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# Spillover Effects of Specialized High Schools

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**Abstract**

Specialized high schools are an increasingly popular way to prepare young adults for postsecondary experiences and expand school choice. While much literature examines charter school spillover effects and the effects of specialized schools on the students who attend them, little is known about the spillover effects of specialized high schools on traditional public schools (TPS). Using an event study design, we show that one type of specialized high school, North Carolina's Cooperative Innovative High Schools, initially attracted students who were higher achieving and more likely to be white than TPS students, but these specialized schools became more representative of the district population over time. On average, the opening of specialized schools had a mix of null and positive spillover effects on TPS student achievement. While there is some evidence of negative spillovers from the first schools that opened, the effects become more positive over time.

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# 1 Introduction

Specialized high schools (such as early college or STEM high schools) are growing in popularity as educators and policymakers seek new ways to prepare young adults for postsecondary education and the labor force (White House, 2016; Means et al., 2021). These schools also expand school choice and, in places such as North Carolina, educate more high schoolers than charter schools. While several papers now examine how charter school openings impact traditional public school (TPS) students (e.g., Slungaard Mumma, 2021; Gilraine, Petronijevic, & Singleton, 2021; Cordes, 2018; Ladd, Clotfleter & Holbein, 2017), or how specialized high schools impact the students who attend them (e.g., Abdulkadiroglu, Angrist & Pathak, 2014; Barrow, Sartain, & de la Torres (2020); Dobbie & Fryer, 2014; Edmunds et al., 2017), no research studies the spillover effects of specialized high schools on TPS students. This is important given the large number of specialized high schools, important differences between them and charter schools, and their potentially large and unique impacts on the types and achievement of students who remain in traditional public schools.

Specialized high schools are district-operated schools, which typically have a particular theme or education focus and require students to apply before they attend. They include early college high schools, exam schools, and subject or career-themed schools, such as STEM schools. Unlike charter schools, they are operated by the local school district rather than an independent charter, but the application process is similar to charter schools since students are not "zoned" to attend them. This paper focuses on early college high schools, called Cooperative Innovative High Schools in North Carolina, which are specialized high schools intended to prepare young adults for postsecondary education and to expand choices for students.

Building on evidence from the charter school literature, we ask two primary research

questions. First, how does the opening of a specialized high school, such as an early college high school, impact the composition of students enrolled in the district's traditional public schools? Evidence on charter schools indicates that schools of choice may attract higher achieving students than traditional public schools and can increase racial and income segregation (e.g., Monarrez, Kisida & Chingos, 2022; Rucinski & Goodman, 2021). Second, does the opening of a specialized high school have spillover effects on the achievement of students in the traditional public schools? Competitive forces or spillovers in innovation and college-going culture may lead to positive effects (Cohodes & Parham, 2021; Hoxby, 2000). However, changes in the types of teachers and students in the TPS may reduce achievement (e.g., through peer effects) (Duflo, Dupas, & Kremer, 2011; Imberman, 2011; Jackson, 2012).

Examining these questions in the specialized high school context is important as these schools become a growing part of the school choice landscape. Important differences between specialized high schools and charter schools also suggest that findings from the charter school literature may not necessarily apply to these schools. First, specialized high schools often have different implications for school district finances because they are typically operated by school districts. Thus, they do not usually draw resources away from the district, and in contexts such as North Carolina, they actually lead to additional funding from the state. They may, however, reduce individual schools' resources if they lower enrollment levels. Second, these schools often target specific types of students, so we may expect them to have larger or different effects on the composition of students remaining in traditional public schools. For instance, there may be important parallels between their effects and those of within-school tracking since one of their purposes is to enable enrolled students to take more advanced courses. The competitive forces driven by the opening of these schools may also differ from those of charter schools because of their focus and district affiliation.

We examine these questions using data on the opening of nearly 100 Cooperative Innovative High Schools (CIHS) in North Carolina between 2002 and 2019. In North Carolina, CIHS are schools of choice that are operated through partnerships between local education agencies and postsecondary institutions. A large majority of these schools are considered early college high schools, and are located on college campuses. At these schools, students can pursue accelerated and college-focused courses of study, and may earn associate or technical degrees alongside their high school diploma. Some CIHS have a STEM or career focus or are middle colleges; however all have a partnership with a postsecondary institution.[1] By 2019, students in 97 of the 115 local education agencies (LEAs) in North Carolina had access to a total of 133 CIHS. We leverage significant variation over time in when students in different LEAs first gained access to a CIHS to measure their effects on traditional public school students. We use an event study design with year and school district fixed effects, accounting for the recent methodological advances in estimation of two-way fixed effects models by implementing a stacked event study design with robustness checks from other recent papers (Borusyak, Jaravel, & Spiess, 2021; Callaway & Sant'Anna, 2021; Cengiz et al., 2019; Goodman-Bacon, 2021; Rambachan & Roth, 2023).

The opening of a district's first CIHS reduces enrollment in traditional public high schools (TPS) by approximately 20 9th grade students per TPS (a 7% decline). The CIHS disproportionately enroll white students and those with higher baseline achievement.[2] This leads traditional public schools to have a higher share of students from underrepresented racial/ethnic minority backgrounds in the years following the opening of a CIHS compared to prior years. These patterns are most prevalent among the CIHS that opened prior to 2012. CIHS opening in more recent years enroll students who are similar to the traditional public school students in terms of their race/ethnicity and 8th grade test

[1] Middle colleges are similar to early colleges but they enroll students starting in 11th grade rather than 9th grade.

[2] This impact is apparent in the first year and persists for the five year time window we examine.

scores. Thus, we find some evidence that state and local efforts to make the CIHS more representative of local schools may be working.

We also find that the opening of these specialized high schools generally had some positive spillover effects on TPS student achievement and attendance. On average, and conditional on the baseline characteristics of students who enroll in the TPS after the CIHS opens, the opening of a CIHS leads to a small increase on end of course Biology exam scores, an increase in absence rates, and no significant changes in algebra and English exam scores or high school graduation rates. This, however, masks important variation over time. Among the very early adopters, there are negative spillover effects on the end of course English and Biology exams, and on attendance. Conversely, CIHS that opened more recently have positive spillover effects on end of course exam scores and high school graduation rates. On net, these findings suggest a mix of positive and null spillover effects, and that spillover effects may become more positive as the specialized high school models become more established.[3]

These estimates are helpful for refining theories about how school choice influences traditional public school achievement levels. First, much evidence on peer effects suggests that students benefit from exposure to higher achieving or higher SES students (e.g., Chetty et al., 2022; Garlick, 2018; Imberman, Kugler & Sacerdote, 2012; Sacerdote, 2011), and there are concerns about school choice removing the highest achieving or high SES students from TPS. We, however, find that students in the TPS may benefit from the higher achieving students leaving their school. These findings are consistent with a few papers showing that low achieving students can benefit from being in classrooms with fewer high achieving peers (Feld & Zőlitz, 2017; Booij, Leuven & Oosterbeek, 2017), evidence that students benefit from having a higher class rank relative to their peers (Den-

[3]We also look at the effects of CIHS openings on teachers. CIHS attract teachers from nearby traditional public schools, but there are no significant differences (in terms of experience and pay) between the teachers who leave and those who replace them in the traditional public schools.

ning, Murphy& Weinhardt, 2023; Elsner & Isphording, 2017) and benefits from receiving more targeted instruction due to in-school tracking (Duflo et al., 2011). Our positive estimates may also be indicative of the importance of school resources. Since the CIHS do not pull resources away from the local school districts, the resources per student should be similar and class sizes smaller in the TPS after the local CIHS opens. Prior research indicates that more resources and smaller classes can lead to improved student achievement (Jackson, Johnson & Persico, 2016; Fredriksson, Őckert & Oosterbeek, 2013). Finally, the growing effects over time are consistent with theories about competition driving school choice spillover effects since competitive effects likely take time to spread (Hoxby, 2000).

More broadly, this paper extends the literature on school choice in three important ways. First, this work builds on research that examines the effects of specialized high schools on the students who attend them by providing the first evidence on their general equilibrium effects on TPS students. Evidence on early college high schools, including in North Carolina, indicates positive effects on the students who attend them (Berger et al., 2013; Edmunds, et al., 2020; Edmunds, et al., 2017; Haxton et al., 2016; Song et al., 2021). The evidence on exam schools and STEM high schools is more mixed, with some evidence of positive impacts on test scores and college attendance (Abdulkadiroglu et al., 2014; Dobbie & Fryer 2014) and other evidence of limited or even negative impacts (Barrow, et al., 2020; Wiswall et al., 2014). None of these studies examine impacts on TPS composition or achievement.

Second, our results build on the charter school literature on skimming and spillover effects on TPS students and indicate that findings from this literature may apply more broadly to school choice systems. For instance, recent work in North Carolina indicates that charter school openings increase segregation by disproportionately attracting white students from the TPS but there does not appear to be skimming in terms of academic achievement (Slungaard Mumma, 2021; Ladd, Clotfleter & Holbein, 2017; Bifulco & Ladd,

2007). This is similar to what we find, suggesting that expanding segregation may be a broader concern with school choice models. Our results are also consistent with work showing that exam schools in Boston and New York disproportionately enroll white and Asian students (Rucinski & Goodman, 2021; Corcoran & Baker-Smith, 2018).

Third, our results may be useful for parsing the mixed literature on the competitive effects of school choice programs and charter schools. Questions about the competitive effects of schools have been of longstanding interest and some of the primary motivation for expanding school choice programs (Hoxby, 2003; Cohodes & Parham, 2021). Consistent with several other papers (e.g., Gilraine, Pretronijevic, & Singleton, 2021; Ridley & Terrier, 2023; Jinnai, 2014), we find evidence of positive effects on TPS achievement especially in later years. This suggests it may take time for these schools (or the state) to establish a model well suited to spurring positive effects on TPS students. Prior papers also suggest their positive estimates may stem from changes in resources, which is consistent with the financial implications of specialized high schools. Finally, there may be larger spillovers associated with specialized high schools than charter schools because they are part of the district (potentially enabling more cross-school communication) and one of their goals is to improve achievement and college readiness expectations across the district.

The paper proceeds as follows: Section 2 discusses the context and data; Section 3 describes the methodological approach; Section 4 presents the results; Section 5 compares the effects of the CIHS on the students who attend them to their spillover effects on TPS students, and Section 6 concludes.

# 2 Context and Data

## 2.1 Cooperative Innovative High Schools

North Carolina's Cooperative Innovative High Schools are schools of choice operated by local education agencies in partnership with institutions of higher education. They are frequently located on the campuses of the higher education partners (which include two and four-year colleges). These high schools are typically small, enrolling fewer than 100 students per grade, and most of the schools (90%) enroll students beginning in 9th grade. The remaining 10% typically start in 11th grade. CIHS were formally established in 2004 under then Governor Easley's Learn and Earn Initiative "in response to workforce needs in North Carolina and to the state's persistent dropout rate"; the Initiative was "designed to improve high schools, to better prepare students for college and career, to create a seamless curriculum between high school and college, and to provide work-based learning experiences to students" (North Carolina Department of Public Instruction, 2008).[4]

Most North Carolina CIHS are five-year programs that offer students, at no financial cost to them, up to two years of transferable college credit and the potential to earn a post-secondary credential (e.g., an associate degree, a technical or vocational credential) as well as a high school diploma. Each CIHS is also expected to implement a shared set of Design Principles developed by North Carolina New Schools (2013) and revised by the North Carolina Department of Public Instruction (2021). Some of the CIHS include a specific focus on themes or subjects, such as STEM-focused high schools or Career Academies.

CIHS were initially supported by a public-private non-profit called North Carolina New Schools.[5] The organization developed a request for proposals (RFP) process through

[4]Five schools started prior to the official state initiative. These schools were folded into the state's Learn and Earn initiative in 2004.

[5]The organization was originally called the New Schools Project. It went suddenly bankrupt in 2016 and the North Carolina Department of Public Instruction took over the technical assistance and support responsibilities. In addition, the CIHS were initially supported by the Learn and Earn initiative. The name

which districts could apply to open a school. The RFP process required that districts hire principals who would then have a planning year prior to the school opening. Although New Schools has closed, the application process continues. The LEA must partner with an institution of higher education and jointly submit the application. Applications cover mandatory requirements (including school size and partnerships with institutions of higher education) as well as the CIHS target population, plans for enrolling students, and program information.[6] Applications are reviewed by representatives from the North Carolina Department of Public Instruction (NCDPI), North Carolina Community College System, University of North Carolina General Administration, and North Carolina Independent Colleges and Universities. If these representatives recommend approval, submissions are sent to the State Board of Education and the governing board of the local institution of higher education for approval. The North Carolina General Assembly also must approve the opening of CIHS.

Both TPS and CIHS receive the same funding allotment for each student but most of the CIHS received supplemental funding from the North Carolina General Assembly. At the beginning of the initiative, each newly approved school received an annual supplement of $400,000 to pay for college textbooks, a college liaison (an individual responsible for coordinating between the high school and the college), and professional development. Over time, the amount allotted to the schools has varied, with schools in poorer parts of the state receiving more funding (NC Appropriations Act, 2017). The partner college also covers portions of the costs of operating a CIHS, usually including in-kind contributions of space and resources. Additionally, the state of North Carolina pays for all dual enrollment tuition. Initial analyses of school-level expenditures conducted by the research team found that districts spent less per student in an early college than in a traditional

shifted from Learn and Earn to CIHS after a change in governors.

[6]The current guidance for applicants can be found here `https://www.dpi.nc.gov/cihs-planning-guidance/download?attachment`.

high school because of the costs being split between the district and the college and the time that students spent in college classes (Unlu et al., 2015).

Unlike magnet schools, CIHS do not have a desegregation goal; however, they are focused on specific populations. According to the authorizing legislation, CIHS are required to target any of the following groups: 1) students at risk of dropping out; 2) students who would be the first in their family to go to college; and 3) students who would benefit from accelerated academic instruction (§ 115C-238.50, Part 9 ).

Like magnet or charter schools, students choose whether to apply to a CIHS, so these schools have no predetermined admission pool. Generally, only students from the host county may apply (and most North Carolina LEAs coincide with county boundaries) but some counties have partnerships where students in a neighboring county may apply. Many CIHS are oversubscribed and screen applicants based on their admission priorities and students' academic and personal traits. Some oversubscribed schools use lotteries to select which of the applicants will be invited to enroll. Since these schools implement accelerated and rigorous college-focused courses of study, they recruit students who are interested in and academically prepared for such rigorous curricula.

In the early years of the initiative, many of the schools focused on recruiting students they believed would be successful in this accelerated model. Starting in approximately 2011, North Carolina New Schools began providing technical assistance around helping the CIHS serve their target population, setting targets of having at least 80% of enrolled students being first generation and ensuring that the schools were representative of the racial, ethnic and socioeconomic makeup of the district in which they were located. Schools were asked to file reports that included a summary of the characteristics of the students in the school. Evidence from site visits and interactions with CIHS principals suggests that the schools began a more intentional focus on reaching underserved populations. For example, one principal described changing their approach to recruitment

from just posting information on their website to visiting each middle school and taking students of color with them to talk about their experiences in the school. Other principals described doing presentations and outreach at non-traditional venues such as churches or after school programs. The state's Design and Implementation Guide also references the legislative requirement that the schools effectively serve target populations (NCDPI, 2021).

For many students, access to schools of choice may be limited by a lack of free lunch or transportation services (Valent & Lincove, 2018). There is no formal tracking of whether districts provide transportation to CIHS; however, a recent survey by the study team of 45 districts indicated that almost all the districts provide transportation to the CIHS and the vast majority provided meals on the college campus to qualifying students. Site visit data suggest that students often ride the bus to their home high school where a shuttle takes them to the CIHS. Thus, transportation and school lunches are unlikely to be major barriers to enrollment in CIHS.

Early college high schools and subject-focused schools are quickly growing in popularity as a model for improving high school success among low- income and historically disadvantaged groups (White House, 2016). For instance, there are nearly 200 early college high schools in Texas, over 170 in Michigan, and more than 40 in California (Smith, 2022; Texas Education Agency, undated; Tucker, 2021). CIHS are of also growing relevance in North Carolina. Approximately 6% of North Carolina's public high school students attend a CIHS, relative to about 5% attending a charter school.[7] Evidence on charter school enrollments in North Carolina suggests that a similar magnitude of skimming or spillover effects could be seen with the CIHS (e.g., Slungaard Mumma, 2021). Furthermore, the specialized focus of these high schools, and different financial structure,

[7]This is based on 2018-2020 data on North Carolina high schoolers. Charter school enrollment in all grades is between 7 and 8% during the same time period.

make it important to examine their unique effects. Finally, early colleges are distinct from magnet schools in their partnership with local colleges and emphasis on college preparation, but other features of the schools and element of choice are similar. Early colleges are also more prevalent in rural areas than magnet schools. Like both magnet and charter schools, CIHS offer students and families a choice about where to attend school and a free alternative to traditional public schools.

Currently, CIHS are spread throughout the state in both urban and rural areas. Between 2002 and 2019, students in 97 North Carolina LEAs gained access to 133 new CIHS.[8] Some CIHS serve multiple LEAs, especially in the more rural parts of the state, and some LEAs have multiple CIHS. We focus on the impacts of an LEA's students first gaining access to a CIHS. This includes the first time a CIHS opens in an LEA or the first time a partner LEA opens a CIHS. Eighty five of the CIHS represent the first opportunity for students in these 97 LEAs to enroll in a CIHS. The earliest adopters were in a mix of urban and rural areas and were in most parts of the state except in the northeast. Initial program expansion occurred most rapidly in the western part of the state, which tends to be rural with a majority white population. Table A.1 illustrates how the number of LEAs with access to one or more CIHS evolved over time. Students in only five LEAs could enroll at a CIHS prior to the 2005-06 school year, and there was substantial growth in the number of CIHS between the 2005-06 school year and 2009-10. By 2010-2011, 82 of the 115 LEAs in North Carolina were linked to at least one CIHS. Students in fifteen additional LEAs gained access to their first CIHS between 2015-16 and 2018-19. Table A.2 summarizes the characteristics of the traditional public schools in the year before their students gained access to a CIHS.

