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Building Better Bridges to Life After High School: Experimental Evidence on Contemporary Career Academies

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Abstract

Modern career academies aim to prepare students for college and the labor market. This paper examines the profile of students entering such academies in one school district and estimates causal effects of participation in one of the district's well-regarded academies on a range of high school and college outcomes. Using rich administrative data from the Wake County Public School System, we find that students who enter contemporary career academies are generally higher performing than their non-academy peers. Further, we document that Hispanic students and those with limited English proficiency are somewhat less likely to enroll than other students, even after we control for differences in prior academic achievement and high school choice sets. Exploiting the lottery-based admissions process of one technology-focused academy, we then estimate causal effects of participation in a career academy on high school attendance, achievement, and graduation, as well as college-going. We find that enrollment in this academy increases the likelihood of high school graduation and college enrollment each by about 8 percentage points, with the attainment gains concentrated among male students. We also find that academy participation reduces 9th grade absences but has little influence on academic performance, AP course-taking, or AP exam success during high school. Analysis of candidate mechanisms suggests that roughly one fifth of the overall high school graduation effect can be attributed to improved student engagement in high school.

I. Introduction

Over the last few decades, the high school graduation rate in the United States has barely budged (NCES, 2015). Gaps in completion by race, ethnicity, and gender persist despite marked gains made by minority students in the early 2000s (Murnane, 2015). Between 15 and 20 percent of adolescents do not complete high school and the graduation rate for females exceeds that of males by about 12 percentage points (Murnane, 2015). Those who fail to complete high school fare very poorly in the labor market and future prospects are dim. Demand for individuals with at least some form of postsecondary training has expanded and labor market projections forecast continued growth for such “middle-skill” jobs (Carnevale, Smith, & Strohl, 2013; Holzer, 2012, 2014). An unintended consequence of recent policy discussions that fiercely focus on college-going and “match” (e.g., Smith, Pender, & Howell, 2013) is that they divert attention from the many students who never confront college choices because they fail to complete high school.

Despite the importance of educational attainment for individuals in terms of skill acquisition and earnings as well as for the country as a whole in terms of economic growth (Hanushek & Woessmann, 2008) and enhanced civic engagement (Dee, 2004), there is a paucity of solid evidence on interventions capable of improving high school completion (Murnane, 2015). Given thin evidence about a key social goal, research that explores promising high school innovations in a manner capable of uncovering causal effects on completion (or lack thereof) is critical to future human capital development.

Career academies represent one initiative aimed at improving students’ attachment to and performance in high school while simultaneously exposing them to options for postsecondary study and work. Such academies are within-school, multi-year programs that integrate career and technical education (CTE) courses, project-based learning, internships, and other activities organized around specific career themes into a college-prep curriculum (Levesque et al., 2008). They are intended to improve student engagement in high school by directly linking schoolwork to local employment contexts and the kinds of jobs students might later pursue. While the concept of career academies is not new, the students they serve, their curricular foci, and their goals have evolved alongside shifts in the surrounding labor market and policy landscapes.

There is little work exploring the causal effects of participation in contemporary career academies. The strongest evidence comes from a study of academies in operation during the 1990s (Kemple & Willner, 2008, 2011; Kemple, 2001, 2004). Since that time, however, the economic and policy contexts in which career academies function have shifted dramatically. The Great Recession swept across the United States during the late 2000s. The academies of the 1990s operated in an era prior to No Child Left Behind (NCLB) and its attendant high-stakes accountability requirements and prior to the unveiling of the Common Core and development of "career- and college-ready" standards for all students. Further, the foci and components of career academies themselves have changed, attracting a much greater variety of students in terms of interests and academic ability. Given these marked shifts, findings from over two decades ago may not apply to today's students attending career academies.

In this paper, we use rich administrative data from the Wake County Public School System (WCPSS) in North Carolina (henceforth "Wake County") to characterize the profile of students enrolling in that district's extensive system of career academies. We are particularly interested in gaps in career academy participation by gender, race and ethnicity. Second, to estimate causal effects of participation in one academy, the Academy of Information Technology (AOIT) within Apex High School, we exploit the fact that enrollees were admitted by lottery. We estimate causal effects of enrollment in this academy on measures of high school engagement, performance, and graduation, as well as college enrollment. In 2013, AOIT was recognized by the National Academy Foundation as an "academy of excellence." Thus, while focused on one academy, our study of this career academy will serve as a severe test: that is, if we find little effect of participation in a modern career academy with well-developed program components, solid implementation, and a clear counterfactual on our outcomes of interest, we should be skeptical that less well-developed programs would lead to meaningful effects.

To preview results, we find that students who enroll in contemporary career academies are generally higher performing than their non-academy peers. We document small gaps in the propensity to enroll in a career academy by ethnicity and English proficiency status that cannot be explained by differences in prior academic achievement or high school choice sets. Specifically, Hispanic and Limited English Proficiency (LEP) students are less likely to enroll in a career academy than their non-Hispanic white, and non-LEP counterparts, respectively.

We then exploit the lottery-based admissions process of one technology-focused academy to estimate causal effects of career academy participation on high school attendance, achievement, and graduation, as well as college-going. We find that enrollment in this academy increases the likelihood of high school graduation and college enrollment each by about 8 percentage points. These attainment gains are concentrated among male students. We also find that academy participation reduces 9^{th} grade absences but has little effect on academic performance and rates of AP course-taking during high school. Analysis of intermediate outcomes suggests that roughly one fifth of the overall high school graduation effect can be attributed to improved student engagement in high school.

The paper proceeds as follows. In the next section, we provide some basic background on career and technical education with a focus on its use in school-based career academies, synthesize existing literature on the effects of career academies, and situate our contribution in that literature. Section III chronicles the development of career academies in Wake County in North Carolina and provides a descriptive overview of student access to career academies. Section IV details the data we use to examine the causal effects of participating in a modern career academy on a range of educational outcomes. Section V describes our empirical approach to estimating those effects. Section VI presents our main findings; and Section VII concludes.

