0.4 standard deviations. My estimate of the effect of an additional semester of supplementary reading on 8th-grade state reading test is not statistically-significant, however, my point estimate for the effect of one semester suggests that the cumulative effect of maximum exposure to supplementary reading (six semesters) may be as high as 0.12 standard deviations. Notably, I report an effect of 2.4 percentile points on the national percentile ranking on the 8th-grade ITBS as evidence of a statistically-significant relationship between the intervention and 8th-grade ITBS percentile.

For all four outcomes the corresponding first-stage results provide confidence in the strength of my instrumental variables. As I present in row one of Panel B in Table 3, the statistics for the omnibus F-test in the first stage well exceed the conventionally-accepted measure of adequate instruments of F equal to ten or more.

As a further presentation of these results I exhibit simultaneously in Figure 4 the discontinuity in exposure to the supplementary reading treatment and its subsequent impact on student test scores. Panels A and B in Figure 4, illustrate both the treatment and outcome trends for 6th-grade reading scores and 8th-grade ITBS percentile, respectively. In each of these two graphs I present the y-axis on the left-hand side as the outcome of interest, and the y-axis on the right-hand side as the measure of total semesters of exposure to treatment. The x-axis in both graphs corresponds to the re-centered 5th-grade ITBS score, and I include a dashed reference line at the point of the exogenously imposed cutoff in 5th-grade ITBS score. The trends corresponding to the left-hand access show the modest effect on the outcome of an additional semester of exposure to supplementary reading, while the trends corresponding to the right-hand axis show the discontinuity in the exposure to the treatment.

5. Discussion:

5.1 Threats to Validity

There are several potential threats to the validity of my findings, some of which are methodological, and others that are related to program implementation. The chief methodological threats to the validity of my findings are that they may be sensitive to my choice of bandwidth, and that a linear specification of the relationship between the forcing variable and my outcomes may not be appropriate. My analyses could also be threatened by selective attrition from the treatment group over time. I consider each of these threats below, beginning with the methodological threats.

In Table 4, I display the results of fitting models across multiple bandwidths, using both a linear and cubic specification of the forcing variable. Panel A contains estimates where 6th-grade state reading scores are the outcome, Panel B presents estimates where 8th-grade ITBS percentile is the outcome. For each outcome, I present a pair of columns for a given bandwidth, where in the even columns I have used a linear specification of the forcing variable, and in the odd columns I have included up to a cubic term in the forcing variable. For instance, the value in row one, column one of Panel A estimates of the effect of an additional semester of supplementary reading on 6^{th}-grade reading scores using a symmetric bandwidth of 5 percentile points around the cutoff score in the forcing variable. The parameter estimate 0.316 suggests that an additional semester of supplementary reading is associated, on average, with a three-tenths standard deviation increase in 6^{th}-grade reading score however this relationship is not statistically-significant. In this same panel and row, but in column (2), I present the analogous estimate of the effect of supplementary reading, but with my up-to-a-cubic specification of the forcing variable. The relationship here is also not statistically-significant.

What is striking, and most important, about the results in Table 4, is that the parameter estimates are relatively stable across choices of bandwidth, and across model specification. Also important is that the relationships exhibited in models where the bandwidth is ten percentile points or greater are consistently statistically significant. The statistical significance and stability of these relationships across the two outcomes presented in Table 4 suggest that these effects are not sensitive to bandwidth choice.

The results in Table 4 also appear to address the potential threat of a non-linear relationship between the forcing variable and my outcomes. To further counter this threat, Table 4 presents the results of fitting several specifications of the forcing variable at a bandwidth of ten percentile points.[3] As with other tables, Table 5 is laid out as two panels that differ only in the outcome variable used. In both panels, columns represent estimates of the effect of an additional

[3] The results present in Table 4 are illustrative of the insensitivity of my findings to non-linear model specifications, and generalize to other choices of bandwidth. For simplicity I present only these results here, but can furnish more upon request.

semester of supplementary reading for different model specifications. Column (1) presents estimates using a linear specification of the forcing variable, column (2) includes up to a quadratic term, in (3) I include up to a cubic, and in (4) I include up to a quartic term in the forcing variable. Though my parameter estimates for the effect of supplementary reading on each outcome are not identical across specifications they do not differ widely – in fact, the linear specification provides a lower bound on point estimates - and the statistical significance of the relationship they represent is also stable. The robustness of my findings with respect to bandwidth choice and functional form of the relationship between the outcomes and the forcing variable, provide evidence that these potential concerns do not threaten the validity of my inferences.