Table 1 also describes how the demographics of the CIHS and where they were located

[8]Five CIHS closed during this time period. 120 of the CIHS serve students beginning in 9th grade and 10 start in 11th grade. The remaining three start in grade 9 but intentionally bring in students in 11th grade. 93 include grade 13.

shifted over time. The CIHS which opened by 2006 were more likely to be in urban areas than those which opened in later years, while those which opened in later years were more likely to be in rural areas. The share of CIHS which were title 1 eligible was relatively constant over time, as was the share of economically disadvantaged students that they served. The newer CIHS had slightly larger 9th grade enrollment than the early CIHS and fewer full-time equivalent teachers. The early adopters also enrolled students with lower 8th grade math test scores and a higher share of students from underrepresented racial/ethnic minority backgrounds than the newer CIHS. The shift in racial/ethnic composition may reflect the shift from urban to rural areas since North Carolina's urban areas are more racially diverse than the rural areas.

Since CIHS are schools of choice, and they aim to serve students who are both prepared to succeed in college-level coursework and historically underserved, economically or academically disadvantaged, their student population may differ notably from students in traditional public high schools. Table A.3 shows the average characteristics of all CIHS and TPS students in North Carolina at three points in time. In general, incoming test scores are higher among CIHS students than traditional public school students and CIHS have much smaller 9th grade enrollments. Though CIHS served a slightly more economically disadvantaged population in earlier years (41 percent versus 33 percent in 2006-2007), as of 2018-2019, this had reversed and CIHS students were less likely to be economically disadvantaged (39 percent versus 47 percent). Table 1 also summarizes how characteristics of CIHS students varied based on the CIHS opening date and how they compared to students in the districts that had access to the CIHS.

## 2.2 Data and Sample

Our analyses draw on administrative student and school-level data from North Carolina which include student demographic and achievement information. Standardized test

scores are available in all years, along with information on student race and school enrollment. Our primary measures of academic achievement in high school are scores on North Carolina's end of course exams in Biology, Algebra and English.[9] We standardize all test scores within each subject and year. We also examine attendance rates (starting in 2004) using the natural log of absences plus one (to deal with outliers).

We supplement the student-level data with school-level data. NCDPI provided a list of all CIHS in the state along with district and school identifiers and the year each school opened. We cross-referenced this information on CIHS opening years with district and school identifiers linked to students in our student-level dataset as well as publicly available information. In addition, we obtained school-level data on schools' four- and five-year cohort graduation rates from 2006 to 2019. We also use data on principals' and teachers' experience, employment, and pay to examine how the set of traditional public school teachers and principals changes when a new CIHS opens.

Our dataset spans 2002-2003 through 2018-2019, with the limitations on data availability in the earliest years noted above. This extended time series allows us to capture the years immediately prior to and following the opening of a CIHS in the vast majority of North Carolina LEAs that gained access to a new CIHS. In total, 133 CIHS opened and served 97 of North Carolina's 115 LEAs from 2002-2003 through 2018-2019. We focus on the 85 CIHS openings between 2003 and 2019 that represent the first CIHS to serve the relevant LEA. These 85 CIHS served students across 97 LEAs. Table A.1 shows how many districts gained access to their first CIHS each school year. Table A.3 presents summary statistics on the TPS students at three points in time and Table A.4 describes the sample we use in our event study analyses.

Our sample consists of all students enrolled in a traditional public high school in

[9] Algebra is typically taken in 9th grade and Biology is in 10th grade. Prior to 2012, English I was taken by all 9th graders. In 2012 this transitioned to an English II exam in 10th grade.

North Carolina between 2002-2003 and 2018-2019. Students attending charter schools and the CIHS are excluded from most analyses. We also exclude TPS students who ever enrolled at a CIHS. This gives us a sample of nearly one million students. Additional details on the sample are in Table A.4. [10] Due to data limitations our analyses focused on high school graduation use school-level data and weights based on the size of the school.

We define treated students as 9th graders who attended a traditional public school in an LEA that operated a CIHS or had access to a CIHS through a partnership with another LEA.[11] CIHS were intended to serve the entire district, so a district-based treatment definition seems more appropriate than other measures (such as distance). There are a handful of CIHS that serve multiple districts, or a small zone outside the district. For students in one of these areas, we define treatment as having a CIHS that served their region. Our identification strategy is based on the opening of new CIHS, so we only focus on the effects the first CIHS each LEA opens. Estimating the effects of the first one is much cleaner in an event study design than including the second or third openings since the changes that arose based on the first CIHS opening may be included in our pre-period estimates for subsequent openings.

# 3 Empirical Approach

We leverage variation across school districts in the year in which they gained access to their first CIHS to estimate the impact of these openings on the students in traditional public schools. In particular, we use an event study specification, or two-way fixed effects model, to measure the causal effects of a CIHS opening. We include district-level

[10] The exact sample size varies some across outcomes as a few outcomes are measured at the school level. Table A.4 contains more details on the sample size by outcome variable.

[11] New CIHS typically only start by enrolling 9th graders so we treat the TPS 9th graders as the first treated cohort. We look at some outcomes in later grades, but we always define treatment based on the 9th grade cohort.

fixed effects to account for time invariant differences across the school districts in their composition and outcomes, as well as calendar time fixed effects to account for trends across the state.

Because traditional two-way fixed effects models can produce biased estimates, we implement models from the recent literature to account for staggered timing of adoption and heterogeneous treatment effects (Sun and Abraham, 2021; Goodman-Bacon, 2021; Borusyak et al., 2021, Rambachan & Roth, 2023).[12] Our primary specification is based on the stacking approach from Cengiz et al. (2019) and we show robustness to using the estimators from Borusyak et al. (2021) and Callaway and Sant'Anna (2021). The Cengiz et al. (2019) approach is advantageous in that it is straightforward to implement, is flexible enough to allow for unbalanced panel data and staggered adoption timing, the estimates are easily interpretable, and it is much less computationally intensive than the Callaway and Sant'Anna estimator (Baker, Larcker, & Wang, 2022).[13]

We start by estimating event-specific treatment effects. Since 97 LEAs gained access to their first CIHS in our study period, we have 97 events for which we estimate treatment effects. To compute these treatment effects, we create 97 event-specific annual panel datasets. For each event, we define the relevant control group as all observations in never treated LEAs. Then, to estimate the treatment effect for event $h$ we fit the following regression

$$Y_{hsi} = \sum_{t \in [-5,5]} \alpha_t I_{hi} + \mu_l + \delta_t + \epsilon_{hsi} \tag{1}$$

Where $Y_{hsi}$ is the outcome for student $i$ in school $s$ for event $h$, such as that student's 8th grade test scores. Students $i$ are nested within years $t$, schools $s$, and LEAs $l$. $\mu_l$ captures

[12] This work shows that traditional two-way fixed-effects models do not estimate the average treatment effect on the treated (ATT) if there is treatment heterogeneity, because these models give more weight to the earliest and latest adopters and they do not account for dynamic treatment effects.

[13] All of this was true at the time of writing. This literature and the tools to compute these estimators continue to change.

the LEA fixed effects and $\delta_t$ indicates the time fixed effects. $I_{hst}$ is an indicator for whether school $s$ is in a district with a new CIHS in year $t$, so $\alpha_{th}$ represents the effect of the new CIHS opening on the composition of students in the traditional public schools in year $t$. We fit this model looking at three and five year windows around when the new CIHS opens, and in all cases the omitted category is year 0 - the year before the CIHS opens.[14] In addition, we fit this model replacing the time indicator $I_{hst}$ with an indicator for being in the post period (within five or three years of the event) $post_{hst}$ to estimate the average effect in the years after the CIHS opens.

Next, we stack these 97 event-specific datasets to calculate an average treatment across all events $\alpha_t$. This approach aligns events by event-time rather than calendar time so that we estimate the treatment effect as if all events happen at once. This prevents negative weighting of some events in the presence of heterogenous treatment effects as in staggered event study designs (Abraham and Sun, 2021; Goodman-Bacon, 2021; Roth et al., 2023).

$$Y_{hsi} = \sum_{t \in [-5,5]} \alpha_t I_{hi} + \mu_{lh} + \delta_{th} + \epsilon_{hsi} \tag{2}$$

To account for the stacking approach, we include LEA-by-event fixed effects $\mu_{lh}$ and time-by-event fixed effects $\delta_{th}$. Standard errors are clustered at the LEA-by-event level. We also fit a version of the model with an indicator for being in the post-treatment period ($post_{hi}$) rather than individual time effects $\alpha_t$.

This approach will identify the causal effect of a CIHS opening on traditional public school students under the assumption that the outcome is uncorrelated with event-time (conditional on the fixed effects). This assumption would be violated if, for example, CIHS opened in districts with increasing enrollment and our outcome of interest was average school enrollment. To account for potential trends leading up to the opening

[14] Years six or more in the future or past were excluded from these analyses.

of a CIHS, we fit a parametric event study specification as in Dobkin et al. (2018) and Rambachan and Roth (2023). To implement this approach, we identify a functional form that fits the data in the pre-period (above and beyond what is captured by the school and year fixed effects) and then control for the expected trend in the post-period (Rambachan & Roth, 2023). As in Dobkin et al. (2018), we fit this in a two-step process. First, we fit the following regression for all observations between time -5 and 0 (or -3 and 0).

$$Y_{hsi} = \beta_1 Time_t + \mu_{lh} + \delta_{th} + \epsilon_{hsi} \tag{3}$$

Then we compute the residuals ($\bar{Y}_{hsi}$) as the difference between the predicted values ($\hat{Y}_{hsi}$) and $\beta_1 Time_t$. Thus the residuals are the estimated effects absent the time trend but inclusive of the fixed effects. This nets out the time trend (based on $Time_t$) in the post period that one would expect based on any trend observed in the pre-period. Then, we fit equations one and two above with our residuals ($\bar{Y}_{hsi}$). Figures 1 and 2 show that our pre-period estimates are indistinguishable from zero, suggesting that this model fits our data well. Thus, it appears that the "no pre-trends" assumption is satisfied in this case. Unless otherwise noted, all estimates we present are from this parametric event study specification.

When looking at changes in student achievement in high school we typically condition on student baseline characteristics (in equation 1) to separate the effects of the CIHS on TPS school composition from potential spillover effects on student achievement. We include as covariates in our model students' 8th grade math and reading test scores, an indicator for whether the student is classified as economically disadvantaged, and an indicator for whether the student is from a racial/ethnic minority background.

Finally, we believe that focusing on treatment at the district level and among schools that opened over 16 years helps to alleviate concerns about other threats to identification.

School-specific shocks that are more likely to occur in a particular year relevant to event time (such as installing air conditioning in TPS in the second year after a CIHS opens) could bias effects. However, it seems unlikely that this would happen consistently across our 16-year time window for anything that is not directly related to the opening of a CIHS (and there is nothing in the program design to suggest this was the case). Focusing on treatment at the district level, rather than the school level, also alleviates some potential channels for bias since there is less variation across districts than schools, and most districts in North Carolina cover large areas (as they are often based on county boundaries). Since there was an intensive process for applying to open a new CIHS as well as heterogeneity in how long it took to receive all the approvals and actually open the CIHS, the precise year in which the CIHS opened is unlikely to be precisely the same year the district expected a larger cohort of entering 9th graders, for example.

## 3.1 Outcomes of Interest

We are interested in three main types of changes that may occur as a result of a specialized high school opening in a school district. First, we aim to quantify how 9th grade enrollment in traditional public high schools changes, in terms of total numbers, demographics (fraction from economically disadvantaged backgrounds or underrepresented racial minority groups) and incoming students' baseline achievement levels (8th grade math and reading test scores on state exams, standardized at the subject by year level). For these analyses, we focus on the how the characteristics of the students in the traditional public schools (excluding charter school students) changed when students in the district could first access a CIHS.

We are also interested in how the opening of a CIHS impacts the outcomes of students remaining in the traditional public schools. For this, we examine both overall changes in high school achievement at the TPS as well as changes in achievement net of those ex-

pected from changes in the characteristics of TPS students. The second set of analyses is useful for trying to separate the effects of CIHS attracting certain types of students from effects due to spillover effects or changes in the types of peers and teachers to whom TPS students are exposed. For these analyses, we fit versions of equations (1) and (2) which include controls, $X_i$, for incoming students' 8th grade math and reading test scores, an indicator for economic disadvantage, and an indicator for an underrepresented racial/ethnic minority background.[15] These control variables are used in all of our main analyses focused on the spillover effects of the CIHS on TPS student achievement.

Finally, we examine how overall district enrollment, composition, and achievement changed when a CIHS opened, as well as whether the types of staff in TPS changed. The district-level analyses are useful for measuring whether opening a specialized high school helps to attract new students to the district (perhaps from charter schools or private schools). For the staff analyses, we study whether the experience level and pay of teachers and principals in the TPS changes to understand if the specialized high schools draw away the best or most experienced personnel.

We also examine how effects vary over time. Early adopters may have had different effects than late adopters if the model they were implementing was still in flux, perhaps because guidelines around implementation were still developing and there were few examples from which they could learn. In addition, the students who applied to the initial CIHS may have been very different from those who applied to later CIHS (and we see some evidence of this in Table 1). For instance, limited awareness of the CIHS in early years may have resulted in higher achieving students or higher income parents being disproportionately likely to apply, while in later years awareness of this alterna-

[15]Some students are missing 8th grade test scores or indicators for economic disadvantage (in the early years). To preserve our sample size across models, we impute missing values as the mean and include flags for missing values. Nine percent of students are missing data on economically disadvantaged status, 11 percent are missing 8th grade math test scores and 10 percent are missing 8th grade reading test scores. No students are missing a value for the underrepresented racial/ethnic minority variable.

tive school may have been much greater, and more broadly distributed across a diverse set of students and families. This pattern has been documented in charter schools (Abdulkadiroglu, 2011; Setren, 2019; Shin, Fuller & Dauter, 2017). The types of students who selected into the CIHS may also have changed the spillover effects on students who remained in the TPS. Furthermore, the competitive effects of the CIHS potentially changed over time since channels for competition may have grown as awareness of these programs expanded and potential mechanisms for influencing them increased.

# 4 Results

Figure 1 shows that 9th grade enrollment in traditional public schools shrinks when a new CIHS opens. The CIHS are public schools intended to draw enrollment from the school district, so it is not surprising that enrollment declines at the traditional public schools. On average, when a CIHS opens, 9th grade enrollment at the other high schools in the district (or partner districts) declines by approximately 20 students (per school).[16] Table 2 indicates that using a window of five years leads to an estimated 20 student decline while using a three-year window leads to an estimated decline of 18 students. This represents a statistically significant 7% decline in 9th grade enrollment at the traditional public high schools. Overall district enrollment does not appear to change much when a new CIHS opens. Figure A.1 indicates that district enrollment increases in the years following the CIHS opening but this estimate is insignificant.[17]

Figure 2 shows that the opening of a CIHS changed the demographic and achievement composition of incoming TPS 9th graders. Table 2 reports that math and reading test

[16]There are multiple high schools in most of the districts so total enrollment at the CIHS is typically much higher than twenty 9th graders.

[17]Thus, specialized high schools may attract some students to the district but it is hard to tell how much with our estimates. Table A.10 indicates a point estimate of 23 to 22 students but the standard errors are all quite large.

scores of incoming 9th grade TPS students are 0.02 to 0.04 standard deviations lower after a new CIHS opens. The bottom panel of Figure 2 also shows that the opening of the CIHS led to increases in the fraction of underrepresented racial/ethnic minority students in the district's traditional public schools. On average, the fraction of TPS students who are from underrepresented racial/ethnic minority backgrounds increases by 1.4 percentage points when a new CIHS opens. Since enrollment is decreasing, the increasing share of minority students is due to CIHS disproportionately enrolling white students from the local district(s). This indicates that these specialized high schools may be attracting the higher achieving and white students from the traditional public schools. We do not find a significant change in the share of economically disadvantaged students in the TPS.

The impacts of specialized high schools on TPS enrollment vary over time. Table 3 presents results by three time periods in which the CIHS opened. Panel A shows estimates for districts with a CIHS that opened in the 2005-2006 academic year or earlier, while Panel B is based on districts with a new CIHS in the 2007-2012 academic years. No CIHS opened between 2012 and 2015 so panel C focuses on those which opened in 2015 or later.[18] These estimates indicate that CIHS were more likely to attract white students from the TPS in the early years. TPS students were 3.4 percentage points more likely to have an underrepresented racial/ethnic minority background when a CIHS opened in 2006 or earlier, relative to 0.9 percentage points in 2007-2012 and no difference in the fraction of underrepresented minority students when the latest CIHS opened. Similarly, we find that the early adopters were most likely to enroll higher achieving students as measured by students' 8th grade test scores.

Thus, Table 3 indicates that in recent years the new CIHS enrolled students more representative of the TPS students, and, if anything, may have enrolled a slightly higher frac-

[18] 25 CIHS opened in the early period, 57 in the middle period and 15 in the later period.

tion of economically disadvantaged students than the TPS.[19] These results are consistent with the earlier described legislative requirements and efforts of program staff to ensure that the schools served first generation students and populations that were representative of their districts.

We also find that opening a new CIHS leads to some improvements in TPS students' high school achievement. Table A.5 and Figure A.2 report the raw differences in outcomes after the CIHS opens while Table 4 and Figure 3 present estimates which condition on the baseline characteristics of the TPS students.[20] Conditioning on students' baseline characteristics is important for distinguishing changes in observed achievement at the TPS driven by different student composition versus potential spillover effects of having a CIHS nearby. Table 4 indicates that, on average, scores on the end of course Biology exams increase by a statistically significant but small 0.022 standard deviations, but absences among TPS students increase roughly 5% when a CIHS opens. There are no significant impacts on Algebra exam scores. There is a very small and significant positive effect on high school graduation, but this estimate is less than 0.1 percentage points (see Figures A.3 and A.4).

Next, we examine how the spillover effects vary based on the time period when the CIHS opened. We may expect different impacts of the early adopters than the late adopters if these schools are enrolling different types of students or if the CIHS model changes over time. Table 5 and Figure A.5 show important variation over time. The spillover effects for the CIHS that opened in 2006 or earlier appear to be negative, with a 0.04 SD reduction in English exam scores, 0.03 SD reduction in Biology exam scores and 13.6% increase in absences. However, most of the negative effects are not present in districts where the CIHS opened in later years. Among those with their first CIHS opening

[19]This estimate is significant at the ten percent level.

[20]This includes their 8th grade math and reading test scores and indicators for whether they are economically disadvantaged or from an underrepresented racial/ethnic minority background.

between 2007 and 2012, there are positive effects on Biology exam scores (0.04 SD) and high school graduation rates (1-2 percentage points).