II. Existing Literature

A. Brief Background on Career and Technical Education

CTE plays an integral role in the educational experience of many American high school students. About nine out of every 10 high school students earn at least one CTE credit before graduating, while a fifth complete a specialized occupational concentration (Levesque et al., 2008). Existing research suggests links between CTE participation and improved mathematics skills (Stone, Alfeld, & Pearson, 2008), as well as higher attendance rates, completion rates, and earnings (Bishop & Mane, 2004), especially for students of low socio-economic status (Rabren, Carpenter, Dunn, & Carney, 2014). Using data from the NSLY97, a recent study finds that vocational coursework is associated with lower rates of attendance at four-year colleges, but that advanced vocational courses are associated with increased earnings, at a rate of 2 percent per advanced course (Kreisman & Stange, 2015). The authors recommend focusing policy efforts on depth of CTE-related course offerings rather than breadth.

The only study to explore effects of CTE coursework on educational outcomes in the modern era of high-stakes accountability, college- and career-ready standards, and the expansion of middle-skill jobs is Dougherty (2016). He uses data from Massachusetts to examine the effects of participating in CTE via regional vocational and technical high schools on measures of academic performance and high school completion. In contrast to regular high schools in which some students elect to take CTE courses, all students in these regional vocational schools participate in some form of CTE. Dougherty (2016) finds that participating in CTE in this fashion boosts expected, on-time high school graduation rates by between 3 and 5 percentage points for higher-income students and roughly 7 percentages points for their more disadvantaged peers. He speculates that this effect of "high-quality" CTE may be partially due to reduced stigma associated with CTE (relative to more "academic" courses), since all students participate. Dougherty (2016) does not explore the effects of participation in high-quality CTE on early postsecondary outcomes. Sequences of CTE courses that are organized around career themes and responsive to local labor markets may provide targeted bridges to meaningful postsecondary training and credential attainment (Cullen, Levitt, Robertson, & Sadoff, 2013).

Regional schools that focus on CTE are not the only form in which concentrated, cohort-based exposure to CTE occurs. Many occupational concentrators, students who earn at least three credits in a specified CTE track, are doing so through school-based "career academies." Career academies took root in Philadelphia in the late 1960s, and expanded through a network developed by NAF in the early 1980s (Stern, Dayton, & Raby, 2010). Current estimates place the number of career academies across the United States between 6,000 and 10,000 (Dayton, 2010).

Career academies are designed to expose students to relevant academic content, improve engagement, and facilitate the transition from high school to college and the workforce, all within small learning community environments (Orr, Bailey, Hughes, Karp, & Kienzl, 2007). Modern academies are embedded within high schools and offer a cohort-based sequence of courses that constitute specialized training in a particular career area (e.g., information technology, engineering, finance, health sciences, agricultural and natural resources). These academies tend to offer students enhanced non-academic supports such as interview practice and work-based learning opportunities (Visher, Altuna, & Safran, 2013). Thus, taken together, these prongs of career academy participation are hypothesized to improve performance and engagement in high school and strengthen transitions to college and work.

B. Effects of Career Academies on Educational and Labor Market Outcomes

The most compelling evidence on the causal effects of career academies comes from a series of studies conducted by MDRC. Researchers at MDRC exploited lottery-based assignments to career academies to measure impacts on high school, postsecondary, labor market, and familial outcomes for nearly 1,800 students (54 percent of whom attended an academy) from nine high schools over a 15-year period, from 1993 through 2008 (Kemple & Willner, 2008). All told, findings from this work paint a mixed picture of career academy effects on outcomes along the trajectory from adolescence to adulthood. On average, the academies had no effects on high school graduation rates and initial postsecondary outcomes (Kemple, 2001). Over the longer term, males in the academy group experienced sustained increases in real yearly earnings (i.e., an average increase of about $3,700 per year or 17 percent) as well as an increased propensity to form and sustain families (Kemple & Willner, 2008).

Findings from other studies raise additional questions about how participation in career academies affects high school and postsecondary educational outcomes. For example, a review of school-choice options in Chicago (Cullen, Jacob, & Levitt, 2005) suggests that career academies may indeed influence rates of high school graduation, not solely antecedent intermediate outcomes (e.g., persistence and credits earned). There is no consensus on the effects of career academies on students' early postsecondary experiences. While MDRC found no effects on college enrollment, other studies provide correlational evidence that participation in older career academies may have enhanced postsecondary academic performance, encouraged persistence, and boosted rates of completion (Maxwell, 2001), especially for at-risk students (Maxwell & Rubin, 2002) and those who completed select occupational concentrations (Neumark & Rothstein, 2006).

In the years following MDRC's culminating study (in 2008), the United States experienced its greatest economic downturn since the Great Depression. Given the influence of that recession on the postsecondary landscape (Long, 2014) and labor market (Farber, 2011), along with a renewed emphasis to prepare all students for college and work, we should not expect the effects of contemporary career academies, nor the student populations that enroll in such academies, to be similar to those of the mid-1990s.

C. Contributions

Our work contributes to the literature on career academies and student transitions in three ways. First, we provide contemporary evidence on student selection into academy programs as they move from middle to high school using rich administrative data from a large, diverse school district that has recently invested in the expansion of career academies. We examine gaps in career academy participation by gender, race and ethnicity and explore whether such demographic characteristics relate to choices of specific types of academies (e.g., information technology, science, services). Second, we provide causal estimates of the effects of enrollment in a well-regarded modern career academy on a variety of educational outcomes. In doing so, we use a variety of linked, student-level administrative data to construct our outcomes of interest – thereby obviating concerns related to survey-based outcomes used by prior studies such as the non-representativeness of respondent populations, differential attrition, and reporting bias.[1]

[1] While MDRC was able to achieve excellent response rates (i.e., roughly 80 percent of the full sample), those outcomes remain self-reported and subject to potential biases (e.g., recall bias). In a technical appendix

Third, we explore a number of candidate mediators through which any effects on high school and college-going may operate. That is, if academy enrollment increases the likelihood of high school graduation, what are the likely channels through which that effect operates? Increased academic performance? Better access to advanced, relevant courses? Enhanced student engagement? Such analyses shed suggestive light on the mechanisms through which any effects of participation in a highly regarded modern career academy may operate.

III. Career Academies in Wake County

Wake County currently operates 20 career academies in 14 high schools.[2] The district launched its first career academy, the Health Science Academy at Athens Drive High School, in 1990. Throughout the 1990s and 2000s career academy growth was modest, with the district adding only six new academies by 2010. Since then, however, the total number of academies has grown rapidly from seven to 20. The most common concentration among academies is in the area of health sciences (three academies), followed by information technology, energy, engineering, and digital media (two academies each). All together, the distribution of concentrations reflects the 18 different occupational areas specified by the U.S. Department of Education (Levesque et al., 2008).