A substantive threat to the validity of my findings concerns the attrition of students from the treatment to the control groups across years. While the school district's policy is designed to keep eligible students who enroll in supplementary reading in 6th grade in the course across all three years of middle school, district officials have stated that parents and administrators sometimes agree to allow students to not participate or to stop participating after a period of time. The chief threat posed by the loss of students from the sample comes from whether the rate of attrition differs across treatment and control groups. Disproportionate attrition from either treatment or control groups undermines the assumptions of randomly-equivalent groups and could invalidate the inference I would make based on my estimate of the treatment effect

To respond to the threat of attrition, I analyze my sample attrition in a manner consistent with the evidence standards for regression-discontinuity designs established by the What Works Clearninghouse (WWC) (Schochet, Cook, Deke, Imbens, Lockwood, Porter, & Smith, 2010). My analyses focus on three analytical samples; those cohorts of students who are observed between 5th and 8th grade, those observed 5th through 7th, and those observed in5th and 6th grade. For the purposes of analyzing attrition, I define the students who scored within ten points of the cutoff score on the ITBS-Reading in 5th grade as the focal group for each of my three analytic cohorts. I consider, in turn, the attrition of both "treatment" (those eligible for the literacy instruction) and "control" (those not eligible) from 5th grade through the last year that they are observed. As suggested by the WWC, differential attrition from the treatment and control groups would undermine the validity of my findings since such attrition could bias my estimates.

I find no evidence of differential attrition from my treatment and control groups in any of the three analytic samples I consider. In Table 6, I display the total number of students defining the sample based on their 5th-grade scores, the division of this sample across treatment and control and the rates of attrition from both treatment and control for each sample. For instance, in column one I present the analysis for students who I include in my analyses of 6th-grade outcomes. There are 6,689 students in this sample in 5th grade with only 332 (about 5% of the original sample) leaving the initial sample by 6th grade. Among those who attrite, 51% were in the treatment group with the remaining in control. The rate and distribution of attrition is comparable in 7th and 8th grades with 11 and 16 percent leaving their respective samples, and just over half of that attrition coming from the treatment group. The slight differential in the rate of attrition (more from treatment than control) is not sufficient to undermine the quality of the inference that I can make from these data.

5.2 *Interpreting Findings*

My findings have several implications, both clear and suggestive, for how HCPS and other districts could consider using their supplementary reading programs in the future. The clearest finding in my study is that there is a boost to student performance on state reading assessments for those students who participate in supplementary reading. I estimated the effect of an additional semester of supplementary reading to be about 0.2 standard deviations per semester in 6th grade, suggesting that students who participated for both semesters of 6th grade could score up to half a standard deviation better on the 6th-grade reading test than those who took no supplementary reading. While the marginal effect of supplementary reading may not be strictly additive, if effects ranged between 0.3 and 0.5 standard deviations for a full year of participation they would be considered large by social-science standards.

Despite the moderate-to-large effects of supplementary reading on 6th-grade reading scores the effect the effects of supplementary reading will likely not be the same across the subsequent two years of middle school. For instance, in 7th grade the benefit of an additional semester of supplementary reading is one-tenth of a standard deviation, suggesting that the upper bound on the effect of four semesters of reading would be about 0.4 SD compared to experiencing zero semesters of supplementary reading. In 8th grade the point estimates of the effect of supplementary reading on state reading test scores, and the implied cumulative potential benefit were even smaller (0.02 and 0.12 SD, respectively) but the relationship between the intervention and the outcome was no longer statistically significant.

One explanation for the decline in the marginal and cumulative effect of the supplementary reading program may relate to students who drop out of the intervention – though are retained in the sample - over time. In Table 7, I display the cumulative exposure to supplementary reading for the students in my sample. It is notable that in 6th grade that roughly 75 percent of those students who are within the analytic window and eligible for supplementary reading take up the offer of both semesters, though by 7th grade those receiving maximum exposure has fallen to fewer than half of eligible students. If the students who remain in the full-exposure group are those that were lower performing on the 6th-grade examination, then by design those remaining in treatment are of lower ability, and those who left treatment are now counted among the control group. This switching behavior is likely to suppress both the magnitude and significance of any marginal differences in 7th or 8th grade.