These results suggest that students are performing better than would be expected based on their demographics and incoming test scores, so the CIHS openings appear to have positive spillover effects on TPS students. Most of the estimates for the most recently opened CIHS are null, perhaps because these estimates are based on a smaller sample than the other time periods. Overall, the shift in results over time indicates that it may have taken time for the state to establish a good model for the specialized high schools to positively influence the traditional public schools. Differences in treatment effects may also reflect differences in the CIHS over time. Table 1 shows that the early CIHS were more likely to be in urban areas, larger, and in districts with lower 8th grade math test scores and a larger share of students from underrepresented racial/ethnic minority backgrounds than the CIHS that opened later. More broadly, these results indicate that it may be important to look at variation in the expansion of school choice programs over time and that there are some conditions under which they appear to generate positive spillover effects on TPS students.

## 4.1 Mechanisms

Next, we examine additional variation in the spillover estimates by student and school characteristics to better understand the mechanisms driving the results. A few important things may be happening. First, the difference between the conditional estimates (Table 4) and unconditional estimates (Table A.5) suggest that some of the raw differences in achievement changes after a CIHS opens are likely driven by changes in the types of students attending the TPS rather than other changes in the schools. Second, there may be competitive effects of the CIHS if, for instance, they implement effective and innovative practices that TPS go on to adopt or if they help strengthen the college-going culture in

the district. This is consistent with larger effects observed in later years at which point the CIHS model may be more well established and more rigorous.

Third, lower-achieving students may benefit from some higher achieving students leaving their school and classes. This is consistent with some evidence showing that low achieving students are made worse off by being assigned to classrooms or groups with more high achieving peers (Feld & Zőlitz, 2017; Booij, Leuven & Oosterbeek, 2017) and students have better educational outcomes when they have a higher achievement level relative to their peers (Denning, Murphy & Weinhardt, 2023; Elsner & Isphording, 2017). Like with in-school tracking, removing the highest achieving students may enable teachers to focus their materials more at the level of the students remaining in the traditional public schools (Duflo et al., 2011). Table 6 shows that spillover effects are negative for traditional public schools with above average test scores and positive in schools with below average test scores.

Similarly, Table A.7 shows that spillover effects are positive (or null) for students whose peers have below average achievement levels while they are negative for students whose peers have above average achievement levels. This is consistent with the tracking hypothesis since removing the highest achieving students from the TPS may lead to more targeted instruction for the lowest achieving students in the below average schools. However, the high achieving students may receive less targeted instruction if there are now fewer high achieving students in the school, which could lead to the decrease in test scores observed for these students. Table A.8 also shows how CIHS spillover effects vary with neighborhood characteristics. Effects are more positive in higher poverty areas as well as areas with a higher share of people with a bachelor's degree. They are also more negative in areas with a larger share of people from underrepresented minority backgrounds.

Fourth, CIHS spillover effects may depend on the implications of a CIHS opening on

the resources available to students in the TPS. Table 7 examines how resources at TPS changed when a local CIHS opened. Class sizes at the TPS decreased by about 0.4 students but there were no significant changes in total district expenditures or per pupil expenditures. The small reduction in class sizes may have benefited students in the TPS but these changes are much smaller than those usually associated with improved outcomes in the literature (Krueger, 1999; Fredriksson, Őckert & Oosterbeek, 2013).

We also examined what types of teachers were hired by the CIHS and whether they may be pulling the most experienced teachers or principals from the TPS. Table 8 shows that when a CIHS opens, 52% of CIHS teachers are from a TPS, 6% are from a charter school, and 39% are novices. The average years of experience when teachers start at the CIHS is 3.2 years. On average, CIHS teachers have slightly more experience than TPS teachers (5 years vs. 4.3 years). However, when we look at teacher experience as an outcome in our event study model (Table A.9) we find that when a district gains access to its first CIHS, the TPS teachers and principals are not significantly less experienced (or paid less) than those in the school prior to when the CIHS opened. Glennie, Mason & Edmunds (2016) also study the experiences of CIHS teachers in one year and find that they are more likely to be novices but no less likely to be retained than TPS teachers with similar levels of experience.

Finally, we examined district level changes in composition since the opening of a CIHS may pull new students into the district (e.g., from private schools or charter schools). Figure A.6 and Table A.10 indicate that there are no significant changes in district size or composition. However, the point estimates for changes in grade 9 enrollment are positive so there may be some small effects that we are unable to detect. We also do not find any evidence that the opening of a CIHS drew in more students from outside the district's middle schools (e.g., from charter schools) or outside the public North Carolina school system (Figure A.7).

## 4.2 Robustness checks

We explore the robustness of our results to alternate model specifications, including some of the alternative two-way fixed effects estimators. Tables A.11 and A.12 summarize these robustness checks. Overall, we find similar results when we implement models that do not include the linear time trend (based on pre-period levels) and when we include not yet treated districts as controls. Our standard errors are much larger when including not yet treated units as controls, and as the recent DiD literature notes (e.g., Abraham & Sun, 2021; Callaway and Sant'Anna, 2021), never treated units are typically a cleaner comparison group, so we focus on the main results based on using never treated units as controls. Table A.13 also contain estimates based on the alternate two-way fixed effects estimators from Borusyak, Jaravel & Speiss (2021) and Callaway and Sant'Anna (2021).[21]

To explore heterogeneity in our average event study estimates, we also estimate effects for each individual event as described in the methodology section. Figures A.8, A.9, and A.10 show the plots of these individual event estimates. Consistent with our average estimates, for most events we find that upon a CIHS opening, students enrolling in the TPS have lower average 8th grade test scores and a higher share of them are from underrepresented racial/ethnic minority backgrounds. In terms of achievement outcomes, we also see more positive estimates for Biology exam scores and an increase in absences. Figures A.11 through A.19 also show these plots separately by time period.

[21] We estimate the Callaway & Sant'Anna (2021) models at the school-level due to computational limitations. We use the did R package developed by Callaway and Santa'Anna. The procedure for computing bootstrapped standard errors on unbalanced panel data is prohibitively slow in our sample of over half a million students. Point estimates should not be affected by whether we use the school or student-level, but standard errors are likely larger than they would be if we used student-level data.

# 5 Benefits of CIHS for Students Attending Them

Two prior papers (Edmunds et al., 2012; Edmunds et al., 2017) estimated the effects of 12 of North Carolina's CIHS on the students who attend them by randomly offering admissions to applicants to oversubscribed CIHS in the 2005-06 through 2008-09 school years. The first paper is focused on 9th grade outcomes (Edmunds et al., 2012) and finds that students randomly offered admission to the CIHS were 10 percentage points more likely to take Algebra 1 in 9th grade and 5.5 percentage points more likely to pass the end of course exam for Algebra. They also find positive effects on taking other math courses but no effects on English coursetaking. In addition, they find that 9th grade CIHS students were 6 percentage points less likely to be suspended and absent for 1.3 fewer days.

The second paper (Edmunds et al., 2017) also finds positive impacts on postsecondary outcomes. Students randomly offered admission to the early college completed roughly seven more transferable college courses by 12th grade than students in the control group. CIHS students were also 15.6 percentage points more likely to attend college than students in the control group. This included positive effects on both two and four-year college enrollment, but larger effects on two-year college enrollment. Finally, CIHS students were more likely to graduate high school but this difference (4 percentage points) was not statistically significant.

In terms of spillover effects, we estimate positive effects overall on the biology exam scores and high school graduation rates of TPS students but negative effects on high school attendance. These patterns match those observed for CIHS which open from 2007-2011 or roughly the same period in which the RCT was conducted. Thus, the overall efficiency gains of the program appear to point towards generally positive effects for both the students attending the CIHS and those in the TPS.

This comparison is, however, subject to several important caveats. First, the spillover

effects are only estimated for the 3-5 years after opening of the first CIHS that a district's students can access. It is possible that their effects change as they are open for longer. Most of the CIHS which participated in the RCT were not brand new when they participated, but they had all opened within the prior 7 years. The sample of schools in the RCT is also different than those included in the analyses of spillover effects.[22] Finally, the evaluation of efficiency gains and losses depends on which period of spillover effects are used for comparison. Above, we focused on the overall effects and those for 2007-2011 to roughly align with the RCT. The worst case scenario for the spillover effects is for the early time period, where exam scores decline in algebra by an insignificant 0.03 SDs, in English by 0.041 SDs and 0.031 SDs in Biology. These are all relatively small declines, especially relative to the positive impact on algebra exam pass rates for the CIHS students, however there are many more TPS students than CIHS students. Thus, in the early years the net benefits on achievement on all three end of course exams across TPS and CIHS students may have been negative. Over time the efficiency gains appear to have shifted to be positive.

# 6 Discussion and Conclusion

Overall, we find that specialized high schools in North Carolina that opened in 2006 or earlier initially enrolled students who were disproportionately white and higher achieving, with students remaining in traditional public school students more likely to be from underrepresented racial/ethnic minority backgrounds and with lower 8th grade test scores. This may have exacerbated racial and academic segregation across schools in North Carolina. However, the new specialized high schools that opened in later years enrolled students who were more representative of the districts they served. This indicates that in-

[22] We choose to report the RCT estimates rather than observational estimates of the CIHS impact on the full sample because selection into the CIHS will likely bias observational estimates.

tentional efforts to enroll populations representative of traditional public schools may be effective and specialized high schools may be a way to increase school choice for students from historically disadvantaged populations as long as there is intentional and purposeful outreach to those students.

We also find some positive spillover effects of a specialized high school opening on the achievement of students in the traditional public high schools. On average, graduation rates and end of course exam scores in Biology increased among TPS students when a CIHS opened, conditional on the changes in TPS students' baseline characteristics. Furthermore, spillover effects on end of course exam scores and graduation rates are positive in more recent years suggesting that, over time, specialized high schools may have become better at creating positive spillover effects.[23]

These results are broadly consistent with those from the literature on charter schools, which find evidence of charter schools enrolling populations that are disproportionately white and higher achieving but mixed effects on the achievement of students remaining in the traditional public schools. It is noteworthy that we find similar results even when the districts open and operate schools of choice, and when such schools target specific subgroups of students. In addition, the CIHS openings do not significantly change per pupil or total district spending. This may explain why we see slightly more positive effects on the TPS students than the charter school literature.

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[23]The spillover effects were, however, negative in the early years so there is potential for these models to reduce the achievement of TPS students.

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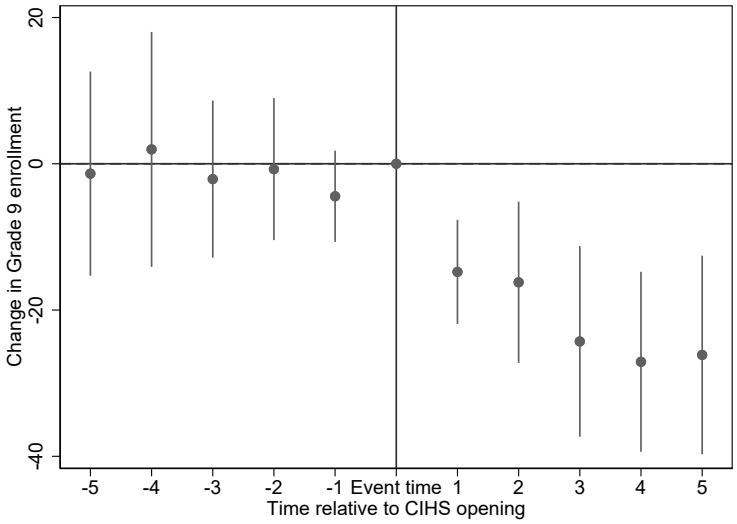
# 8 Figures and Tables

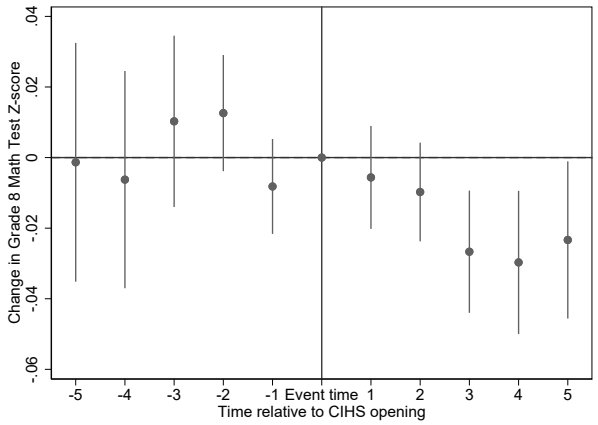
Figure 1: 9th grade Enrollment



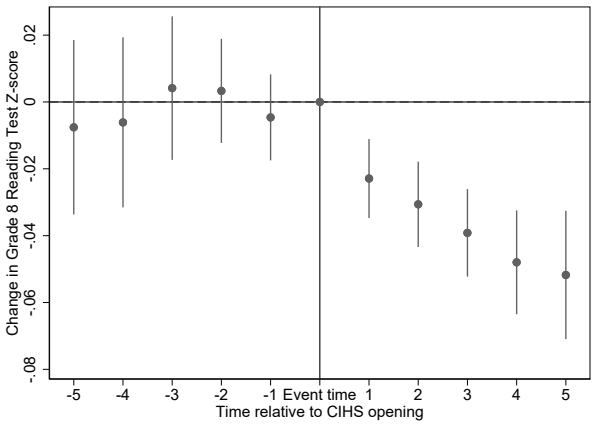

Notes: This figure shows how the traditional public school 9th grade enrollment changed relative to the opening of the district's first CIHS. The first CIHS opened in time 1. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. Enrollment is measured at the school-level so these estimates represent an unweighted average across traditional public high schools.

Figure 2: Change in Traditional Public School Composition Relative to CIHS Opening

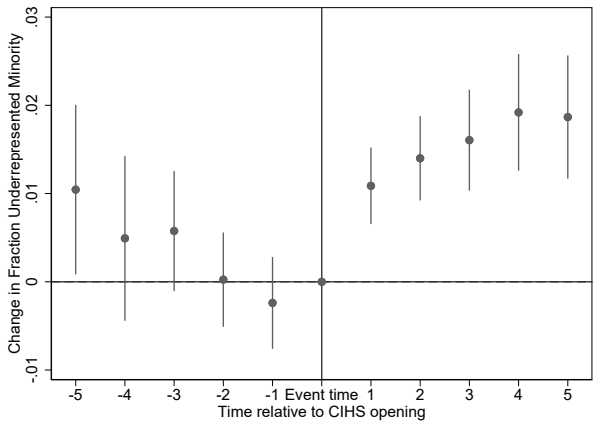
(a) 8th Grade Math Test Score



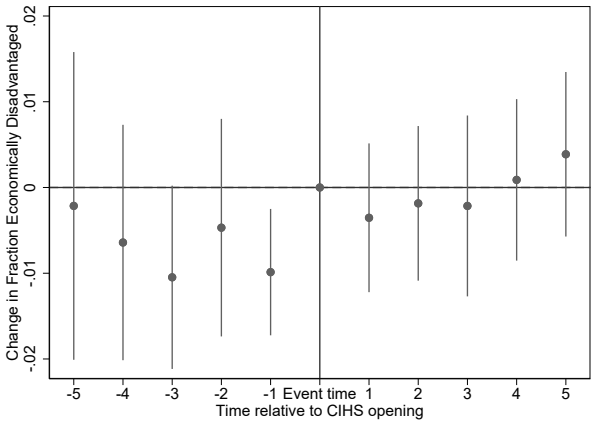

(b) 8th Grade Reading Test Score




(c) Fraction Underrepresented Racial/Ethnic Minority

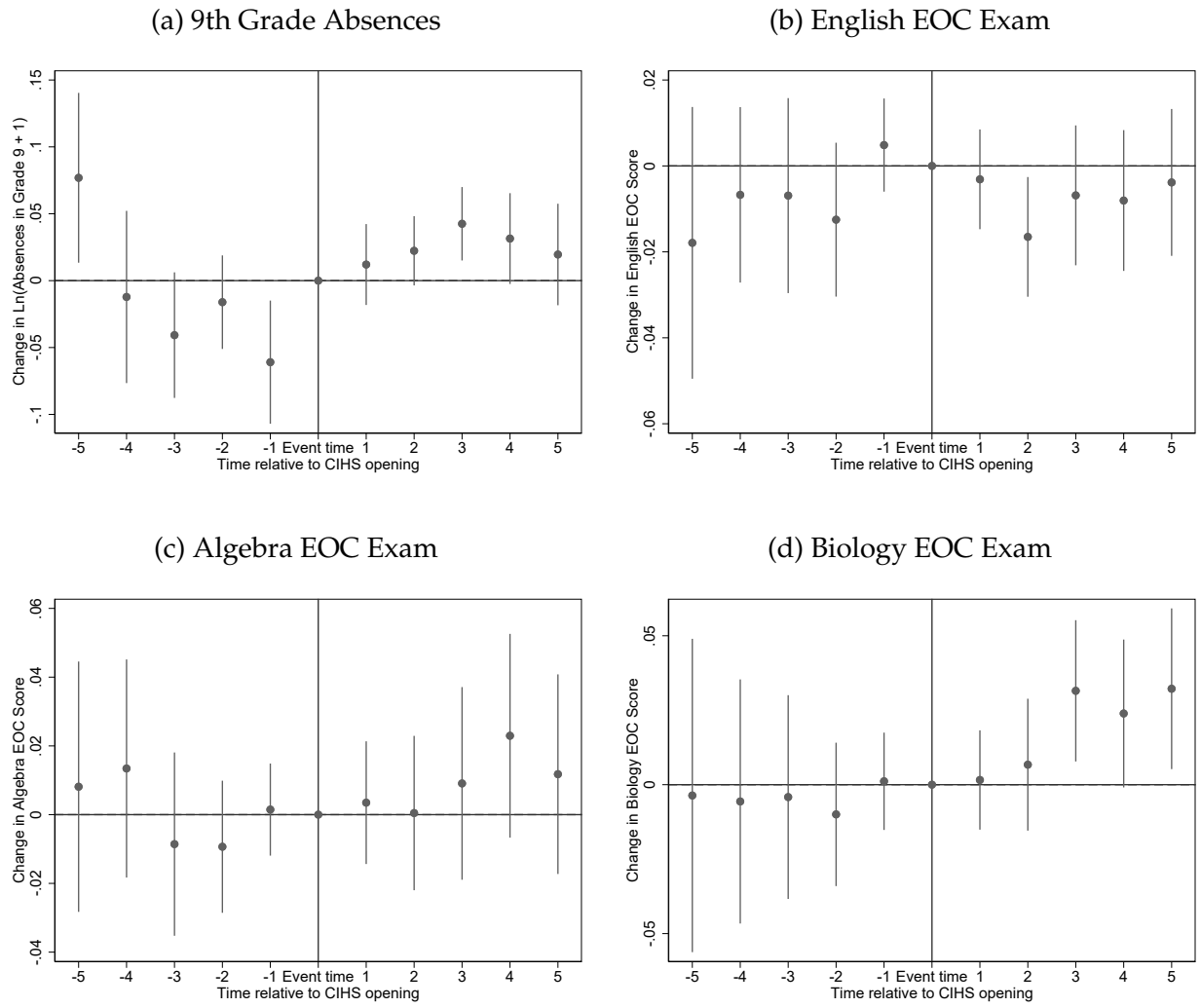



(d) Fraction Economically Disadvantaged




Notes: These graphs show how the composition of traditional public schools changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on incoming 9th graders in the traditional public schools. Panels (a) and (b) are based on z-scores of incoming 9th graders scores on the state's 8th grade math and reading exams. Panels (c) and (d) are based on indicators for students being from an underrepresented racial minority or an indicator for economic disadvantage. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on student-level regressions.