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accompanying MDRC's evaluation reports, the authors explore if and how survey respondents differed from non-respondents. They found that "in the respondent sample students in the high-risk subgroup were underrepresented and students in the low-risk subgroup were overrepresented" (Kemple, 2001, p. 2). While there were no subsequent differences in the characteristics of these respondents by treatment group (i.e., academy group versus the non-academy group), the fact that (all) respondents differed meaningfully from the population demands caution when applying MDRC's estimated effects of career academies to all high-risk (or all low-risk) students in the full analytic sample. That is, MDRC estimated causal effects for the *respondent* population. These effects do not necessarily reflect what the causal effects of career academies would be for all students (or any subgroup of interest) in the full sample.

[2] Appendix Table A2 for a full list of Wake County career academies by launch year.

A. Profile of Student Participation in Wake County Career Academies

Figure 1 depicts the geographic distribution of career academies across the district. These academies are arrayed across the county's vast geographic footprint – more than 800 square miles – and are located in high schools that span the socioeconomic spectrum. Wake County tends to be relatively more affluent in the west and north and less affluent in the east and south.

To determine how recent academy enrollees compare to their non-academy peers, we use administrative data from Wake County on cross-sections of all first-time 9th graders in 2014-15 and 2015-16.[3] The vast majority of academies admit students in the 9th grade. In Table 1, we present descriptive statistics that compare the traits of all Wake County 9th graders in these years to 9th graders who enroll in career academies of any type and separately by thematically grouped areas of concentration. A few patterns emerge. First, as a general group, career academy enrollees represent roughly 5 percent of district-wide 9th grade enrollment and appear less likely to be minority and more likely to be male, relative to all 9th graders in the district. Second, and in contrast to much of the work on CTE, academy enrollees are higher achieving than their peers within the same school who did not enroll in a career academy. The fact that career academy enrollees are positively selected suggests that the view held by parents, families, and schools concerning CTE (at least in the form of career academies) is changing from one that sees such academies as targeting underperforming students to an initiative that has the potential to benefit a broad swath of fledgling high school students.

We formalize our analysis of transitions into career academies in Table 2. We begin with an analytic sample of first-time 8th graders in 2013-14 and 2014-15. We then model enrollment in a career academy in 9th grade as a function of demographic characteristics, achievement

[3] The academic year 2014-15 is the first year in which we can identify academy enrollees in the district-wide administrative data.

measures. We estimate linear probability modes via OLS. We are particularly interested in gaps in participation likelihood by gender, race and ethnicity. In column 1 of Table 2, we begin with the simplest specification that includes measures of a student's gender, race, special education status, English proficiency status, and indicators for 8th grade cohort year. In column 2 we add controls for 8th grade math and reading scores along with an indicator denoting whether the student was identified as "academically gifted" in either math or reading.[4] Finally, in column 3, we add middle school fixed effects. These fixed effects control for any access disparities that are driven by high school choice sets associated with school assignment policies. In columns 4 through 7, we examine choices among enrollees about career academies of different types using the fully saturated model from column 3.

Estimates in column 1 suggest that female, black, Hispanic, LEP, and special education students are all less likely to enroll in a career academy, relative to their male, white, non-LEP, and non-special-education counterparts, respectively. Controlling for academic achievement through the use of 8th grade test scores eliminates most of the racial and ethnic gaps and reduces other gaps. Further restricting our comparison to students with equivalent 8th grade test scores in the same middle school does not further diminish gaps in career academy participation by ethnicity or LEP status: Hispanic (LEP) students are about 1 percentage point (2 percentage points) less likely to enroll in a career academy, relative to their non-Hispanic, white (non-LEP) counterparts. Note that students with special education needs are equally likely to attend a career academy as those without such needs. Findings in columns 4 through 7 indicate that conditional

[4] We standardized all test scores across the district by subject, grade, and year. The traditional pathway to gifted identification in Wake County requires students entering grade 3 to score at or above the 95th percentile on the Cognitive Abilities Test (CogAT) or the Iowa Test of Basic Skills (ITBS). Students can only qualify through ITBS testing if they score at or above the 85th percentile on the CogAT. Once students meet qualifying cutoffs, they are referred to the district's School-Based Committee for Gifted Education for final determination. The district has implemented four additional pathways to gifted identification since 2014-15.

on enrolling in any career academy, female students are much more likely to enter an academy focused on science and less likely to enter an engineering academy, relative to their male counterparts. Black students are more likely to choose academies with an engineering focus and less likely to enter academies with largely non-STEM foci (i.e., the “Other Focus” category), relative to their white, non-Hispanic counterparts. Finally, LEP students are much more likely to choose these “other,” largely non-STEM career academies and much less likely to enter science-focused academies.

These patterns are of interest in their own right. In addition, however, the positive selection of academy enrollees relative to their peers also makes it difficult to assess the causal effects of participation in a modern career academy on outcomes of interest such as high school graduation or college-going. The problem is that simple observational analysis cannot compellingly purge the influence of a student’s own characteristics and ability from her participation in a career academy in terms of effects on educational outcomes. In the next section of the paper, we exploit the fact that interest in one academy, Apex Academy of Information Technology (AOIT), has outpaced capacity for several years. As a result, AOIT has admitted students to its academy by lottery since the 2009-10 academic year.[5] We use this lottery to approximate a randomized controlled trial and identify the causal effects of participation in AOIT on measures of engagement and performance in high school, high school graduation, and college-going.