There are also several other potential explanations for the smaller and insignificant effect in eighth grade. First, curricular changes in grades 7 and 8, and differences in the skill content tested on the state standardized tests may also alter the extent to which I could observe a statistically-significant marginal effect of participating in supplementary reading. Alternatively, the difference between having three semesters of additional reading instruction or four semesters, compared to someone with zero may not register as significant if the content that is tested is not well-aligned with the skills that are being taught in the additional semester. And finally, the absence of a statistically-significant effect may also be explained by a simple plateauing of effect. That is, there are likely diminishing returns to an additional semester of reading.

One concern that these apparent positive effects might raise, is that supplementary-reading teachers in emphasize test preparation exercises as a way to produce the positive results in 6th and 7th grade. The possibility of coaching to tests, or "score inflation" is a phenomenon noted in other scholarly work, and a possibility that schools and districts would do well to make attempts to mitigate (Hamilton & Koretz, 2002; Jennings & Bearak, 2010; Koretz, 2003, 2005). As an informal check on whether score inflation is the likely cause of the positive effects, I used an audit test, in the form of the 8th-grade ITBS reading test, as one of my outcomes. In Table 4, the coefficient on the dosage variable for 8th-grade ITBS percentile rank is positive. The sign and magnitude of these coefficients is consistent with real learning (i.e. – positive effects on a generalized test of literacy standards).[4]

A limitation on the interpretability of my findings is posed by their external validity. By construction, the effects I estimated in my study apply only to those students who were just below the cutoff and eligible for the treatment, in comparison to those who were just above and not eligible. Though these treatment-on-the-treated estimates are helpful, it does not answer the ITT question of the average effect of supplementary reading for all those students who were eligible and participated. Importantly, the reduced-form estimates that I presented suggest that the ITT effects may be smaller, and that the relationship between supplementary reading and later test scores may not be statistically-significant in my sample. If only ITT estimates were used to measure the effect of this supplementary reading program it may have been modified or cancelled based on those null findings.

5.3 Policy Alternatives

Beyond the apparent academic benefits of providing a supplementary reading course, it may also have other attractive qualities such as cost neutrality. For example, it may be no more expensive for HCPS to offer supplementary reading course than to provide no such course. The zero net cost difference is likely to arise from the fact that, by not taking supplementary reading students would otherwise take an elective course in its place, often a foreign-language course. If true, the total number of teachers employed by the school district is likely the same whether they offer or do not offer supplementary reading. In addition, there is no reason to suspect that the cost of course materials for these two types of courses would not be comparable. An implicit cost of supplying this supplementary reading class is the opportunity cost to the student of being

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[4] I also performed this check using 8^{th}-grade ITBS test score, rather than percentile rank, as the outcome. The coefficient of interest in this fitting was positive, though not statistically significant. Despite the insignificance, the sign and magnitude in both of these instances seems indicative of real learning.

enrolled in the reading class rather than a course of their choosing. For the district, however, they must examine whether the cost of providing the reading teacher is higher relative to the foreign-language classes. Teacher costs could differ if teachers of supplementary reading have a higher probability of having a master's degree than their counterparts in foreign language, or other plausible alternative to supplementary reading.

Supplementary reading may also appear attractive when compared to proven alternatives to generating positive impacts on reading outcomes. A review of the evidence provided through the What Works Clearinghouse (WWC) revealed that of the ten experimental or quasi-experimental programs reviewed that promote effective adolescent literacy interventions, six of them are copyrighted or registered trademarks, and one other is available through a major educational publishing company (WWC, 2012, see also Rouse & Krueger, 2004). In each case, these copyrighted programs are available for purchase to school districts that wish to implement them. These purchasable programs may be particularly enticing for schools operating within a tier of the school-improvement cycle enforced by states when schools fail to meet aspects of the NLCB adequate yearly progress (AYP) provision (NCLB, 2002). However, districts may face this increased incentive to purchase programs at a time when they are already financially constrained. In the case of computer-based learning, these programs require purchases of site licenses, professional development, and both infrastructure (computers and networks) as well as technological support (likely some fraction of one IT staff member). Such programs result in costs above and beyond those associated with hiring the classroom teacher to monitor and implement them. By comparison, one reading teacher, teaching five classes of 20 students each can reach one hundred students.