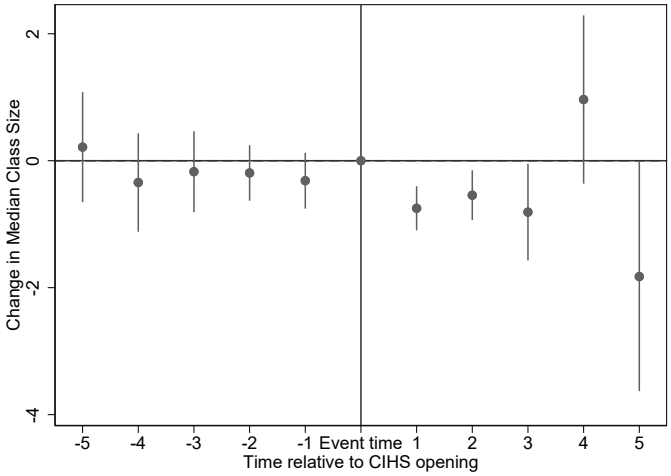
Figure 3: Achievement Changes in Traditional Public Schools Relative to CIHS Opening Conditional on Students' Baseline Characteristics



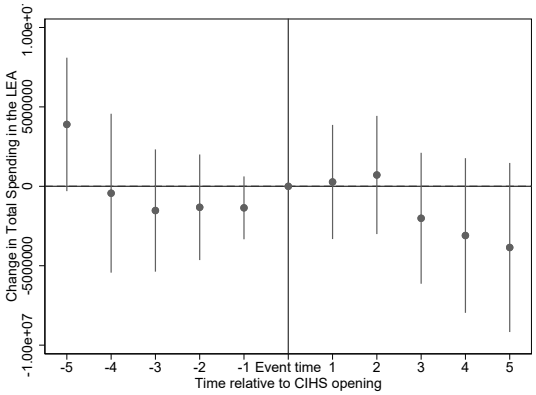

Notes: These graphs show how the achievement of traditional public school students changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Not all outcomes (i.e. exams) occurred during 9th grade so the year does not necessarily correspond to the year of the outcome. Panel (a) is based on the natural log of student absences in grade 9 plus one. North Carolina requires all high schoolers to take an end of course math (algebra), English, and biology exam. The outcomes in panels (b)-(d) are the students' standardized end of course exam scores. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background.

Figure 4: Changes in Class Size and District Spending Relative to CIHS Opening

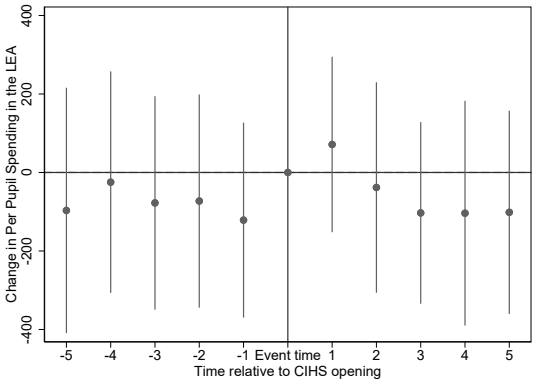
(a) Median Class Size




(b) Total District Expenditures




(c) Per Pupil District Expenditures




Notes: Panel (a) shows how the class size of traditional public school students changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on student-level regressions. Panels (b) and (c) show how total district expenditures, and spending per pupil changed when a district's first CIHS opened. These are district-level regressions with standard errors clustered by school district and event.

Table 1: Characteristics of Schools Over Time and by CIHS Opening Date

| | 2006 | | 2011 | | 2019 | |
|---|---|---|---|---|---|---|
| | CIHS | Traditional | CIHS | Traditional | CIHS | Traditional |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| (A) Open 2006 or earlier | | | | | | |
| Title 1 Eligible | | | 0.579 | 0.753 | 0.611 | 0.785 |
| Urban | 0.368 | 0.371 | 0.368 | 0.403 | 0.444 | 0.387 |
| Rural | 0.316 | 0.350 | 0.368 | 0.371 | 0.278 | 0.307 |
| FTE Teachers | 8.42 | 65.02 | 10.00 | 57.07 | 10.28 | 56.96 |
| 8th grade Math Scores | 0.116 | -0.190 | 0.248 | -0.210 | 0.279 | -0.189 |
| 8th grade Reading Scores | 0.138 | -0.167 | 0.301 | -0.192 | 0.544 | -0.219 |
| Share Underrepresented Minority | 0.459 | 0.441 | 0.350 | 0.466 | 0.399 | 0.495 |
| Share Economically Disadvantaged | | | 0.514 | 0.495 | 0.372 | 0.480 |
| Average 9th Grade Enrollment | 43 | 296 | 55 | 272 | 63 | 235 |
| Number of Schools | 19 | 143 | 19 | 161 | 18 | 150 |
| (B) Open 2007 - 2011 | | | | | | |
| Title 1 Eligible | | | 0.784 | 0.802 | 0.725 | 0.737 |
| Urban | | 0.174 | 0.078 | 0.186 | 0.118 | 0.219 |
| Rural | | 0.539 | 0.725 | 0.593 | 0.529 | 0.466 |
| FTE Teachers | | 66.04 | 8.18 | 55.42 | 8.55 | 54.79 |
| 8th grade Math Scores | | -0.143 | 0.306 | -0.179 | 0.374 | -0.130 |
| 8th grade Reading Scores | | -0.137 | 0.332 | -0.164 | 0.508 | -0.204 |
| Share Underrepresented Minority | | 0.391 | 0.325 | 0.425 | 0.397 | 0.441 |
| Share Economically Disadvantaged | | | 0.501 | 0.511 | 0.403 | 0.467 |
| Average 9th Grade Enrollment | | 309 | 50 | 264 | 54 | 242 |
| Number of Schools | | 219 | 51 | 261 | 51 | 247 |
| (A) Open after 2012 | | | | | | |
| Title 1 Eligible | | | | 0.667 | 0.667 | 0.878 |
| Urban | | 0.091 | | 0.089 | 0.067 | 0.122 |
| Rural | | 0.636 | | 0.644 | 0.467 | 0.561 |
| FTE Teachers | | 55.21 | | 51.84 | 4.73 | 50.76 |
| 8th grade Math Scores | | -0.151 | | -0.242 | 0.404 | -0.151 |
| 8th grade Reading Scores | | -0.120 | | -0.194 | 0.418 | -0.247 |
| Share Underrepresented Minority | | 0.428 | | 0.426 | 0.360 | 0.445 |
| Share Economically Disadvantaged | | | | 0.493 | 0.385 | 0.464 |
| Average 9th Grade Enrollment | | 260 | | 230 | 46 | 212 |
| Number of Schools | | 44 | | 46 | 15 | 41 |

Notes: This table shows the average characteristics of CIHS and Traditional schools among districts that have a CIHS open by 2006 in panel A, 2011 in panel B, and 2019 in panel C. This excludes charter schools (since they are excluded from our analyses). CIHS opening date refers to the first CIHS in the district. Math and reading test scores are based on incoming 9th graders average z-scores on the state test as 8th graders. Title 1 Eligible is an indicator for whether the school is eligible for Title 1 status. Schools in suburban areas and towns are not in the urban or rural group. Share economically disadvantaged and share underrepresented minority are based on incoming 9th graders. Chronically absent is defined as enrolled at least ten days and absent at least ten percent of days. Above averages weight each school equally (rather than weighting by student) so they show the characteristics of the average school rather than the average student. Data on Title 1 eligibility and economically disadvantaged status was not available in 2006.

Table 2: CIHS Spillovers on Traditional Public School Student Enrollment

| | Grade 9 Enrollment (1) | Grade 8 Math (2) | Grade 8 Reading (3) | Under-represented Minority (4) | Economically Disadvantaged (5) |
|---|---|---|---|---|---|
| (A) Within 5 Years | | | | | |
| CIHS Open | -19.916*** | -0.020** | -0.037*** | 0.014*** | 0.005 |
| | (4.886) | (0.008) | (0.007) | (0.003) | (0.004) |
| Observations | 53,377 | 9,5704,90 | 9,570,490 | 9,570,490 | 9,570,490 |
| (B) Within 3 Years | | | | | |
| CIHS Open | -18.174*** | -0.007 | -0.028*** | 0.014*** | 0.001 |
| | (4.670) | (0.007) | (0.006) | (0.002) | (0.004) |
| Observations | 52,338 | 9,304,419 | 9,304,419 | 9,304,419 | 9,304,419 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' enrollment and the characteristics of enrolled students over the three or five years after the CIHS first opened. Standard errors are clustered by event and school district. Grade 9 enrollment is measured at the school level and all other outcomes are at the student level. Grade 8 math and reading test scores are standardized z-scores from the NC state tests.

Table 3: CIHS Spillovers on Traditional Public School Student Enrollment by Time Period

| | Grade 9 Enrollment (1) | Grade 8 Math (2) | Grade 8 Reading (3) | Under-represented Minority (4) | Economically Disadvantaged (5) |
|---|---|---|---|---|---|
| (A) Open 2003 -2006 | | | | | |
| CIHS Open | -9.077 | -0.004 | -0.042*** | 0.034*** | -0.001 |
| | (7.904) | (0.012) | (0.010) | (0.003) | (0.009) |
| Observations | 13,334 | 2,336,868 | 2,336,868 | 2,336,868 | 2,336,868 |
| (B) Open 2007-2011 | | | | | |
| CIHS Open | -24.714*** | -0.008 | -0.027*** | 0.009*** | 0.002 |
| | (6.370) | (0.010) | (0.008) | (0.003) | (0.004) |
| Observations | 31,897 | 5,561,656 | 5,561,656 | 5,561,656 | 5,561,656 |
| (C) Open 2015-2019 | | | | | |
| CIHS Open | -15.095* | -0.010 | -0.007 | -0.004 | 0.015 |
| | (7.668) | (0.016) | (0.014) | (0.005) | (0.010) |
| Observations | 8,146 | 1,405,895 | 1,405,895 | 1,405,895 | 1,405,895 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' enrollment and the characteristics of enrolled students over the three years after the CIHS first opened. Effects are estimated separately by the time period in which the district's first CIHS opened. Standard errors are clustered by event and school district. Grade 9 enrollment is measured at the school level and all other outcomes are at the student level. Grade 8 math and reading test scores are standardized z-scores from the NC state tests.

Table 4: CIHS Spillovers on Traditional Public School Achievement, Controlling for Baseline Achievement and Demographics

| | Grade 9 Absences (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Within 5 Years | | | | | | |
| CIHS Open | 0.0468*** | 0.0107 | -0.0035 | 0.0221** | 0.0001* | 0.0001** |
| | (0.0112) | (0.0122) | (0.0061) | (0.0110) | (0.0001) | (0.0001) |
| Observations | 7,960,640 | 7,815,214 | 7,899,033 | 7,041,252 | 7,908,697 | 7,312,697 |
| (B) Within 3 Years | | | | | | |
| CIHS Open | 0.0364*** | 0.0026 | -0.0114* | 0.0140 | 0.0001 | 0.0001 |
| | (0.0101) | (0.0120) | (0.0061) | (0.0107) | (0.0001) | (0.0000) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,680,279 | 7,091,334 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three or five years after the CIHS first opened, conditional on students' 8th grade math and reading test scores, underrepresented minority status, and average share of economically disadvantaged students in the school. When students are missing data on 8th grade tests scores or demographics, we recode the missing values as the 0 (the mean for the test scores) and include indicators for missing these values . This ensures our sample is consistent with the unconditional estimates. Nine percent of students are missing data on economically disadvantaged status, 11 percent are missing 8th grade math test scores and 10 percent are missing 8th grade reading test scores. No students are missing a value for the underrepresented racial/ethnic minority variable. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate.

Table 5: CIHS Spillovers on Traditional Public School Student Achievement by Time Period with Baseline Controls

| | Grade 9 Absence (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Before 2006 | | | | | | |
| CIHS Open | 0.1356*** | -0.0196 | -0.0414*** | -0.0306** | | |
| | (0.0132) | (0.0126) | (0.0122) | (0.0154) | | |
| Observations | 1,928,610 | 1,900,438 | 1,926,026 | 1,715,817 | | |
| (B) Before 2012 | | | | | | |
| CIHS Open | 0.0111 | 0.0123 | -0.0029 | 0.0360** | 0.0127** | 0.0206*** |
| | (0.0138) | (0.0176) | (0.0074) | (0.0141) | (0.0061) | (0.0060) |
| Observations | 4,630,599 | 4,542,664 | 4,591,700 | 4,091,906 | 4,734,875 | 4,374,737 |
| (C) After 2015 | | | | | | |
| CIHS Open | 0.0443** | -0.0176 | 0.0031 | -0.0509 | 0.0099 | 0.0008 |
| | (0.0196) | (0.0238) | (0.0097) | (0.0370) | (0.0100) | (0.0106) |
| Observations | 1,181,778 | 1,146,551 | 1,141,152 | 1,021,183 | 1,216,839 | 1,139,968 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three years after the CIHS first opened conditional on students' 8th grade math and reading test scores, economic disadvantage, and underrepresented minority status. When students are missing data on 8th grade tests scores or demographics, we recode the missing values as the 0 (the mean for the test scores) and include indicators for missing these values. This ensures our sample is consistent with the unconditional estimates. Nine percent of students are missing data on economically disadvantaged status, 11 percent are missing 8th grade math test scores and 10 percent are missing 8th grade reading test scores. No students are missing a value for the underrepresented racial/ethnic minority variable. Effects are estimated separately by the time period in which the district's first CIHS opened. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. High school graduation data was not available prior to 2006.

Table 6: CIHS Spillovers on Traditional Public School Student Achievement by Baseline School Characteristics

| | Grade 9 Absence (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A)8th Grade Test Scores | | | | | | |
| School Above Average | 0.026** | -0.046*** | -0.046*** | -0.035*** | -0.134*** | -0.166*** |
| | (0.012) | (0.014) | (0.008) | (0.013) | (0.014) | (0.021) |
| School Below Average | 0.061*** | 0.066*** | 0.033*** | 0.077*** | 0.144*** | 0.141*** |
| | (0.013) | (0.019) | (0.010) | (0.022) | (0.017) | (0.019) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (B) Economically Disadvantaged | | | | | | |
| School Above Average | 0.095*** | -0.013 | 0.007 | 0.021 | -0.033*** | -0.039*** |
| | (0.014) | (0.017) | (0.009) | (0.016) | (0.009) | (0.009) |
| School Below Average | -0.015 | 0.017 | -0.023*** | 0.001 | 0.033*** | 0.036*** |
| | (0.013) | (0.013) | (0.007) | (0.013) | (0.006) | (0.007) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (C) Share Underrepresented Minority | | | | | | |
| School Above Average | 0.080*** | 0.031 | -0.031*** | 0.017 | -0.010 | -0.028*** |
| | (0.012) | (0.020) | (0.008) | (0.017) | (0.008) | (0.008) |
| School Below Average | 0.009 | -0.019 | 0.005 | 0.006 | 0.011** | 0.022*** |
| | (0.012) | (0.014) | (0.008) | (0.013) | (0.005) | (0.007) |
| *N* | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (D) Chronic Absenteeism (8th grade) | | | | | | |
| School Above Average | 0.050*** | 0.066*** | 0.033*** | 0.067*** | 0.145*** | 0.190*** |
| | (0.017) | (0.020) | (0.011) | (0.018) | (0.023) | (0.026) |
| School Below Average | 0.024** | -0.036*** | -0.046*** | -0.030** | -0.085*** | -0.091*** |
| | (0.011) | (0.014) | (0.008) | (0.012) | (0.011) | (0.013) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (E) Urbanicity | | | | | | |
| Urban | -0.002 | -0.044* | -0.017* | 0.014 | -0.018** | -0.032** |
| | (0.011) | (0.026) | (0.009) | (0.013) | (0.009) | (0.012) |
| Non-urban | 0.043*** | 0.018 | -0.006 | 0.012 | 0.008 | 0.002 |
| | (0.011) | (0.012) | (0.006) | (0.012) | (0.005) | (0.005) |
| Observations | 7,737,153 | 7,585,485 | 7,654,327 | 6,825,111 | 7,369,329 | 6,757,955 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three years after the CIHS first opened. The indicator for the post period is interacted with information about the 8th grade characteristics of the students in the school, including whether each of the following is above or below average: 8th grade test scores, share of economically disadvantaged students, the share of students from underrepresented racial/ethnic minority backgrounds, the share chronically absent in 8th grade and an indicator for whether the school is in an urban setting. All regressions include controls for continuous measures of 8th grade test scores, share of economically disadvantaged students and share of students from underrepresented racial/ethnic minority backgrounds. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. High school graduation data was not available prior to 2006.

Table 7: CIHS Spillovers on Class Size and Expenditures

| | Median Class Size (1) | Total District Expenditures (2) | Per Pupil District Expenditures (3) |
|---|---|---|---|
| (A) Within 5 Years | | | |
| CIHS Open | -0.352** | -989,000 | 12.134 |
| | (0.162) | (1,800,000) | (77.701) |
| Observations | 3,448,779 | 27,287 | 27,287 |
| (B) Within 3 Years | | | |
| CIHS Open | -0.423*** | 57,764 | 14.717 |
| | (0.157) | (1,800,000) | (77.413) |
| Observations | 3,321,651 | 27,003 | 27,003 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on class size at the traditional public schools, total district expenditures and district expenditures per pupil. Panel A is based on the five years before and after the district's first CIHS opened, and Panel B is based on a three year window. The class size regression is at the student level and the expenditures regressions are at the district level. Standard errors are clustered by event and school district.