B. Academy of Information Technology (AOIT) and the Treatment-Control Contrast

AOIT is a career academy housed within Apex High School and located in the southwest part of the district. Only rising 9th graders assigned to Apex High School may apply for

[5] Appendix Table A2 provides information on the number of applications, seats, and oversubscription ratio by 9th grade cohort year for AOIT from 2009-10 to 2015-16.

admission to AOIT, which accepts cohorts of roughly 90 students per year. AOIT does not admit students after their freshman year because it views the academy as a four-year, cohort-based commitment. In Table 3, we outline the most salient components of the treatment-control contrast, that is, the elements and opportunities to which a student is exposed when she enrolls in AOIT, relative to her counterpart in the wider high school. Primary distinguishing features include the technology-based paid internship,[6] a four-year sequence of IT courses/electives (students must select applications/web development or programming), homogenous grouping with fellow AOIT enrollees, and soft-skills training throughout the four-year program. AOIT IT electives are first filled with AOIT students and if seats remain open, non-AOIT students are eligible to enroll. Such students typically represent up to 5 percent of each elective in grades 9 and 10 and up to 10 percent in grades 11 and 12. But by design, this number remains small because each course from the 10th grade onward requires a pre-requisite, which non-AOIT students are unlikely to have.

Before we proceed to detailing our analytic approach, we underscore a unique and policy-relevant attribute of the character of the control condition. The counterfactual condition embodied by students who do not win the lottery for AOIT is exceptionally clear. In the vast majority of lottery-based studies that focus on within-school programs or magnets, the counterfactual condition is infrequently discussed and much less clear since students who lose the lottery often have a set of other schools (or programs) to which they can apply or school choice options to exercise. In our case, the overwhelming majority of students (i.e., 96 percent)

[6] AOIT takes this internship component very seriously and has developed a rich guide to internships for high school juniors that includes a contract students must sign detailing responsibilities and expectations, a timeline for student journal entries, and a number of other resources: http://www.apexaoit.com/wp-content/uploads/2015/09/Career-Academy-Student-Internship-Guide-2015_16-1.pdf. Further, district records show that 99 percent of AOIT graduates over our sample's time period completed paid internships during their junior year of high school.

who lose the lottery enter Apex High School in the regular track (i.e., non-career-academy program).[7] This allows us to estimate the effects of participation in a cohort-based, career academy relative to "traditional" high school, which is the comparison of greatest policy relevance.

IV. Data and Analytic Sample for AOIT Analyses

We obtained records from AOIT on all applicants from 2009-10 to 2015-16. These files contain information on lottery and enrollment outcomes for each student as well as sibling information. In order to estimate effects on high school completion and initial college enrollment, we restrict our analytic sample to the 9th grade cohorts of 2009-10 to 2012-13. We merge the applicant files with administrative data housed by Wake County, which include baseline measures of academic achievement and demographics along with measures of high school course-taking, academic performance, attendance, and graduation.[8] Finally, we submit rosters of applicants to the National Student Clearinghouse (NSC) to obtain information on college-going and initial college choice.[9]

AOIT typically receives about twice as many applications as it has seats (Appendix Table A2). To construct our analytic sample, we begin with a total of 646 applications in the 9th grade

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[7] For cohort-specific shares, please see Appendix Table A2.

[8] While we include the most commonly used student-level characteristics, we omit the district's variable for free-and-reduced price lunch (FRL) status. This is because the North Carolina Department of Public Instruction (NCDPI) restricts access to and use of this measure based on its interpretation of National School Lunch Act disclosure provisions. NCDPI's annual memorandum to this effect summarizes entities and/or programs permitted to access and/or use FRL data, including state and federal child nutrition programs, federal education programs (e.g., Title I), and state education programs administered by a local education agency (LEA). Evaluations of LEA programs, such as AOIT, are not permitted to utilize FRL data. The annual memorandum, entitled "Disclosure of Student's Eligibility Status for Free and Reduced Price Meals: Memorandum of Agreement" (dated August 24, 2016) is available on NCDPI's website (NCDPI, 2016).

[9] The NSC matches students to their postsecondary records by name and date of birth. Wake County submitted the files to the NSC and then anonymized the resultant data set before analysis. NSC data exhibit very high coverage rates for enrollment in colleges and universities in North Carolina (and surrounding states) over the relevant, college-going time period for our sample (Dynarski, Hemelt, & Hyman, 2015; Shapiro, Dundar, Wakhungu, Yuan, & Harrell, 2015).

cohorts of 2009-10 to 2012-13. We first exclude applicants with siblings already enrolled in AOIT (136 students) because they are guaranteed admission. Second, we exclude students missing baseline test score or demographic information (41 students).[10] This results in an analytic sample of 469 students.

V. Empirical Approach

Our core analyses focus on estimating the effects of being offered a spot in AOIT (i.e., winning the lottery) as well as actually enrolling in the academy on a range of high school and college outcomes. Since students are randomly given the chance to participate in AOIT, the only difference between students who won the lottery and those who lost should be the opportunity to attend the academy. In all other observable and unobservable ways, both groups of students ought to be the same (in expectation). As shown in Table 4, we detect no statistically significant differences between these groups in terms of demographic characteristics or achievement at baseline, thereby substantiating a functional lottery that approximates a randomized experiment. Indeed, a joint test of the statistical relationship between all baseline measures and winning the AOIT lottery produces a p-value of 0.76, indicating that we are unable to reject the null hypothesis that the means of these baseline characteristics are the same for lottery winners and losers.

Table 4 also provides descriptive information on all 9th graders across Wake County as well as all freshmen in Apex High School over the same time period that our AOIT applicants were entering high school. Though Apex High School draws from an economically diverse area (see Figure 1A), its enrollees are less racially and ethnically diverse then the district as a whole (see Figure 1B). Comparisons of AOIT enrollees with the full set of 9th graders in Apex High

[10] Results are nearly identical and conclusions unchanged if we keep these observations in the analytic dataset and control for missing information using indicator variables in our regressions.

School confirm earlier district-wide patterns of positive selection into career academies that we documented in Tables 1 and 2: that is, AOIT applicants are higher achieving than their non-applicant peers.

To estimate intent-to-treat (ITT) effects of the offer to enroll in AOIT, we use models of the following basic shape:

$$Y_{ic} = \alpha + \beta_1 CA_{ic} + \varphi X_{ic} + \sum_c \delta_c + \varepsilon_{ic} \tag{0}$$

Here, Y_{ic} is the outcome of interest (e.g., high school graduation) for student *i* in lottery cohort *c;* CA_{ic} is a variable equal to one if student *i* won admission via lottery to AOIT during lottery cohort *c;* X_{ic} is a vector of pre-lottery covariates (e.g., demographic characteristics such as gender, race and ethnicity, prior academic achievement) included to increase statistical precision; δ_c is a set of lottery-cohort fixed effects; and ϵ_{isc} is a stochastic error term. Indicators for the lottery/cohort are necessary to ensure equivalent ex-ante probabilities of admission between lottery winners and losers given that winning a seat in the career academy varies from year to year. In equation 1, β_1 represents the causal effect of winning the lottery on students' outcomes.