Another alternative, curricular reform, may also be comparatively expensive. Purchase of new materials, professional development, and (at least in the short run) the potential loss of efficiencies in instruction as teachers learn a new system, all contribute to the increased cost of choosing curricular reform as a means to improve literacy outcomes. Though the conclusions of cost deliberations will vary by district, if the average annual cost of a reading teacher is $70,000, it may very well prove to be the most flexible and affordable option available. Moreover, if schools can leverage their existing human capital, rather than purchasing alternative programs, they may have greater flexibility to adapt over time, and be poised to better address the needs of their students.

5.4 Conclusion

In an era of high-stakes testing and school accountability, schools care as much now as at any time in the past about improving the literacy skills of their students. For the students, there is nothing more important to their long-term success than their ability to participate in their lives, and the economy, as fully-literate individuals. My findings suggest that a research-based supplementary reading course in middle school can boost short-term measures of student's reading comprehension. These findings are particularly impressive in that they were achieved by deploying this "double dose" strategy across twenty individual middle schools, and taught by more than twenty individual teachers. The potential for heterogeneity in the delivery of this intervention made it doubtful that any effects might be found. And even if the benefits of the course are limited to those students who were just below the cutoff used for assigning students to the course, there is likely sufficient evidence to warrant its continuation. These findings are encouraging, and suggest that adopting assignment rules when deciding who to assign to support courses could be fruitful in other school districts (Schlotter, Schwerdt, &Woessmann, 2011).

Such rules allow for the estimation of causal estimates and can reduce the continuation of ineffective program, and help districts develop or switch to interventions that have been proven to be effective. These results may also encourage districts to modify either their assignment rules, or their curriculum. Changing the threshold used to make assignment to supplementary courses allows for the examination of the effectiveness of the program at different margins. Analogously, modifying curricula while maintaining the existing cutoffs can provide evidence for whether program effects can be enhanced to induce larger effects.

Choosing cutoff scores to assign students to academic interventions is not without risk, however, and the determination of whether and where to apply these rules warrants careful consideration. Though there are clear merits to the ability to assess the effectiveness of interventions that are deployed in a way that allows quasi-experimental evaluation, the potential for rationing of inputs could have deleterious effects. Cutoff scores must be chosen, and interventions designed, in such a way as to be consistent with the needs of the population it is intended to impact. In HCPS, all students scoring below the 60^{th} percentile were eligible for supplementary reading however, this evaluation only addresses the impact of those who were eligible but near the cutoff. Other means of evaluation, and perhaps interventions tailored to learners who scored in lower percentiles, is necessary if we are to achieve equitable outcomes in education. It bears further note that simply because a program is successful on one margin, it need not necessarily maintain its impact when extended to students on other margins and of different abilities.

School and district officials may find it valuable to use my results to impact their own decisions about policy and practice. As schools and districts make decisions about how to allocate funding for literacy programs, they may find it advantageous to develop and deploy a second dose of literacy instruction that resembles the structure used in HCPS. This double dose approach is appealing for several reasons. First, there is a well-defined literature about what practices are effective in literacy instruction, and the HCPS example provides a concrete example of how this may be done. Second, deploying the intervention using district employees allows for flexibility in scheduling teachers and classes within and across schools and school years. Third, teachers that are credentialed to teach a literacy class are likely equally well-qualified to teach more traditional language arts and English curricula which provides additional flexibility. Fourth, a double dose approach is likely to have has strong face validity among stakeholders in the community. Most groups will find it hard to argue with the idea of using research-proven instruction to supplement traditional curricula, as a way to bolster literacy skills. And finally and most importantly, I have illustrated that this approach can be effective. While other literacy interventions have produced mixed results, there is now credible evidence that this approach to intervening in contexts like HCPS can produce the desired results.

Further research into “double dose” literacy interventions like the one in HCPS is certainly warranted. Since our ultimate concern is with long-term outcomes that we believe are associated with measures of adolescent literacy, future research should collect data across more years so that we may learn whether there are longer-term impacts on SAT scores, high school graduation, or decisions to apply to or attend college. Establishing the effectiveness of similar supplementary literacy coursework should be pursued in other research contexts as well. While the HCPS context is representative of many large changing suburban districts, there may be factors associated with HCPS that could limit the generalizability of my findings.