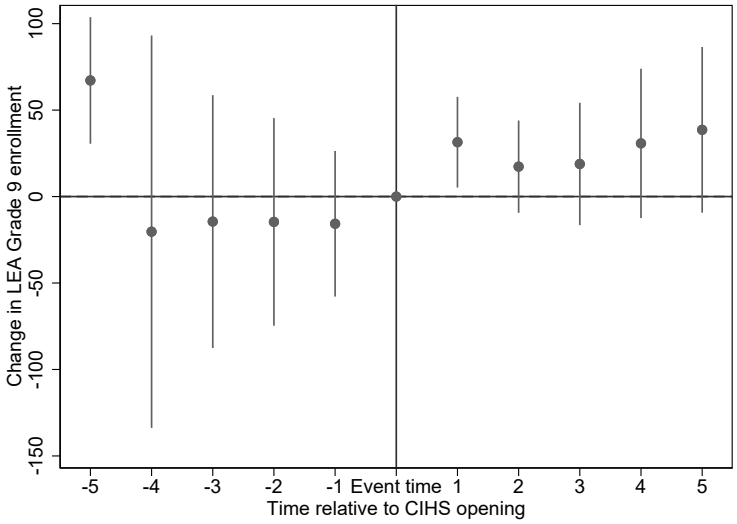
Table 8: Experience of CIHS Teachers

| | |
|---|---|
| (A) Experience of CIHS Teachers when they Start | |
| Come from TPS | 0.516 |
| Come from Charter School | 0.058 |
| Novice (in NC) | 0.387 |
| Years of Experience when Start | 3.162 |
| (B) Average years of Teaching Experience in NC | |
| CIHS Teachers | 4.995 |
| TPS Teachers | 4.325 |
| Charter School Teachers | 3.082 |

Notes: This table shows the experience of CIHS teachers and how it compares to NC teachers in charter schools and traditional public schools. This is based on 2007-2010 and 2012-2019. Teacher data is not consistently available prior to 2007 and there is a large amount of missing data in 2011. Years of experience are estimated based on years observed in the NC data. Teachers may have experience from other states, private schools, or from a time period prior to the current data.

# 9 Appendix

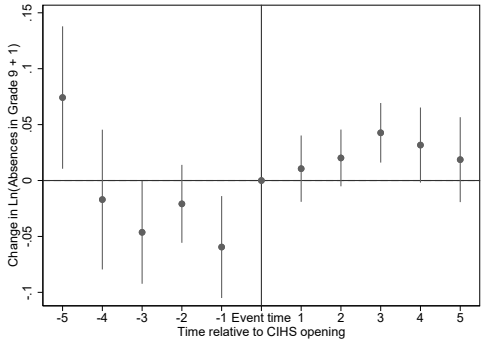
Figure A.1: Total District 9th Grade Enrollment



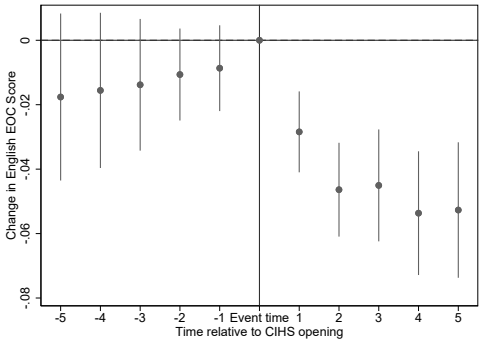

Notes: This figure shows how the district's 9th grade enrollment changed relative to the opening of the district's first CIHS. The first CIHS opened in time 1. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. Enrollment is measured at the district-level and they include CIHS students.

Figure A.2: Achievement Changes in Traditional Public Schools Relative to CIHS Opening

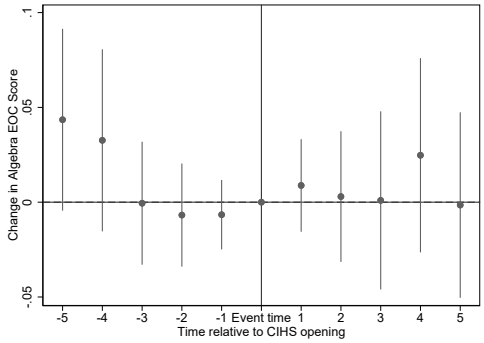
(a) 9th Grade Absences



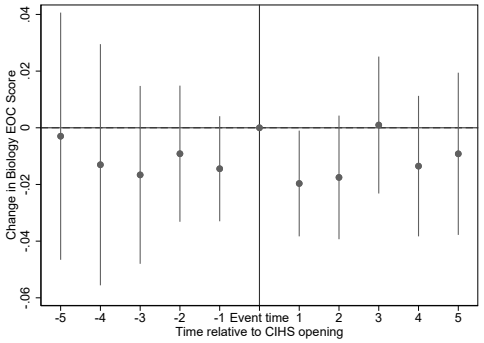

(b) English EOC Exam




(c) Algebra EOC Exam



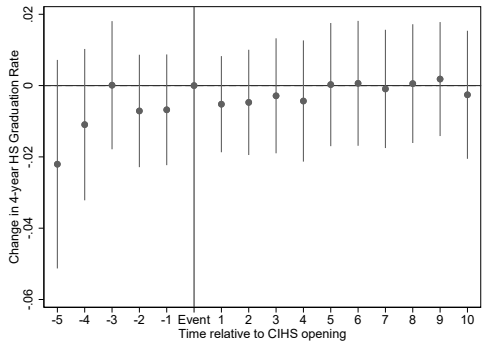

(d) Biology EOC Exam



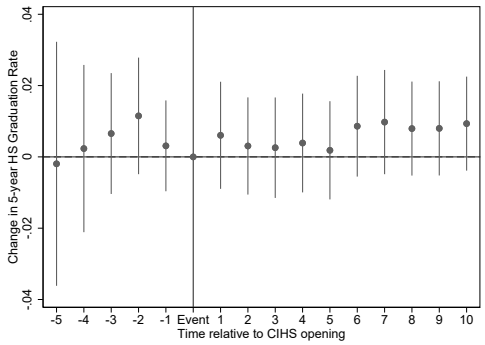

Notes: These graphs show how the achievement of traditional public school students changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Not all outcomes (i.e. exams) occurred during 9th grade so the year does not necessarily correspond to the year of the outcome. Panel (a) is based on the natural log of student absences in grade 9 plus one. North Carolina requires all high schoolers to take an end of course math (algebra), English, and biology exam. The outcomes in panels (b)-(d) are the students' standardized end of course exam scores. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on student-level regressions and they do not condition on students' baseline characteristics.

Figure A.3: Change in TPS Graduation Rates Relative to CIHS Opening

(a) Four-Year Graduation Rate



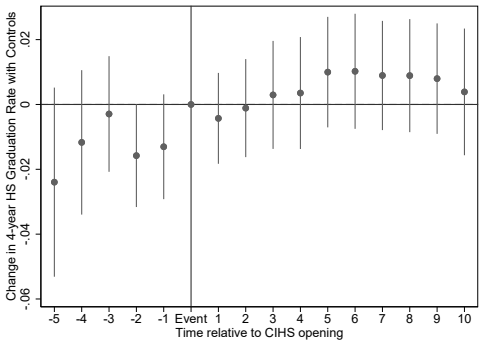

(b) Five-Year Graduation Rate



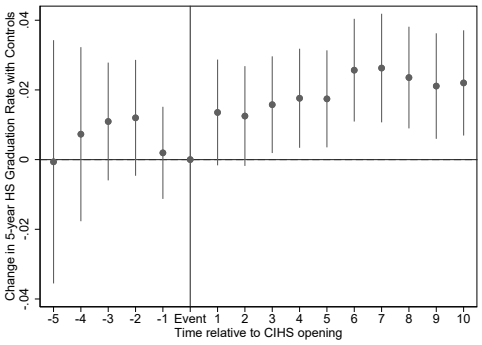

Notes: These graphs show how the high school graduation rate of traditional public school students changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Thus, we may not expect graduation rates to be impacted until four or five years after the first CIHS opened. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on school-level regressions with weights for school size.

Figure A.4: Change in TPS Graduation Rates Relative to CIHS Opening Conditional on Students' Baseline Characteristics

(a) Four-Year Graduation Rate



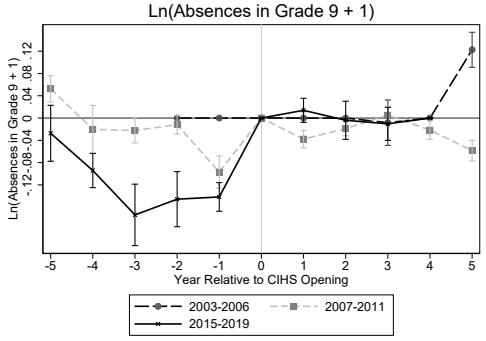

(b) Five-Year Graduation Rate



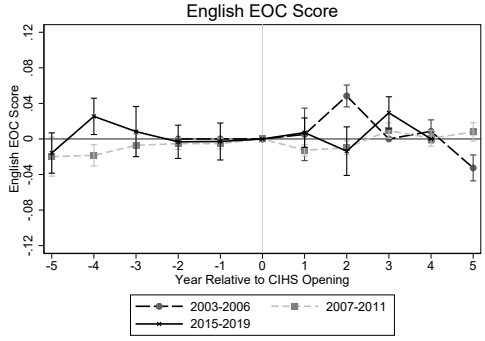

Notes: These graphs show how the high school graduation rate of traditional public school students changed after the first CIHS opened in their district. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Thus, we may not expect graduation rates to be impacted until four or five years after the first CIHS opened. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on school-level regressions with weights for school size and they condition on the baseline characteristics of students in the school, including share of students who are economically disadvantaged, share from an under-represented racial/ethnic minority background, and average 8th grade test scores in math and reading.

Figure A.5: Achievement Changes in Traditional Public Schools Relative to CIHS By Opening Time Period

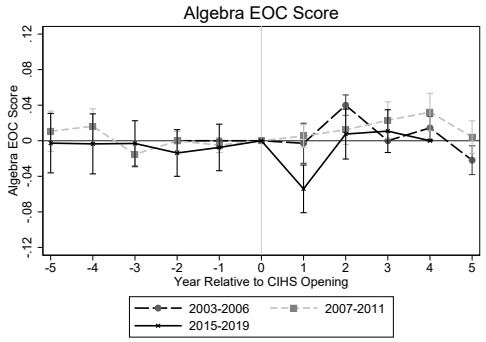
(a) 9th Grade Absences



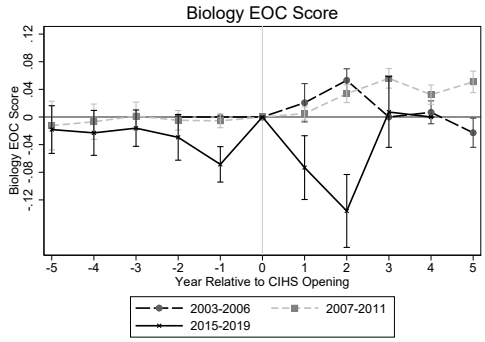

(b) English EOC Exam




(c) Algebra EOC Exam



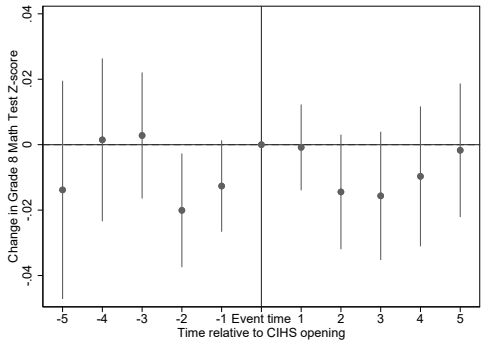

(d) Biology EOC Exam



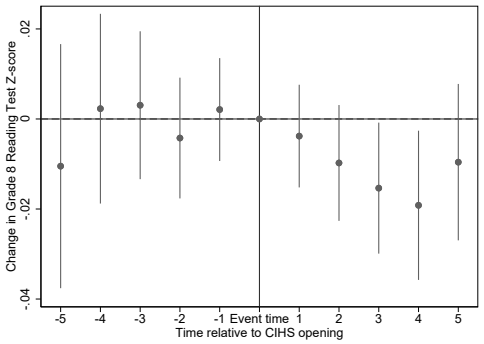

Notes: These graphs show how the achievement of traditional public school students changed after the first CIHS opened in their district separately by the period in which the CIHS opened. Event time is years relative to the year when the CIHS opened, where time 1 is the first year with a CIHS. All estimates are based on cohorts of entering 9th graders (so time 1 is the 9th graders the year the CIHS opened and time 2 is for the 9th graders in the following year). Not all outcomes (i.e. exams) occurred during 9th grade so the year does not necessarily correspond to the year of the outcome. Panel (a) is based on the natural log of student absences in grade 9 plus one. North Carolina requires all high schoolers to take an end of course math (algebra), English, and biology exam. The outcomes in panels (b)-(d) are the students' standardized end of course exam scores. Error bars represent the standard errors (clustered by school district and event). These estimates are from the stacked event study approach where never-treated units are used as controls. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background.

Figure A.6: District-level Changes in Student Composition Relative to CIHS Opening

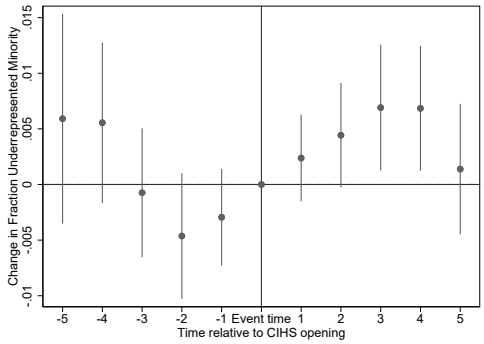
(a) 8th Grade Math Test Scores



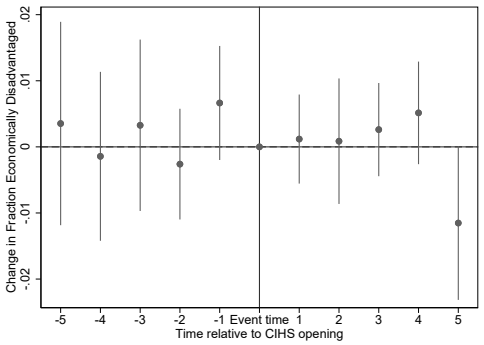

(b) 8th Grade Reading Test Scores




(c) Fraction Underrepresented Racial/Ethnic Minority



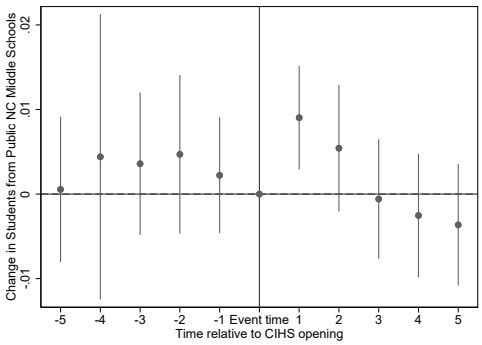

(d) Fraction Economically Disadvantaged



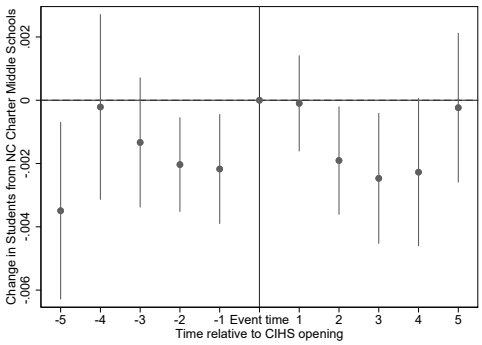

Notes: These graphs show how the composition of school districts changed when a CIHS opened. These estimates include CIHS students and broadly reflect whether the opening of the CIHS attracted new/more students to the districts (such as those who may have otherwise chosen a charter school). These are based on student-level regressions.