To study the effects of participating in a career academy (i.e., treatment-on-the-treated (TOT) effects) we use lottery assignment as an instrumental variable (IV) for *enrollment* in a career academy. The intuition behind this approach is that we can exploit random variation in the choice to participate in a career academy insofar as it is a consequence of being offered a spot via the lottery. Thus, we employ the following two-stage least squares (2SLS) setup, with enrollment (E_{ic}) as the endogenous variable in the first stage:

$$E_{ic} = \alpha + \theta_1 CA_{ic} + \gamma X_{ic} + \sum_c \delta_c + \omega_{ic} \tag{2}$$

$$Y_{ic} = \alpha + \beta_1 \hat{E}_{ic} + \phi X_{ic} + \sum_c \delta_c + \varepsilon_{ic} \tag{3}$$

Similarly named variables and vectors in equations 2 and 3 are the same as their counterparts described in equation 1. The additional variable of interest in this set of equations is E_{ic} – which is equal to one if student *i* enrolls in the career academy as part of lottery cohort *c*. In equation 2, we use lottery assignment to isolate exogenous variation in whether a student enrolls in the career academy. In equation 3, we then use this remaining, exogenously determined variation in enrollment to identify the causal impact of participating in a career academy on our outcomes of interest. Specifically, β_1 represents the weighted average treatment effect: that is, the weighted average of outcome differences between enrollees and non-enrollees summed over each individual lottery with weights equal to $N \times [p(1-p)]$, where *N* is the number of career academy applicants and *p* is the probability of admission (Cullen, Jacob, & Levitt, 2006).

We estimate average effects as well as effects on policy-relevant subgroups of students. Given prior evidence of differential effects of career academy participation for men and women (Kemple & Willner, 2008), we explore impacts by gender. We also examine effects for subgroups of students defined by baseline achievement levels (i.e., 8th grade test scores). We estimate all models using heteroskedasticity-robust standard errors.

VI. Findings

We first discuss findings related to the effects of career academy participation on the key outcome of high school graduation. We next present findings related to intermediate outcomes that could function as mechanisms: attendance in 9th grade, academic performance during high school, and participation in advanced course-taking during high school. We then conduct an exercise in which we attempt to assess how much of any effect of career academy participation on high school graduation can be accounted for by impacts on the intermediate outcomes we can measure. We close this section with a look at the effects of involvement in AOIT on college enrollment.

A. Effects on High School Graduation

In Table 5, we present first-stage, ITT, and TOT results related to participation in AOIT and high school graduation. First-stage estimates in Panel A can be interpreted as take-up rates. On average, about 84 percent of lottery winners enrolled in AOIT. In columns 1 through 3, we show that the inclusion of covariates has little effect on the point estimates of interest, as it should if students are truly balanced in terms of their observed and unobserved characteristics across the treatment and control groups. Panel B (Panel C) provides the ITT (TOT) effect of winning the lottery on the outcome of interest. Focusing on our preferred specification in column 3, we conclude that enrolling in AOIT increases the likelihood that a student graduates from high school by about 8 percentage points (which is equivalent to about 9 percent of the control mean). Our measure of high school graduation captures on-time, expected high school graduation as a function of the 9th grade cohort to which a student belongs. If a student leaves the district and graduates form a public high school elsewhere in the state, our measure records this event.[11] Our basic finding remains unchanged if we reconstruct the outcome to measure graduation from high school at any time point captured by our data. Thus, academy enrollment appears to boost overall rates of high school graduation and not simply “on-time” rates of completion.

In columns 4 and 5 of Table 5, we explore differential effects of AOIT enrollment by gender. In columns 6 to 8, we examine whether impacts differ by terciles of baseline (i.e., 8th grade) math scores. Our estimates suggest that the overall effect on high school graduation is

[11] Wake County gathers audited information from the state on its students who graduate from other high schools outside the district (but within North Carolina) and then integrates that information into its district-wide administrative dataset.

being driven by impacts on males as well as students in the middle to upper-middle of the baseline math achievement distribution. We now turn to an exploration of plausible mediators that may underlie these effects.

B. Effects on Attendance, Performance, and Course-taking in High School

One mechanism through which participation in a career academy is hypothesized to boost rates of high school completion is student engagement. Given past work that highlights attendance in 9th grade as a powerful predictor of success in high school (Allensworth & Easton, 2007),[12] we focus on this outcome as our measure of engagement. Table 6 presents our attendance results. We find that participation in AOIT reduces the number of days the typical 9th grader is absent by about 1.4 days (or 38 percent of the control mean). This conclusion is robust to alternative ways of constructing the outcome, such as a rate.

In columns 3 and 4 of Table 6, we explore impacts on indicators that demarcate a student's position in the distribution of 9th grade absences. Though we find little movement in the share of students with absence rates above the median due to career academy enrollment, we see a large decline in the share of students with absence rates that place them in the top 5 percent of the distribution. Specifically, we find enrollment in AOIT to reduce the likelihood a 9th grader falls above this threshold by 4.4 percentage points (column 4) – which is equivalent to nearly two-thirds of the control mean. Taken together, these findings suggest that the average reduction in 9th grade absences is being driven by effects on students with the worst attendance records. We find little difference in the effect of AOIT enrollment on attendance by gender. We fail to detect statistically significant differences in effects of academy participation by terciles of

[12] Allensworth & Easton (2007) argued that moderate rates of absence early in high school were also problematic, not just extremely high rates of absence.

baseline achievement – though the size and direction of the coefficients is suggestive of relatively greater impacts on lower-achieving students.

We next turn to the effect of enrolling in AOIT on high school test scores. In North Carolina, the ACT became a mandatory exam for high school juniors starting in the spring of 2012. Thus, even our earliest cohort of first-time 9th graders (2009-2010) would have reached 11th grade under this policy.[13] We explore the effects of career academy participation on composite ACT test scores as well as subject-area scores in Table 7. Overall, we detect little to no effect of AOIT enrollment on measures of academic achievement during high school – neither on average nor for subgroups of students defined by gender and baseline academic performance.