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Tables & Figures:

Table 1. Testing the assumption of equality in expectation: Estimates of differences in background variables at the point of the discontinuity

Dep. Variable:	Prior Reading	Prior Math	Black	Asian	Latino	Female	ELL	FRPL	SWD
	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)
ELIG	0.01	0.00113	0.0102	0.00599	0.00941	0.00166	0.00148	0.0104	0.00419
	(0.032)	(0.0424)	(0.0338)	(0.0111)	(0.0108)	(0.0229)	(0.0111)	(0.0233)	(0.0213)
ITBS	0.0278***	0.0251***	-0.00639*	0.00185	-0.00318~	-0.00157	-0.00147	-0.0114***	-0.00270~
	(0.00174)	(0.00321)	(0.00263)	(0.00141)	(0.00163)	(0.00272)	(0.00130)	(0.00243)	(0.00140)
Intercept	-0.0511**	-0.0534	0.380***	0.0704**	0.0920***	0.523***	0.0652*	0.433***	0.159***
	(0.0177)	(0.0380)	(0.0788)	(0.0204)	(0.0174)	(0.0158)	(0.0252)	(0.0779)	(0.0171)
N	5480	5484	6412	6412	6412	6412	6412	6412	6412

Note: Standard errors in parentheses, ~ p<0.10 * p<0.05 ** p<0.01 *** p<0.001. All models fit using a bandwidth of 10 percentile points. Models are specified to allow the slope to vary on both sides of the discontinuity.

Table 2. Reduced-form estimates for effect of supplementary reading on 6th-grade reading and 8th-grade ITBS percentile

Outcome:	6th Grade Reading (1)	8th-Grade ITBS %-tile (2)
Additional Semester of Reading	0.0343	0.453
	(0.0384)	(1.152)
ITBS	0.0084	0.559~
	(0.0096)	(0.286)
Year Fixed Effects	Y	Y
School Fixed Effects	Y	Y
Non-linear Forcing Variable	Y	Y
N	27256	15228
R-sq	0.648	0.789

Note: Standard errors in parentheses, ~ p<0.10 * p<0.05 ** p<0.01 *** p<0.001. All models fit using a bandwidth choice of 10 percentile points on either side of the cut score in 5th-grade ITBS percentile. Models are specified to allow the slope to vary on both sides of the discontinuity.

Table 3. Fitted estimates of the effects of supplementary reading on subsequent test scores

Panel A: Second Stage: Marginal Effect of Additional Semester of SUPREAD

Dependent Variable:	6th-Reading (1)	7th-Reading (2)	8th-Reading (3)	ITBS - 8th (4)
Additional Semester of Reading	0.265*	0.103*	0.0263	2.422*
	(0.133)	(0.0494)	(0.0442)	(1.055)
Year Fixed Effects	Y	Y	Y	Y
School Fixed Effects	Y	Y	Y	Y
Non-linear Forcing Variable	N	N	N	N

Panel B: First stage(Dependent Variable: Supplementary Reading Exposure)

F-Statistic	52.75	55.74	42.73	42.73
N	5380	4100	3074	3074

Note: Standard errors in parentheses, ~ p<0.10 * p<0.05 ** p<0.01 *** p<0.001. All models fit using a bandwidth choice of 10 percentile points on either side of the cut score in 5th-grade ITBS percentile. Models are specified to allow the slope to vary on both sides of the discontinuity. The coefficients reported across columns are not directly comparable because the treatment is measured as total semesters of exposure to the reading intervention. Therefore, the marginal effect of an additional semester is likely to decrease In later years as students have more semesters to participate.