Figure A.7: Changes in the types of Middle Schools from which District High School Students are Drawn

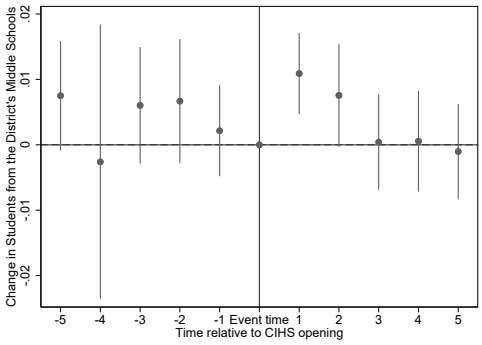
(a) From a North Carolina Public Middle School




(b) From a North Carolina Charter Middle School

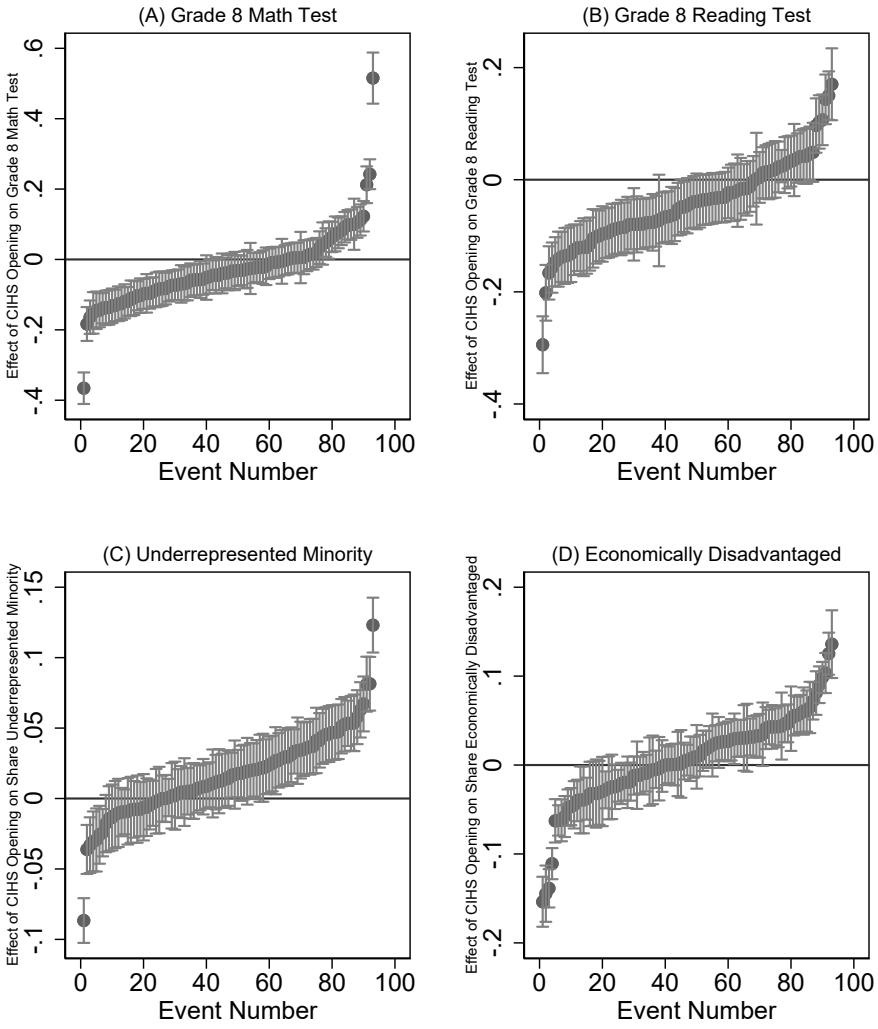



(c) From the District's Public Middle Schools



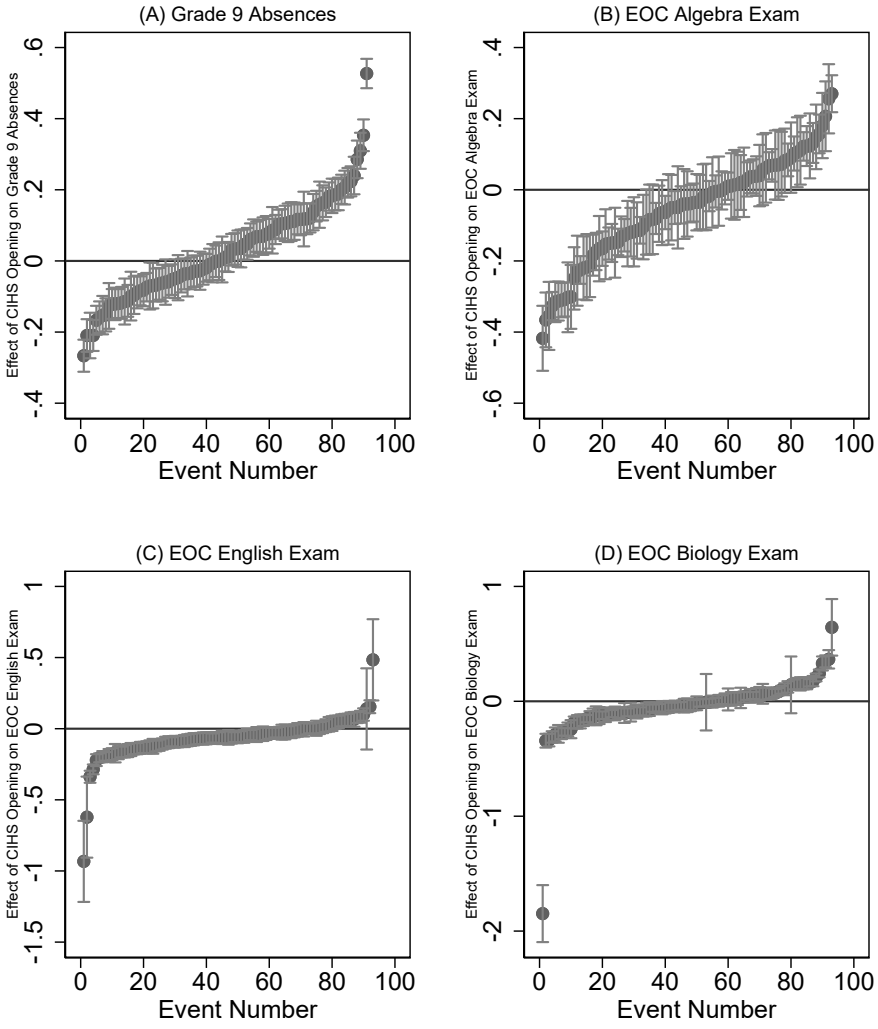

Notes: These graphs show how the share of students coming from a) public middle schools, b) charter schools, or c) the district's middle schools changes when a CIHS opens. These estimates include CIHS students and broadly reflect whether the opening of the CIHS attracted new/more students to the districts (such as those who may have otherwise chosen a charter school). These are based on student-level regressions.

Figure A.8: Estimates of Changes in TPS Composition for Individual Events



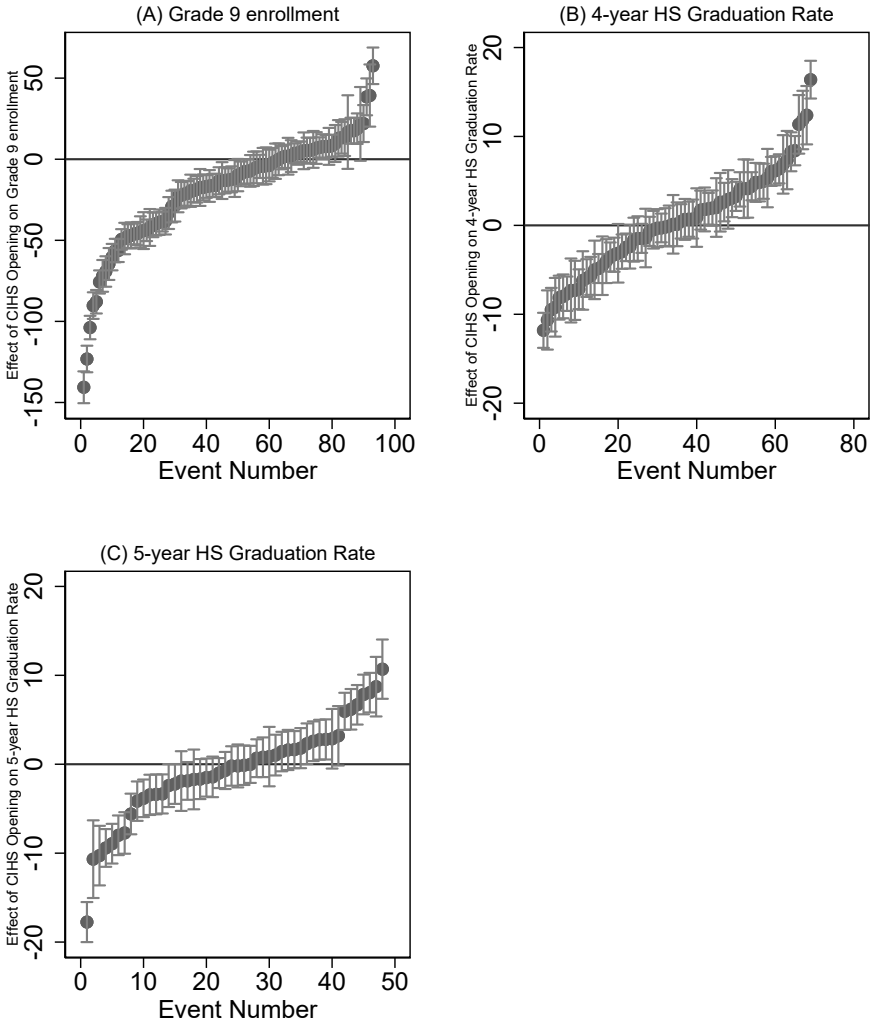

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest.

Figure A.9: Estimates of Changes in TPS Achievement for Individual Events Conditional on Students' Baseline Characteristics



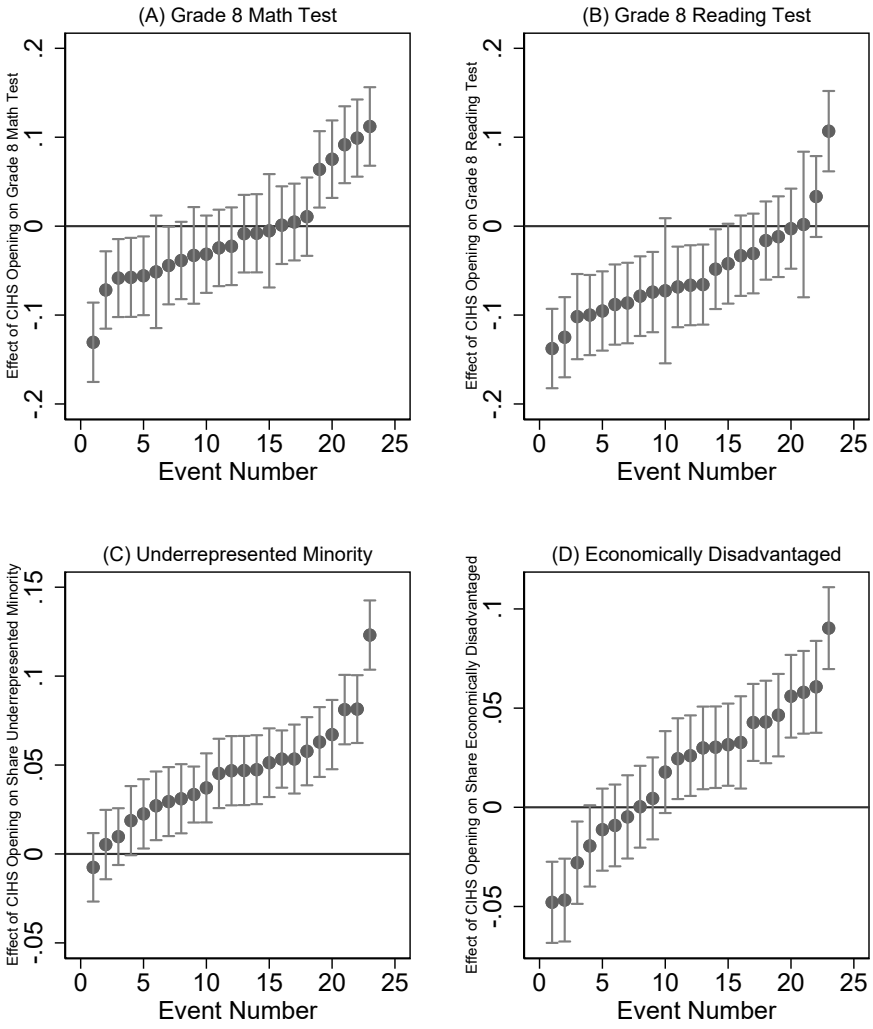

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background.

Figure A.10: Estimates of Changes in School Level Outcomes for Individual Events: Grade 9 Enrollment and High School Graduation



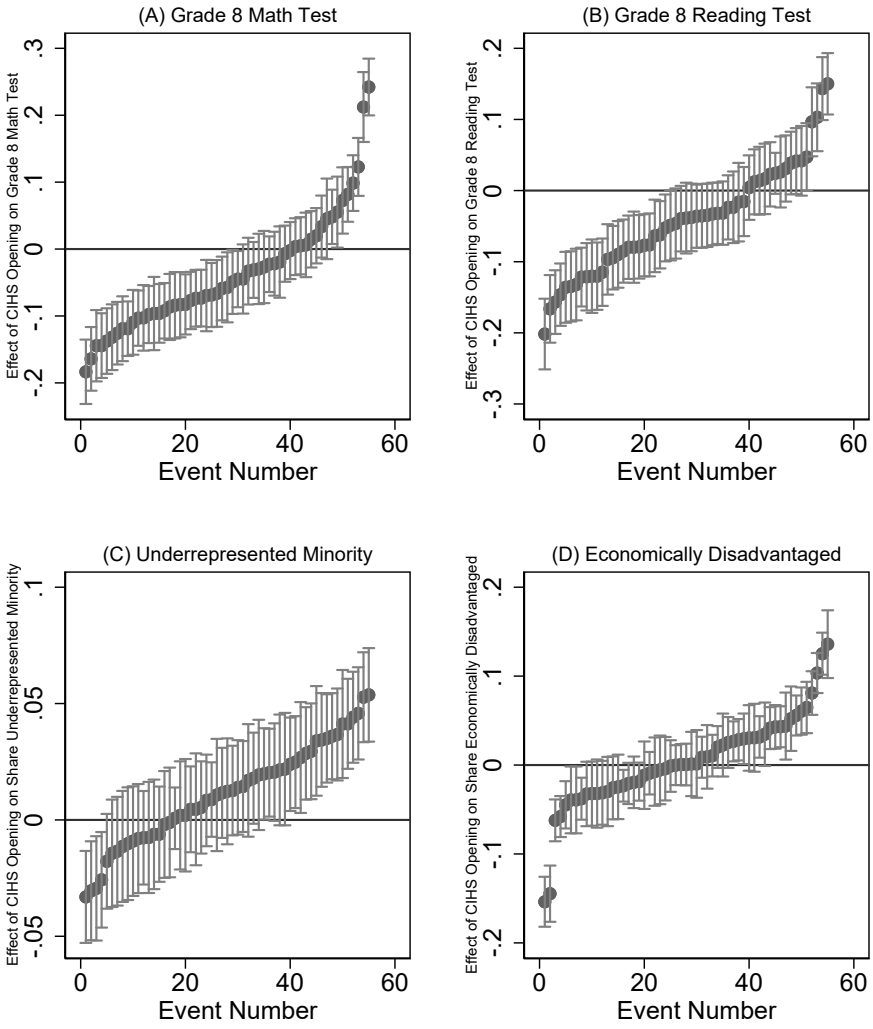

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on school-level regressions. The estimates for high school graduation condition on average 8th grade math and reading test scores, share economically disadvantaged and share of students from an underrepresented racial/ethnic minority background.

Figure A.11: Estimates of Changes in TPS Composition for Individual Events in the Early Time Period



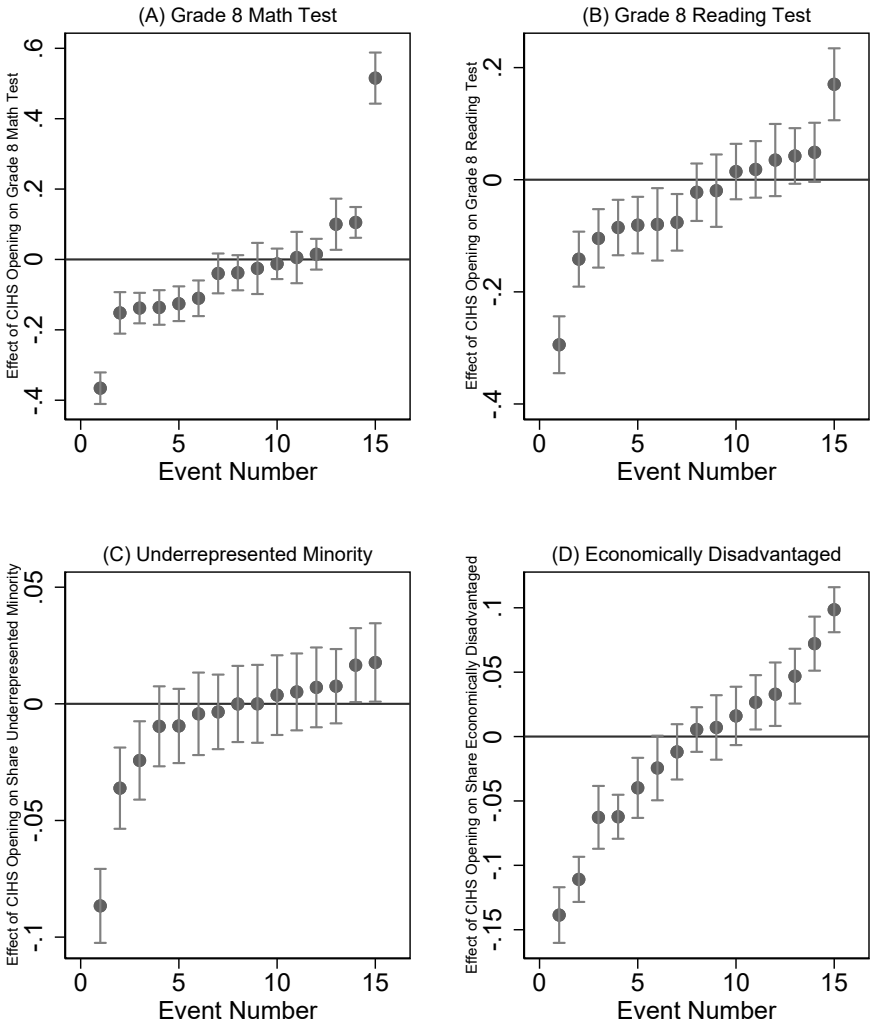

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. This figure shows estimates for events based on CIHS which opened from 2003-2006.