A third way in which enrollment in a career academy might influence high school completion, the transition to some form of postsecondary training, and other longer-run labor market outcomes is through participation in advanced courses during high school. We explore this hypothesis using data on students' AP course-taking during high school in Table 8. Overall, we detect little to no impact of AOIT enrollment on measures of Advanced Placement (AP) course-taking and success. Though statistically insignificant, the size, direction, and pattern of coefficients across the table suggest that AOIT enrollment may boost a student's propensity to enroll in a math or science AP course – and that this may be especially true for male students and those in the middle and upper parts of the baseline achievement distribution. Of course, access to and performance in elective courses that fit within the academy's theme of information technology (like those outlined in Table 3) may matter more in terms of effects on longer-run

[13] Though the test was mandatory for all cohorts in our sample, 40 students are missing ACT scores even though they have full demographic and baselines test score information. Thus, we predict scores for these students as a function of their baseline demographic and achievement information. Alternatively, if we drop these students from the analytic sample, our conclusions remain unchanged, point estimates are extremely similar in magnitude and direction, and the standard errors are slightly larger.

postsecondary and labor market outcomes than more traditional measures of advanced course-taking like AP courses. Access to such elective courses is one element of the bundled treatment to which students who enroll in AOIT are exposed – and thus separating the effect of that one element from others such as the paid internship is impossible in our context.

Before we move to a discussion of the impact of AOIT enrollment on college-going, we conduct an exercise in which we assess the degree to which effects on these intermediate outcomes can explain the overall effect on high school graduation. We present the results of this exercise in Table 9. We begin with our preferred estimates of the ITT and TOT effects of AOIT enrollment on high school graduation in column 1. We then sequentially add vectors of controls to the model that measure intermediate outcomes in columns 2 through 4. Results in column 2 suggest that intermediate effects on 9th grade absences account for nearly one fifth of the downstream effect on high school graduation. Advanced course-taking as measured by participation in AP courses and high school academic performance as measured by ACT scores add no explanatory power. Thus, given the plausible mediators at our disposal, we can account for about one fifth of the total, downstream effect of career academy enrollment on high school graduation – with impacts on our measure of engagement responsible for that fifth.

C. Effects on College Enrollment

One of the primary goals of modern career academies is to prepare students for some form of postsecondary study and not solely equip them to enter the labor market. Academies like AOIT appear to be taking this charge seriously. Consider the effort AOIT exerts to facilitate an integrated curriculum for its students. Apex High School provides weekly planning time during which teachers of the CTE courses that are a key part of the AOIT experience collaborate with teachers of the regular “academic” high school courses to weave common content and relevant applications through both sets of courses for AOIT students. In addition, AOIT aims to have its students take some sort of college-level IT course in their senior year of high school.

We examine the effects of AOIT enrollment on college-going in Table 10.[14] We find that career academy participation increases the likelihood of college attendance within one year of on-time, expected high school graduation by about 8 percentage points (which is equivalent to about 10 percent of the control mean). Among the college-goers in our analytic sample, about 78 percent first enroll in an in-state, public institution – with 60 percent starting at 4-year, public, in-state institutions and 18 percent beginning at 2-year, public, in-state colleges. We fail to detect meaningful impacts of AOIT enrollment on the type of college in which a student first enrolls.

Results in columns 2 and 3 clearly show that the overall effect of career academy enrollment on college-going is driven by male students, with the effect of participation in AOIT on college-going for males statistically different from the effect for females. Our estimates for male students imply that about 92 percent of male 9th graders in the career academy will attend college, compared to just 78 percent of their non-academy, male counterparts. Given that the female-male gap in college enrollment rates for the control group favors females by about 7 percentage points, AOIT participation essentially reveres the gender gap. Estimates in columns 4 through 6 suggest that students in the middle of the baseline achievement distribution drive the overall impact of AOIT participation on college enrollment, though relatively large standard errors preclude strong conclusions.

[14] Given the timing of the most recent NSC submission, we can observe one year after on-time, expected high school graduation for the 9th grade cohorts of 2010, 2011, and 2012 – but only about one semester after on-time, expected high school completion for the 9th grade cohort of 2013. To test the sensitivity of our estimates to the inclusion of the 2013 cohort and relatively limited time horizon, we repeat our analysis dropping the 9th grade cohort of 2013. We present results of this sensitivity check in Appendix Table A3. Our findings and conclusions remain unchanged.

VII. Conclusions and Implications

In this paper, we examine the profile of students entering contemporary career academies and estimate causal effects of participation in a well-regarded example of such academies on a range of high school and college outcomes. To do so, we use rich administrative data from a large school district in North Carolina that has heavily invested in the growth of its career academies over the past few years.

In contrast to much of the prior work on CTE, we find that students who enroll in career academies are generally higher performing than their non-academy peers. We document small gaps in the propensity to enroll in a career academy by ethnicity and English proficiency status that cannot be explained by differences in prior academic achievement or high school choice sets (which are determined by the middle school in which a student is enrolled). Conditional on academy entry, we find that choices of specific academy types are correlated with observable demographic characteristics, net of the influence of prior achievement and originating middle school. For example, we find that female enrollees are less likely to enter an engineering academy and more likely to enter a science academy, relative to their male counterparts. LEP students are much more likely to enter career academies that largely concentrate in non-STEM areas such as hospitality, culinary arts, and public safety than their non-LEP counterparts.

When we turn to estimating the causal effects of participation in an oversubscribed career academy focused on information technology, we find clear increases in high school graduation and college enrollment that are concentrated among male students. These findings are noteworthy for at least two reasons. First and most broadly, they illustrate the capacity of modern-day career academies to benefit students across the achievement spectrum – indeed, our findings imply that enrollment in AOIT induced an appreciable share of average- to above-average-achieving students to complete high school and enter college who otherwise would not have done so. Our findings further suggest that a non-trivial mediator of this effect was attendance early in high school. These findings contrast with the MDRC evaluation of career academies that operated during the 1990s, which found no effects of academy participation on high school graduation or college enrollment (Kemple, 2001). Recent work that exploited admissions lotteries to estimate effects of attendance at a group of charter high schools in Boston on a range of similar outcomes found no effects on high school graduation or overall rates of college-going in spite of marked increases in SAT scores and the likelihood of taking and passing an AP exam (Angrist et al., 2016).