Table 4. Fitted estimates of the effects of receiving reading intervention in 6th grade across multiple choices of bandwidth

Panel A: Multiple Bandwidths for 6th-Grade Reading

Bandwidth:	5 Percentile Points		10 Percentile Points		15 Percentile Points		20 Percentile Points	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Addit. Semester of Reading	0.316	0.331	0.269~	0.388*	0.235**	0.381**	0.263**	0.395**
	(0.198)	(0.234)	(0.148)	(0.190)	(0.0853)	(0.136)	(0.0834)	(0.132)
Year Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
School Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Non-linear Forcing Var. (cubic)	N	Y	N	Y	N	Y	N	Y
N	2804	2804	5380	5380	7262	7262	10288	10288

Panel B: Multiple Bandwidths for 8th-Grade ITBS Percentile

Bandwidth:	5 Percentile Points		10 Percentile Points		15 Percentile Points		20 Percentile Points	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Addit. Semester of Reading	1.733	2.410	2.422*	2.150~	1.073	1.998~	1.184*	2.811**
	(1.847)	(1.951)	(1.055)	(1.218)	(0.814)	(1.142)	(0.537)	(0.986)
Year Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
School Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Non-linear Forcing Var. (cubic)	N	Y	N	Y	N	Y	N	Y
N	1578	1578	3041	3041	4143	4143	5816	5816

Note: Standard errors in parentheses, ~ p<0.10 * p<0.05 ** p<0.01 *** p<0.001.

Table 5. Testing the sensitivity of the effects of supplementary reading to non-linear specifications of the forcing variable

Panel A: Dependent Variable, 6th-Grade Reading				
Order of Polynomial:	Linear	Quadratic	Cubic	Quartic
	(1)	(2)	(3)	(4)
Additional Semester of Reading	0.265~	0.416~	0.395*	0.487~
	(0.146)	(0.251)	(0.192)	(0.280)
N	5380	5380	5380	5380
Panel B: Dependent Variable, 8th-Grade ITBS Percentile				
Additional Semester of Reading	2.422*	2.286~	2.150~	4.074*
	(1.055)	(1.371)	(1.218)	(1.608)
N	3041	3041	3041	3041

Note: Standard errors in parentheses, ~ p<0.10   * p<0.05   ** p<0.01   *** p<0.001. All models fit using a bandwidth choice of 10 percentile points on either side of the cut score in 5th-grade ITBS percentile. Models are specified to allow the slope to vary on both sides of the discontinuity. All models include fixed effects for schools and cohorts.

Table 6. *Attrition from analytic sample from point of identification for treatment eligibility in 5th grade through the grade of analysis*

	6th-Grade Sample	7th-Grade Sample	8th-Grade Sample
	(1)	(2)	(3)
Initial Treatment	4,193	3,588	2,910
Iniital Control	2,164	1,446	944
Treatment Units Lost	170	362	394
Control Units Lost	162	317	357
% of Attriters - Treatment	51.2%	53.3%	52.5%
% of Attriters - Control	48.8%	46.7%	47.5%

Table 7. Distributions of Semesters of Exposure to Supplementary Reading for students above and below the ITBS cutoff in each grade sample

Panel A: Enrollment

	6th Grade		7th Grade		8th Grade	
	Below	Above	Below	Above	Below	Above
Sem. in Supp. Reading	(1)	(2)	(3)	(4)	(5)	(6)
0	22.4%	44.7%	17.9%	38.7%	15.4%	31.5%
1	3.0%	2.7%	2.3%	2.2%	1.5%	1.9%
2	74.5%	52.6%	28.4%	36.1%	23.0%	34.2%
3	-	-	5.2%	3.9%	3.2%	2.5%
4	-	-	46.1%	19.1%	8.6%	8.5%
5	-	-	-	-	3.7%	3.4%
6	-	-	-	-	44.6%	18.0%
Sample Size	3036	3321	2363	2642	1841	2093

Panel B: Average 6th-Grade Reading Score by Semesters of Participation

	6th Grade	7th Grade	8th Grade
Sem. in Supp. Reading	(1)	(2)	(3)
0	-0.01	0.03	0.09
2	-0.11	0.13	0.23
4	-	-0.23	-0.16
6	-	-	-0.17

Figure 1: Kernel density plot of the recentered ITBS score in 5th grade.