Figure A.12: Estimates of Changes in TPS Composition for Individual Events in the Middle Time Period



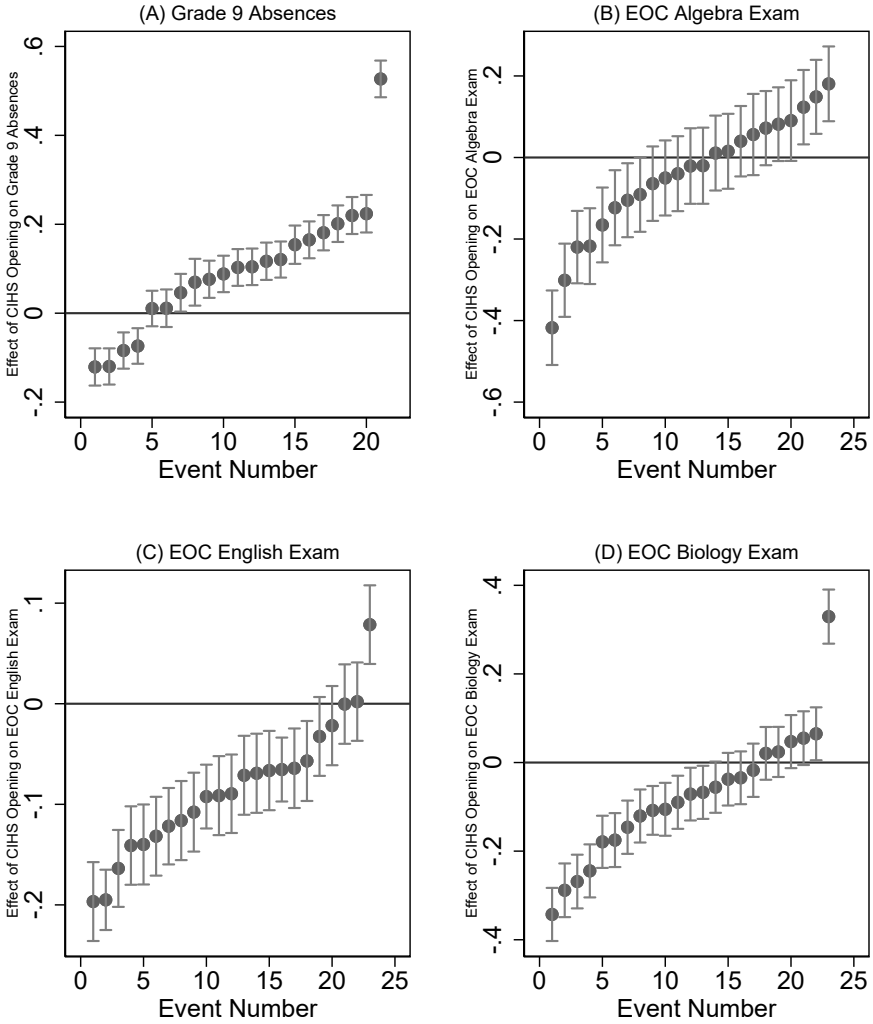

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. This figure shows estimates for events based on CIHS which opened between 2007 and 2011

Figure A.13: Estimates of Changes in TPS Composition for Individual Events in the Late Time Period



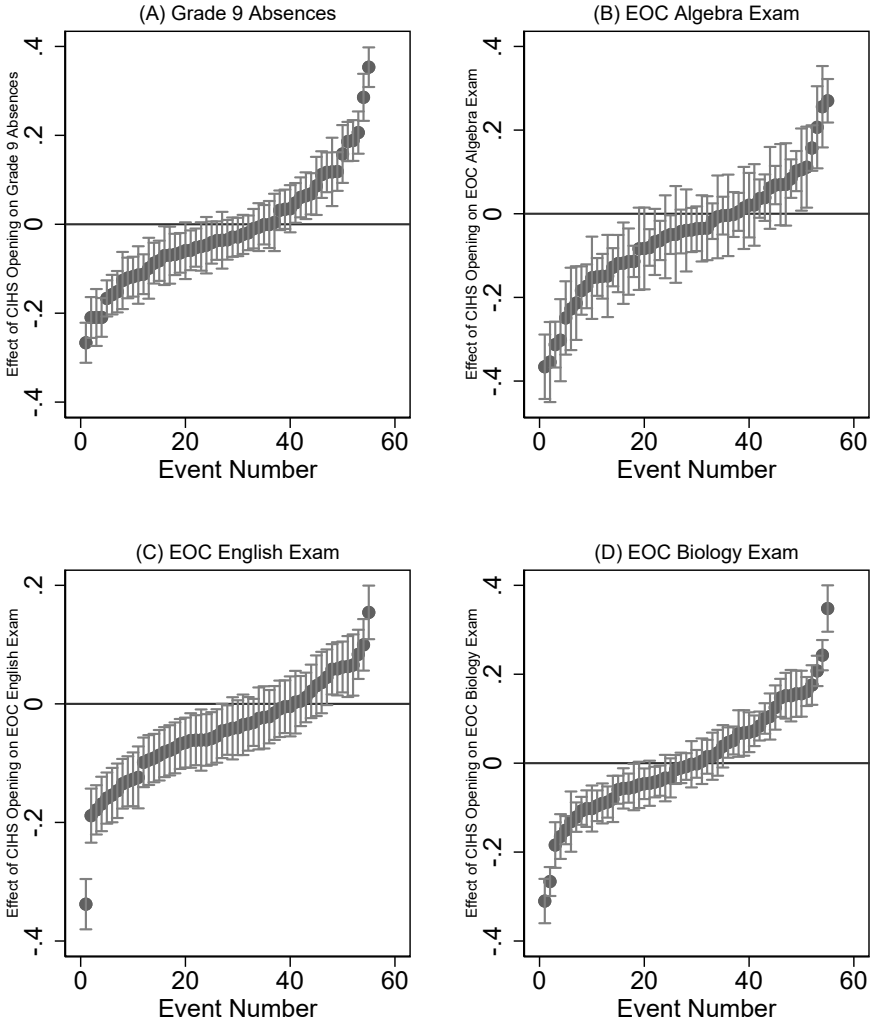

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. This figure shows estimates for events based on CIHS which opened from 2015-2019.

Figure A.14: Estimates of Changes in TPS Achievement for Individual Events in the Early Time Period Conditional on Students' Baseline Characteristics



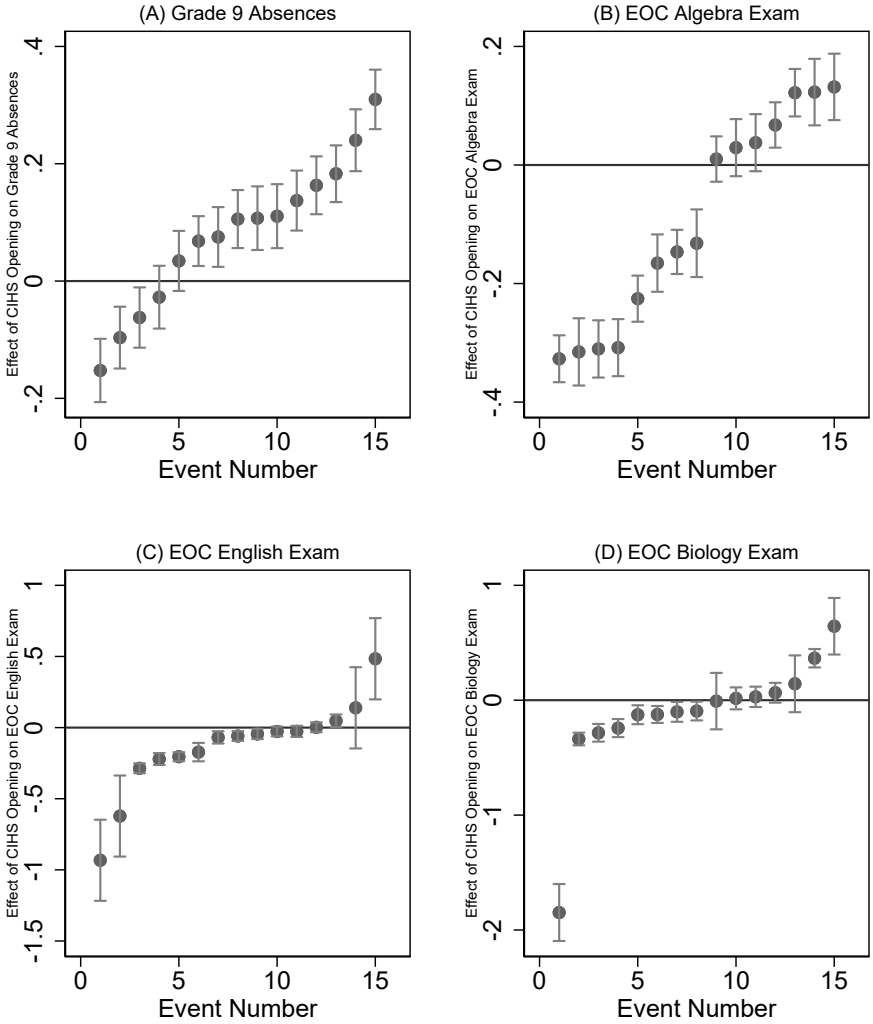

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background. This figure shows estimates for events based on CIHS which opened from 2003-2006.

Figure A.15: Estimates of Changes in TPS Achievement for Individual Events in the Middle Time Period Conditional on Students' Baseline Characteristics



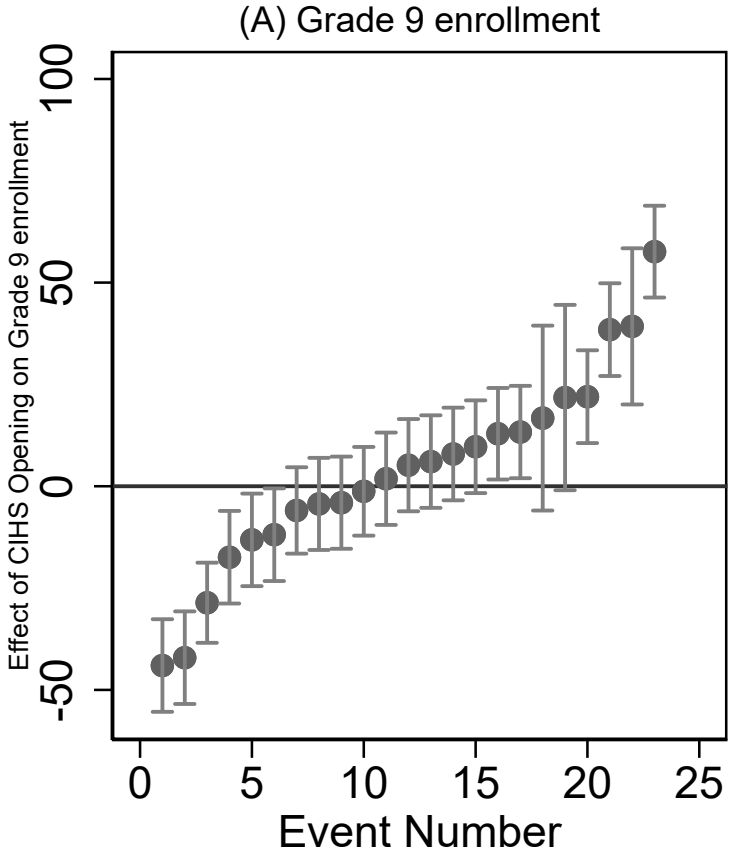

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background. This figure shows estimates for events based on CIHS which opened from 2007-2011.

Figure A.16: Estimates of Changes in TPS Achievement for Individual Events in the Late Time Period Conditional on Students' Baseline Characteristics



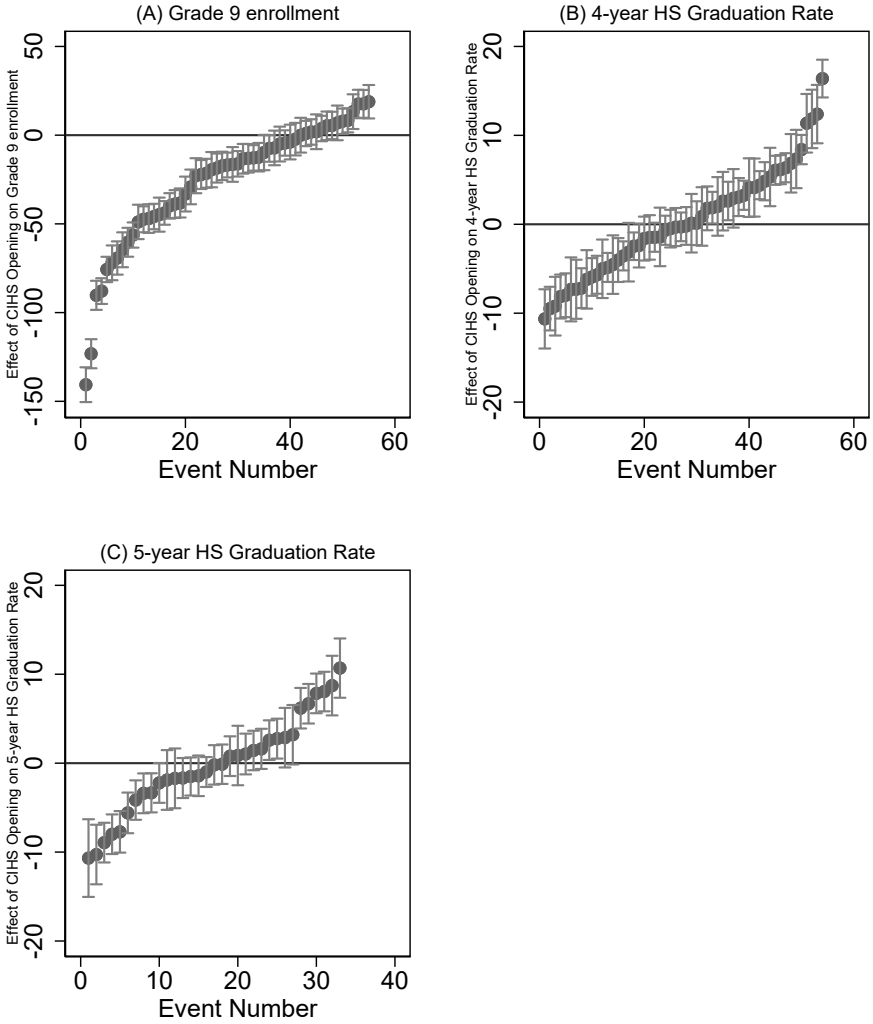

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on student-level regressions which condition on student's 8th grade math and reading test scores, economic disadvantage status and an indicator for whether they are from an underrepresented racial/ethnic minority background. This figure shows estimates for events based on CIHS which opened from 2015-2019.

Figure A.17: Estimates of Changes in School Level Outcomes for Individual Events in the Early Time Period



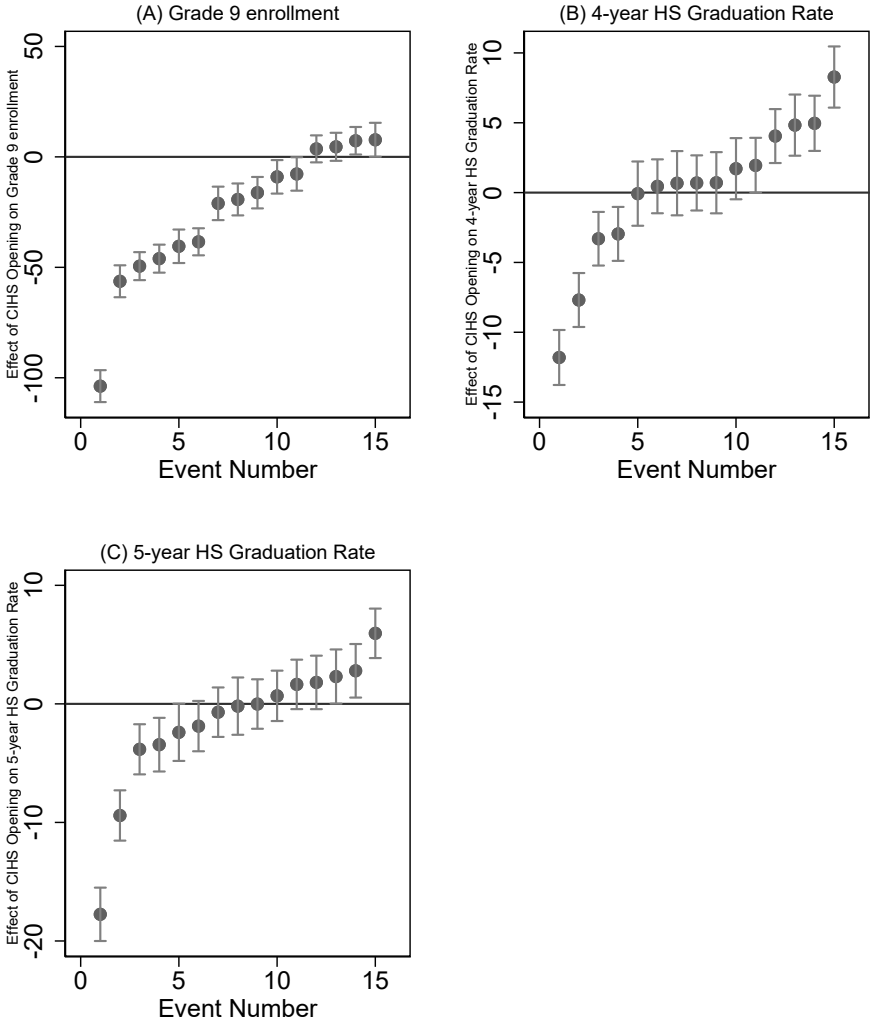

Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on school-level regressions. This figure shows estimates for events based on CIHS which opened from 2003-2006. Data on high school graduation rates was not available for this time period

Figure A.18: Estimates of Changes in School Level Outcomes for Individual Events in the Middle Time Period




Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on school-level regressions. The estimates for high school graduation condition on average 8th grade math and reading test scores, share economically disadvantaged and share of students from an underrepresented racial/ethnic minority background. This figure shows estimates for events based on CIHS which opened from 2007-2011.

Figure A.19: Estimates of Changes in School Level Outcomes for Individual Events in the Late Time Period




Notes: These figures show the point estimates and confidence intervals for estimated effects of each individual CIHS opening on the students in the relevant school district. These are the estimates from equation one, where effects are estimated separately for each event and where controls for individual student characteristics are included. These are based on a five year time window around the event and indicate the average effect over the five years after the CIHS opened for the relevant school district. All effects are sorted from smallest to largest. These are based on school-level regressions. The estimates for high school graduation condition on average 8th grade math and reading test scores, share economically disadvantaged and share of students from an underrepresented racial/ethnic minority background. This figure shows estimates for events based on CIHS which opened from 2015-2019.

Table A.1: LEAs with CIHS by School Year

| School Year | LEAS with access to first CIHS (1) | Cumulative Total LEAs (2) |
|---|---|---|
| 2001-02 | 1 | 1 |
| 2002-03 | 1 | 2 |
| 2003-04 | 2 | 4 |
| 2004-05 | 1 | 5 |
| 2005-06 | 20 | 25 |
| 2006-07 | 21 | 46 |
| 2007-08 | 9 | 55 |
| 2008-09 | 11 | 66 |
| 2009-10 | 15 | 81 |
| 2010-11 | 1 | 82 |
| 2015-16 | 2 | 84 |
| 2016-17 | 4 | 88 |
| 2017-18 | 5 | 93 |
| 2018-19 | 4 | 97 |

Notes: This table shows the number of local education agencies (i.e. school districts) that gained access their first CIHS in each year, and the cumulative total number of LEAs. Some CIHS served multiple LEAs so the total number of LEAs served is greater than the total number of CIHS. (Some LEAs also gained access to a second or third CIHS over this time period but these are excluded from these counts and our analyses.) No LEAs gained access to their first CIHS between the 2012-12 school year and 2014-15.