The second reason the findings are noteworthy is the fact that these overall effects are largely driven by impacts on male students. This contrasts with an increasingly vast literature in the economics of education that finds females much more responsive than males to programs and policies aimed at improving a host of educational outcomes across the K-20 spectrum (e.g., Anderson, 2008; Angrist et al., 2009; Deming et al., 2014). For example, Deming, Hastings, Kane, and Staiger (2014) studied the public school choice lottery in Charlotte-Mecklenburg, North Carolina. The authors found statistically significant increases in high school graduation, postsecondary enrollment, and degree completion for students who won the lottery to attend their first-choice school – and these effects were driven by female students. They conclude that "… girls responded to a more academically demanding environment with increased effort, while boys did not" (p. 933). Our evidence suggests that boys responded to the technology-rich, applied academic setting of AOIT while girls did not. Taken together, these findings illustrate one way in which our rigorous, detailed study of one contemporary career academy can have broader implications. As districts and states assemble portfolios of reform initiatives and interventions, they must be armed with causal evidence on how those initiatives and programs affect subgroups of students – whether by prior achievement, gender, race, or ethnicity – differently. Only with such evidence can policymakers weave a tapestry of reform activities capable of improving outcomes for all students.

Given that our study of the causal effects of AOIT on a range of educational outcomes focuses on only one career academy, the external validity of our findings is necessarily limited. Yet, the detailed manner in which we are able to study AOIT paints clear paths for future research. We document and verify a set of key treatment elements to which academy enrollees are exposed, such as a paid internship in 11th grade, cohort-based progression of students through courses, and shared planning time for CTE and non-CTE teachers (see Table 3). A natural next question is whether these components can achieve similar results when implemented by a career academy with a different focus such as health services, public safety, or advanced manufacturing. As additional academies across the district move to lottery-based admissions, we plan to address this question in future work. Similarly, as the cohorts in this study move through college and into the labor market, we will be able to study the early labor market experiences of academy enrollees. At present, our study provides an existence proof for the potential of high-quality career academies to improve rates of high school graduation and college-going, especially among male students.

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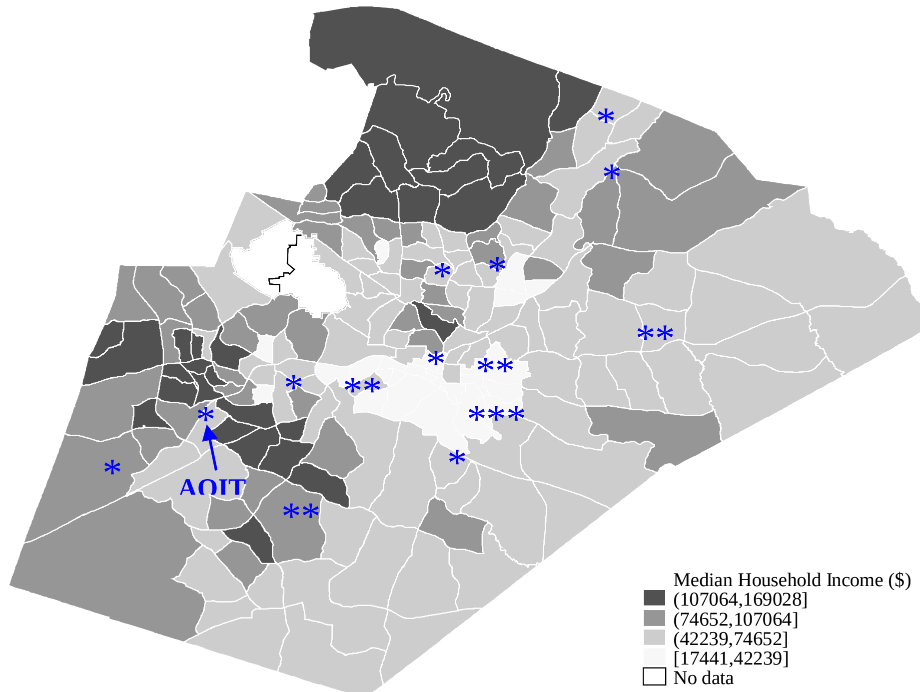
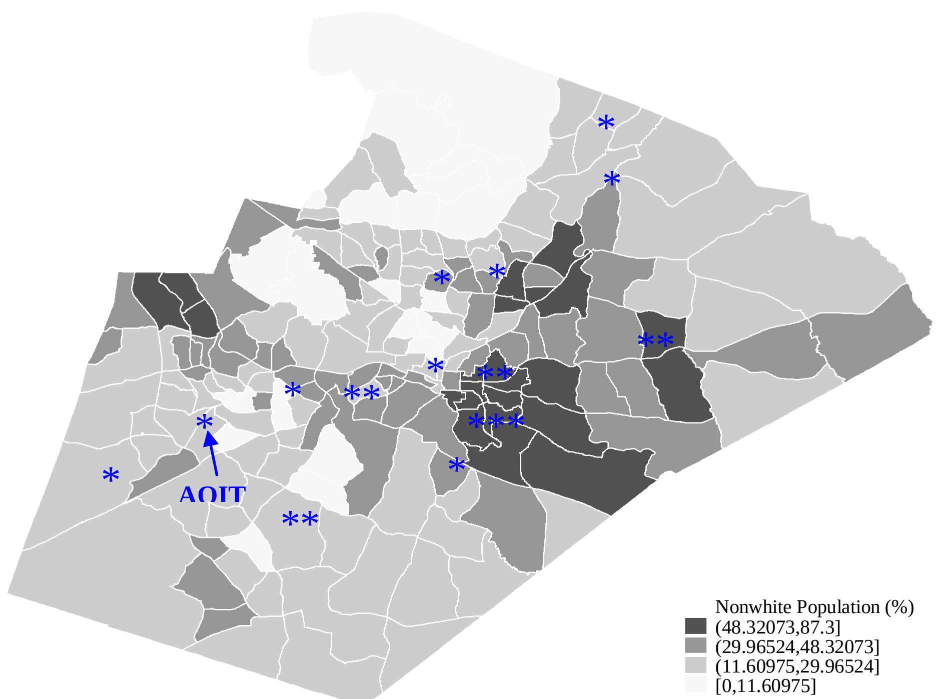
Figure 1. Geographic Distribution of WCPSS Career Academies

A. Overlaid by Census-Tract Level Median Household Income



B. Overlaid by Census-Tract Level Non-White Population



Sources: U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates (Table B19013: Median Household Income in the Past 12 Months, Table DP05: ACS Demographic and Housing Estimates) and WCPSS administrative data.