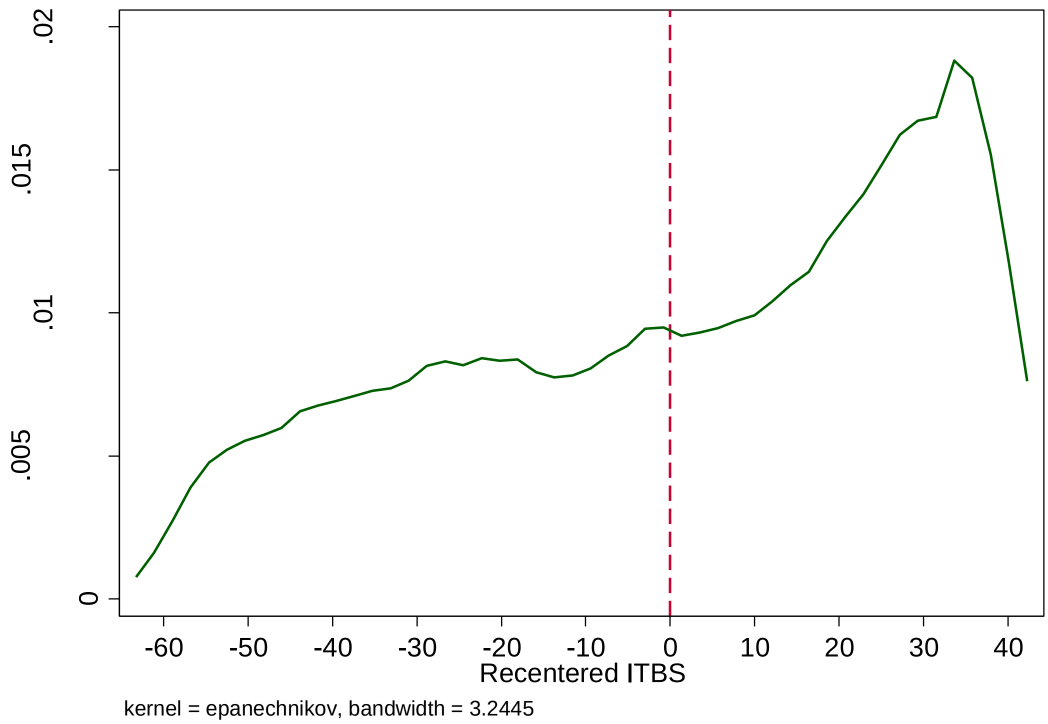


Figure 2: Evidence of discontinuity in treatment exposure in 6th, 7th, and 8th-grade samples