Table A.2: Characteristics of Traditional High Schools in the year before a CIHS opens

| | |
|---|---|
| Average 9th Grade Enrollment | 286 |
| 8th gr Math Scores | -0.176 |
| 8th gr Reading Scores | -0.160 |
| Share Underrepresented Racial Minority | 0.413 |
| Share Economically Disadvantaged | 0.407 |
| Share Chronically Absent in 8th gr | 0.169 |
| Observations | 397 |

Notes: This table shows the average characteristics of the TPS in the year before a CIHS that their students can access opens. This excludes charter schools (since they are excluded from our analyses). Math and reading test scores are based on incoming 9th graders average z-scores on the state test as 8th graders. Share economically disadvantaged and share underrepresented minority are based on incoming 9th graders. Chronically absent is defined as enrolled at least ten days and absent at least ten percent of days . Above averages weight each school equally (rather than weighting by student) so they show the characteristics of the average school rather than the average student.

Table A.3: Characteristics of CIHS and Traditional High Schools

| | 2006-2007 | | 2012-2013 | | 2018-2019 | |
|---|---|---|---|---|---|---|
| | CIHS | Traditional | CIHS | Traditional | CIHS | Traditional |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Number of Schools | 47 | 471 | 99 | 476 | 132 | 478 |
| Average 9th Grade Enrollment | 53.90 | 287.77 | 54.73 | 249.00 | 55.89 | 230.97 |
| 8th gr Math Scores | 0.204 | -0.151 | 0.276 | -0.202 | 0.281 | -0.142 |
| 8th gr Reading Scores | 0.282 | -0.136 | 0.300 | -0.173 | 0.455 | -0.209 |
| Share Underrepresented Minority | 0.348 | 0.427 | 0.397 | 0.413 | 0.427 | 0.451 |
| Share Economically Disadvantaged | 0.406 | 0.334 | 0.547 | 0.557 | 0.390 | 0.473 |
| Chronically Absent 8th gr | 0.142 | 0.219 | 0.053 | 0.189 | 0.080 | 0.222 |

Notes: This excludes charter schools (since they are excluded from our analyses). Math and reading test scores are based on incoming 9th graders average z-scores on the state test as 8th graders. Share economically disadvantaged and share underrepresented minority are based on incoming 9th graders. Chronically absent is defined as enrolled at least ten days and absent at least ten percent of days. Above averages weight each school equally (rather than weighting by student) so they show the characteristics of the average school rather than the average student.

Table A.4: Sample Characteristics

| | Unique Students in Sample | | Weighted by Frequency in Stacked Sample | |
|---|---|---|---|---|
| | Mean | N | Mean | N |
| | (1) | (2) | (3) | (4) |
| Grade 8 Math Test Z-score | 0.009 | 9,615,75 | 0.020 | 9,570,490 |
| Grade 8 Reading Test Z-score | 0.002 | 961,575 | 0.002 | 9,570,490 |
| URM | 0.375 | 961,575 | 0.300 | 9,570,490 |
| Economically Disadvantaged | 0.373 | 961,575 | 0.416 | 9,570,490 |
| Ln(Absences in Grade 9 + 1) | 1.635 | 778,144 | 1.641 | 7,960,640 |
| Algebra EOC Score | 0.069 | 788,038 | 0.057 | 7,815,214 |
| English EOC Score | 0.050 | 842,175 | 0.006 | 7,899,033 |
| Biology EOC Score | 0.049 | 750,814 | 0.002 | 7,0412,52 |

Notes: This excludes charter schools (since they are excluded from our analyses). Math and reading test scores are based on incoming 9th graders average z-scores on the state test as 8th graders. Share economically disadvantaged and share underrepresented minority are based on incoming 9th graders. Chronically absent is defined as enrolled at least ten days and absent at least ten percent of days. Students can appear multiple times in the stacked event study regressions so columns (3) and (4) show weighted averages by the number of times a student appears and the total number of observations.

Table A.5: CIHS Spillovers on Traditional Public School Student Achievement

| | Grade 9 Absences (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Within 5 Years | | | | | | |
| CIHS Open | 0.047*** | 0.005 | -0.036*** | -0.003 | 0.001 | 0.002 |
| | (0.011) | (0.021) | (0.007) | (0.012) | (0.005) | (0.005) |
| Observations | 7,960,640 | 7,815,214 | 7,899,033 | 7,041,252 | 8,301,273 | 7,707,439 |
| (B) Within 3 Years | | | | | | |
| CIHS Open | 0.035*** | 0.005 | -0.037*** | -0.004 | 0.004 | 0.004 |
| | (0.010) | (0.019) | (0.007) | (0.012) | (0.005) | (0.005) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 8,082,131 | 7,491,743 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three or five years after the CIHS first opened. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. These estimates do not condition on baseline student characteristics.

Table A.6: CIHS Spillovers on Traditional Public School Student Achievement by Time Period

| | Grade 9 Absence (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Open 2003 -2006 | | | | | | |
| CIHS Open | 0.127*** | -0.019 | -0.067*** | -0.060*** | | |
| | (0.013) | (0.020) | (0.011) | (0.017) | | |
| Observations | 1,928,610 | 1,900,438 | 1,926,026 | 1,715,817 | | |
| (B) Open 2007-2011 | | | | | | |
| CIHS Open | 0.011 | 0.016 | -0.025*** | 0.022 | 0.003 | 0.006 |
| | (0.013) | (0.028) | (0.008) | (0.015) | (0.006) | (0.006) |
| Observations | 4,630,599 | 4,542,664 | 4,591,700 | 4,091,906 | 4,734,875 | 4,374,737 |
| (C) Open 2015-2019 | | | | | | |
| CIHS Open | 0.050** | -0.029 | -0.040* | -0.040 | 0.004 | -0.004 |
| | (0.021) | (0.032) | (0.021) | (0.063) | (0.010) | (0.011) |
| Observations | 1,181,778 | 1,146,551 | 1,141,152 | 1,021,183 | 1,216,839 | 1,139,968 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three years after the CIHS first opened. Effects are estimated separately by the time period in which the district's first CIHS opened. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. High school graduation data was not available prior to 2006. These estimates do not condition on baseline student characteristics.

Table A.7: CIHS Spillovers on Traditional Public School Student Achievement by Peer Achievement Levels

| | Grade 9 Absence (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) By Average 8th Grade Test Scores | | | | | | |
| Peers Above Average | -0.038** | -0.032 | -0.037*** | 0.026 | -0.050*** | -0.071*** |
| | (0.016) | (0.020) | (0.010) | (0.017) | (0.012) | (0.012) |
| Peers Below Average | 0.068*** | 0.027 | 0.015* | -0.007 | 0.006 | 0.006 |
| | (0.017) | (0.020) | (0.009) | (0.014) | (0.011) | (0.010) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (B) Attendance | | | | | | |
| Peers Above Average | -0.052** | -0.052* | 0.009 | 0.019 | -0.013 | -0.017 |
| | (0.024) | (0.028) | (0.015) | (0.028) | (0.016) | (0.021) |
| Peers Below Average | 0.098*** | 0.061** | -0.020 | -0.006 | 0.020 | 0.018 |
| | (0.022) | (0.026) | (0.016) | (0.027) | (0.019) | (0.024) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (C) Algebra Scores | | | | | | |
| Peers Above Average | -0.029* | -0.064** | -0.071*** | -0.040* | -0.138*** | -0.174*** |
| | (0.016) | (0.025) | (0.010) | (0.023) | (0.019) | (0.021) |
| Peers Below Average | 0.054*** | 0.037 | 0.036*** | 0.021 | 0.071*** | 0.077*** |
| | (0.015) | (0.026) | (0.009) | (0.025) | (0.018) | (0.018) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (D) English Scores | | | | | | |
| Peers Above Average | -0.044** | 0.014 | -0.006 | 0.052** | 0.010 | -0.001 |
| | (0.018) | (0.024) | (0.013) | (0.022) | (0.011) | (0.009) |
| Peers Below Average | 0.057*** | 0.001 | -0.009 | -0.028 | -0.006 | -0.004 |
| | (0.014) | (0.023) | (0.012) | (0.019) | (0.009) | (0.008) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |
| (E) Biology Scores | | | | | | |
| Peers Above Average | -0.067*** | -0.091*** | -0.018 | -0.040** | -0.071*** | -0.095*** |
| | (0.020) | (0.026) | (0.012) | (0.018) | (0.014) | (0.014) |
| Peers Below Average | 0.084*** | 0.063** | 0.008 | 0.038* | 0.043*** | 0.047*** |
| | (0.021) | (0.029) | (0.012) | (0.021) | (0.011) | (0.010) |
| Observations | 7,740,987 | 7,589,653 | 7,658,878 | 6,828,906 | 7,369,332 | 6,757,958 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three years after the CIHS first opened. The indicator for the post period is interacted with information about peer achievement. In particular, for each student we measure the average achievement of the students at their school on the 8th grade test scores, end of course exams and attendance rates. Then we interact the post indicator with indicators for whether peer achievement is above or below average. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. High school graduation data was not available prior to 2006.

Table A.8: CIHS Spillovers on Traditional Public School Student Achievement by Neighborhood Characteristics

| | Grade 9 Absence (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Poverty Levels | | | | | | |
| Higher Poverty | 0.028 | 0.042** | 0.016* | 0.031 | -0.007 | -0.004 |
| | (0.020) | (0.019) | (0.009) | (0.019) | (0.015) | (0.012) |
| Lower Poverty | 0.042*** | -0.003 | -0.019*** | 0.007 | 0.008 | -0.001 |
| | (0.015) | (0.014) | (0.007) | (0.012) | (0.007) | (0.007) |
| Observations | 7,514,532 | 7,361,776 | 7,420,422 | 6,639,872 | 7,170,498 | 6,584,773 |
| (B) Household Income | | | | | | |
| Above State Median Inc | 0.070*** | 0.008 | -0.009 | -0.010 | 0.003 | -0.003 |
| | (0.016) | (0.016) | (0.009) | (0.014) | (0.007) | (0.007) |
| Below State Median Inc | 0.009 | 0.012 | -0.010 | 0.037*** | 0.004 | -0.001 |
| | (0.013) | (0.013) | (0.007) | (0.014) | (0.007) | (0.007) |
| Observations | 7,514,532 | 7,361,776 | 7,420,422 | 6,639,872 | 7,170,498 | 6,584,773 |
| (C) Share Underrepresented Minority | | | | | | |
| High Share URM | -0.020 | -0.040 | -0.063*** | 0.017 | -0.043*** | -0.046*** |
| | (0.015) | (0.028) | (0.014) | (0.023) | (0.016) | (0.016) |
| Low Share URM | 0.050*** | 0.019 | 0.001 | 0.012 | 0.013** | 0.007 |
| | (0.012) | (0.012) | (0.006) | (0.011) | (0.006) | (0.006) |
| Observations | 7,514,532 | 7,361,776 | 7,420,422 | 6,639,872 | 7,170,498 | 6,584,773 |
| (D) By Educational Attainment | | | | | | |
| High Share BAs | 0.040*** | 0.045* | 0.025** | 0.007 | 0.021 | 0.016 |
| | (0.015) | (0.026) | (0.013) | (0.021) | (0.014) | (0.014) |
| Low Share BAs | 0.038*** | -0.000 | -0.019*** | 0.012 | 0.000 | -0.005 |
| | (0.010) | (0.014) | (0.006) | (0.013) | (0.006) | (0.005) |
| Observations | 7,514,532 | 7,361,776 | 7,420,422 | 6,639,872 | 7,170,498 | 6,584,773 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the three years after the CIHS first opened. The indicator for the post period is interacted with information about the characteristics of the census tract in which the CIHS is located, so the estimate indicates the effect for schools in the noted type of neighborhood. Standard errors are clustered by event and school district. Neighborhood characteristics are based on the 2010 ACS. Higher poverty is an indicator for more than 20% of the census tract being below the poverty line, while lower poverty tracts are those with 20% or fewer of households below the poverty line. Above state median income means the average household income in the census tract is above the North Carolina average in 2010, while below state median income means the average household income is below this level. High share URM is an indicator for whether at least 50% of the census tract's population is Black or Hispanic. Low share URM is an indicator for whether 50% or less of the tract's population is Black or Hispanic. High Share BAs is an indicator for whether at least 20% of the census tract's population has a BA. Low Share BAs is an indicator for whether 20% or less of the census tract's population has a BA. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. High school graduation data was not available prior to 2006.

Table A.9: CIHS Spillovers on Composition of TPS Staff

| | Principal Experience (1) | Teacher Experience (2) | Teacher Pay (3) |
|---|---|---|---|
| (A) Within 5 Years | | | |
| CIHS Open | 0.004 | -0.183 | -39.417 |
| | (0.058) | (0.302) | (28.964) |
| Observations | 37,448 | 37,448 | 37,448 |
| (B) Within 3 Years | | | |
| CIHS Open | -0.003 | -0.037 | -36.267 |
| | (0.063) | (0.311) | (27.270) |
| Observations | 36,825 | 36,825 | 36,825 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on the teachers and principals employed at traditional public high schools in the district over the three or five years after the CIHS first opened. Experience is measured in years and teacher pay refers to annual salary in dollars. Standard errors are clustered by event and school district.

Table A.10: Impact of CIHS Opening on District Composition

| | Grade 9 Enrollment (1) | Grade 8 Math (2) | Grade 8 Reading (3) | Under-represented Minority (4) | Economically Disadvantaged (5) |
|---|---|---|---|---|---|
| (A) Within 5 Years | | | | | |
| CIHS Open | 32.983 | 0.002 | -0.009 | 0.004 | -0.002 |
| | (34.977) | (0.008) | (0.006) | (0.003) | (0.004) |
| Observations | 28,666 | 9,677,844 | 9,677,844 | 9,677,844 | 9677844 |
| (B) Within 3 Years | | | | | |
| CIHS Open | 23.047 | 0.003 | -0.006 | 0.004* | -0.001 |
| | (26.513) | (0.007) | (0.005) | (0.002) | (0.004) |
| Observations | 28,382 | 9,361,671 | 9,361,671 | 9,361,671 | 9,361,671 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' enrollment and the characteristics of enrolled students over the three or five years after the CIHS first opened. Standard errors are clustered by event and school district. Grade 9 enrollment is measured at the school level and all other outcomes are at the student level. Grade 8 math and reading test scores are standardized z-scores from the NC state tests. These estimates include CIHS students.

Table A.11: Robustness Checks for Estimated Spillovers on TPS Enrollments

| | Grade 9 Enrollment (1) | Grade 8 Math (2) | Grade 8 Reading (3) | Under-represented Minority (4) | Economically Disadvantaged (5) |
|---|---|---|---|---|---|
| (A) Include Not Yet Treated | | | | | |
| CIHS Open | -0.531 | -0.023*** | -0.020*** | 0.003** | 0.016*** |
| | (1.343) | (0.003) | (0.003) | (0.001) | (0.001) |
| Observations | 1,338,833 | 16,921,857 | 16,921,857 | 16,921,857 | 16,921,857 |
| (B) Without Linear Trend | | | | | |
| CIHS Open | -15.478 | -0.037*** | -0.053*** | 0.025*** | 0.018*** |
| | (4.910) | (0.008) | (0.007) | (0.003) | (0.004) |
| Observations | 833,480 | 9,570,490 | 9,570,490 | 9,570,490 | 9,570,490 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' enrollment and the characteristics of enrolled students over the five years after the CIHS first opened. Standard errors are clustered by event and school district. Grade 9 enrollment is measured at the school level and all other outcomes are at the student level. Grade 8 math and reading test scores are standardized z-scores from the NC state tests. Panel A includes students in not yet treated districts as controls (while the main specifications only use never treated units as controls). Panel B does not include the linear time trend based on how outcomes were trending in the pre-period.

Table A.12: Robustness Checks for Estimated Spillovers on TPS Student Achievement conditional on Baseline Characteristics

| | Grade 9 Absences (1) | EOC Algebra (2) | EOC English (3) | EOC Biology (4) | Graduate 4 Years (5) | Graduate 5 Years (6) |
|---|---|---|---|---|---|---|
| (A) Include Not Yet Treated | | | | | | |
| CIHS Open | 0.071*** | 0.000 | 0.001 | -0.024*** | 0.0001*** | 0.0001*** |
| | (0.003) | (0.003) | (0.002) | (0.005) | (0.0000) | (0.0000) |
| Observations | 14,580,023 | 13,682,647 | 13,099,093 | 11,720,357 | 972,181 | 907,340 |
| (B) Without Linear Trend | | | | | | |
| CIHS Open | 0.052*** | 0.015 | -0.011* | 0.042*** | 0.0001*** | 0.0002*** |
| | (0.011) | (0.012) | (0.006) | (0.011) | (0.0001) | (0.0001) |
| Observations | 7,960,640 | 7,815,214 | 7,899,033 | 7,041,252 | 676,386 | 613,836 |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' achievement in high school over the five years after the CIHS first opened. These models control for the TPS students'8th grade test scores in math and reading, an indicator for whether they are from an underrepresented racial/ethnic minority background, or economically disadvantaged. Standard errors are clustered by event and school district. Grade 9 absences are measured as the natural log of absences plus one (to deal with large outliers). Due to data limitations, high school graduation rates (in four or five years) are measured at the school level and estimates are weighted by school size. For estimates of effects on graduation rates, treatment is defined as three years after the district's first CIHS opened, since the incoming 9th graders need at least three years to graduate. Panel (A) includes students in not yet treated districts as controls (while the main specifications only use never treated units as controls). Panel (B) does not include the linear time trend based on how outcomes were trending in the pre-period.

Table A.13: Results based on Alternative DiD Estimators with controls

| | EOC Math Exam (1) | EOC English Exam (2) | EOC Bio Exam (3) | Grade 9 Absences (4) |
|---|---|---|---|---|
| (A) Borusyak, Javarel & Spiess | | | | |
| CIHS Open | 0.022 | -0.014 | -0.011 | 0.029 |
| | (0.029) | (0.010) | (0.037) | (0.019) |
| (B) Callaway & Sant'Anna | | | | |
| CIHS Open | 0.004 | -0.016 | -0.036 | 0.065** |
| | (0.079) | (0.031) | (0.056) | (0.043) |

Notes: (* p<.10 ** p<.05 *** p<.01). These estimates show the average effects of a CIHS opening in the school district on traditional public school students' enrollment and the characteristics of enrolled students over the five years after the CIHS first opened. Standard errors are clustered by event and school district. These models control for the TPS students' 8th grade test scores in math and reading, an indicator for whether they are from an underrepresented racial/ethnic minority background, or economically disadvantaged. The estimates in panel (A) are based on the estimator described in Borusyak, Javarel & Spiess (2021) and STATA's did_imputation command. The estimates in panel (B) are based on the approach described in Callaway & Sant' Anna (2021) and their R package "did". These estimates are based on school-level values because of computational limitations.