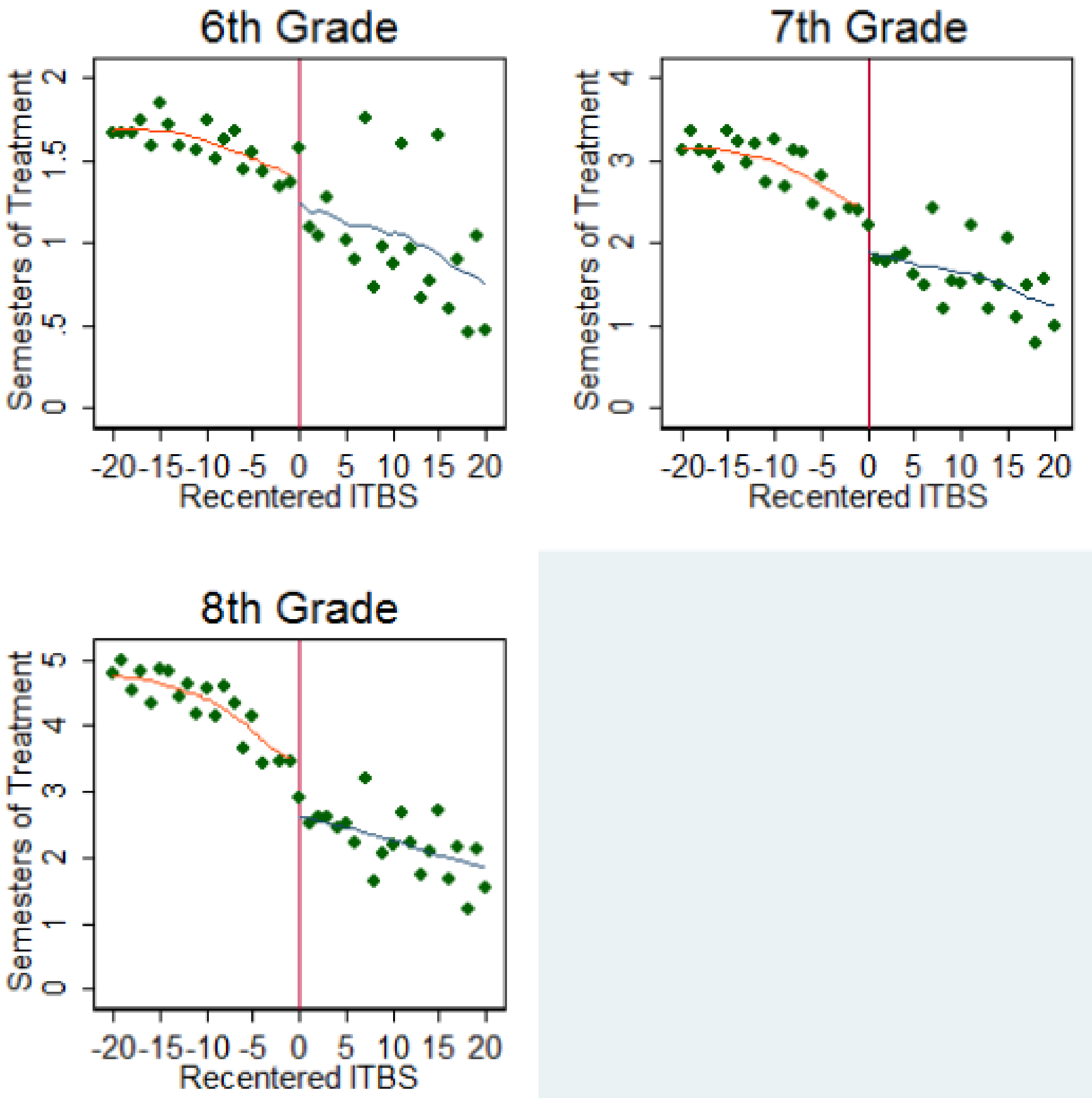
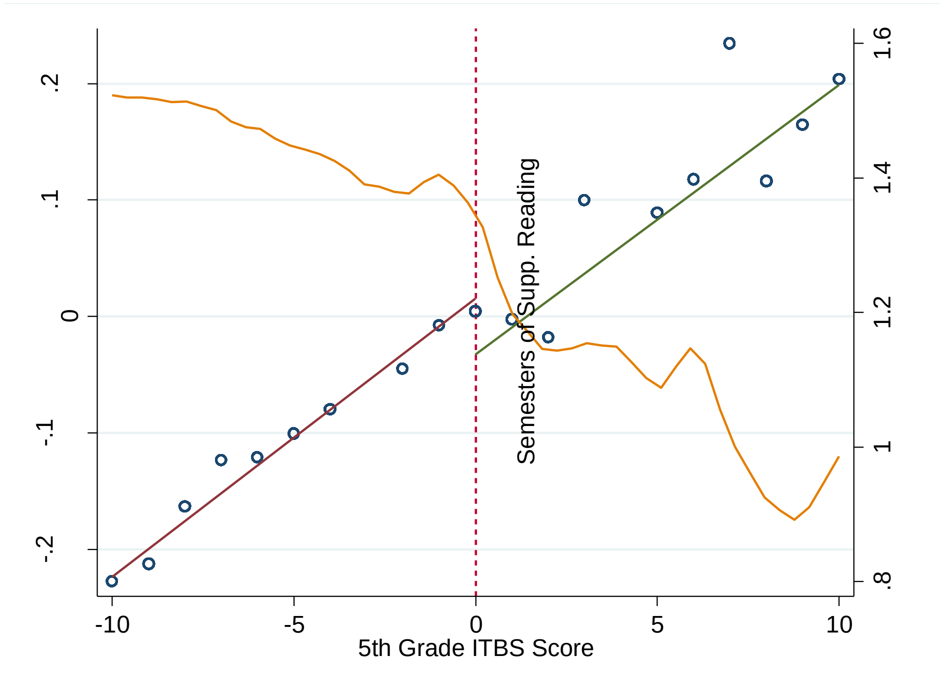


Figure 3: Fitted outcomes in 6th-grade reading and 8th-grade ITBS percentile overlaid on evidence of discontinuity in exposure to treatment.

Panel A: 6th-grade Reading



Panel B: 8th-grade ITBS Percentile