Table 1. Profile of Enrollees at Career Academies Across WCPSS, 2014-15 and 2015-16

			Concentration Area							
			Technology		Science		Engineering		Other	
Sample Variable	9th Graders in WCPSS (1)	9th Grade CA Enrollees, All Career Academies (2)	9th Grade CA Enrollees (3)	Non-CA 9th Graders in Same High Schools (4)	9th Grade CA Enrollees (5)	Non-CA 9th Graders in Same High Schools (6)	9th Grade CA Enrollees (7)	Non-CA 9th Graders in Same High Schools (8)	9th Grade CA Enrollees (9)	Non-CA 9th Graders in Same High Schools (10)
Demographics										
Female	0.498	0.448	0.411	0.493	0.660	0.500	0.285	0.493	0.415	0.490
Black, non-Hispanic	0.254	0.204	0.133	0.286	0.296	0.400	0.203	0.288	0.201	0.324
Hispanic	0.151	0.089	0.052	0.155	0.116	0.206	0.072	0.146	0.125	0.189
White, non-Hispanic	0.484	0.570	0.712	0.448	0.328	0.272	0.609	0.507	0.607	0.384
Asian, non-Hispanic	0.068	0.098	0.065	0.069	0.240	0.076	0.063	0.021	0.018	0.060
Other race/ethnicity, non-Hispanic	0.043	0.039	0.039	0.041	0.020	0.046	0.053	0.037	0.049	0.044
Special education	0.116	0.090	0.110	0.118	0.044	0.133	0.092	0.141	0.112	0.127
Limited English Proficiency (LEP)	0.018	0.003	0.000	0.020	0.004	0.029	0.000	0.017	0.009	0.029
Academic Achievement										
8th Grade Math Score (std)	0.009	0.417	0.517	0.005	0.432	-0.212	0.562	-0.107	0.112	-0.172
	(0.999)	(0.931)	(0.889)	(1.046)	(1.005)	(1.077)	(0.902)	(0.974)	(0.875)	(1.014)
8th Grade Reading Score (std)	0.002	0.316	0.360	-0.015	0.402	-0.204	0.396	-0.108	0.088	-0.132
	(0.999)	(0.870)	(0.873)	(1.032)	(0.843)	(1.070)	(0.851)	(0.992)	(0.879)	1.039
Academically Gifted (Math or Reading)	0.280	0.434	0.460	0.312	0.524	0.268	0.396	0.218	0.335	0.257
N(students)	20,968	993	309	5,524	250	3,270	207	2,965	224	5,921
N(schools)	33	14	7	7	4	4	4	4	6	6

Notes: Analytic sample includes first-time 9th grade students in 2014-2015 and 2015-2016 in the Wake County Public School System with non-missing prior test scores and demographic information. Technology academies (7): Academy of Information Technology (2), Digital Media Technology (3), Game Art and Design (1), and IT and Cyber Security (1). Science academies (4): Academy of Environmental Studies (1), BioMed Academy (1), Health Science (1), and Medical BioScience. Engineering academies (4): Construction Technology (1), Engineering and Design (1), Engineering Academy (1), and Engineering and Advanced Manufacturing (1). Other academies (6): Academy of Finance (1), Culinary Arts (1), Design and Merchandising (1), Hospitality, Tourism and Sports Marketing (1), and Public Safety (2).

Table 2. Student Participation in Contemporary Career Academies: WCPSS, 2014-15 and 2015-16

				Sample = Career Academy Enrollees			
	Enroll in Career Academy in Grade 9			Enroll in CA with Technology Focus	Enroll in CA with Science Focus	Enroll in CA with Engineering Focus	Enroll in CA with Other Focus
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Demographics							
Female	-0.010***	-0.009***	-0.008	-0.020	0.130***	-0.102***	-0.008
	(0.003)	(0.003)	(0.006)	(0.023)	(0.029)	(0.022)	(0.026)
Black, non-Hispanic	-0.015***	0.003	0.000	0.003	0.06	0.090**	-0.153***
	(0.003)	(0.004)	(0.005)	(0.041)	(0.048)	(0.035)	(0.056)
Hispanic	-0.020***	-0.008**	-0.009*	-0.042	0.105*	-0.048	-0.014
	(0.004)	(0.004)	(0.005)	(0.042)	(0.060)	(0.040)	(0.046)
Asian, non-Hispanic	0.013*	0.003	0.007	-0.076	0.264***	-0.021	-0.168**
	(0.006)	(0.007)	(0.010)	(0.065)	(0.084)	(0.059)	(0.062)
Other, non-Hispanic	-0.011*	-0.004	-0.002	-0.033	-0.035	0.094	-0.026
	(0.006)	(0.006)	(0.007)	(0.068)	(0.052)	(0.056)	(0.034)
Limited English Proficiency (LEP)	-0.027***	-0.013***	-0.017***	0.053	-0.305**	-0.040	0.293***
	(0.004)	(0.005)	(0.004)	(0.125)	(0.130)	(0.098)	(0.078)
Special education	-0.010***	0.005	0.004	0.085**	-0.051	-0.019	-0.016
	(0.004)	(0.004)	(0.004)	(0.042)	(0.040)	(0.045)	(0.031)
Academic Achievement							
Academically Gifted (Math or Reading)	--	0.011**	0.009	-0.034	0.049	0.027	-0.043
		(0.006)	(0.008)	(0.038)	(0.030)	(0.037)	(0.030)
8th Grade Math Score (std)	--	0.013***	0.013***	-0.011	-0.024	0.054**	-0.019
		(0.002)	(0.002)	(0.029)	(0.033)	(0.025)	(0.018)
8th Grade Reading Score (std)	--	0.001	0.003	-0.013	0.011	0.01	-0.008
		(0.002)	(0.002)	(0.031)	(0.026)	(0.023)	(0.016)
Middle school fixed effects	No	No	Yes	Yes	Yes	Yes	Yes
Outcome mean	0.043	0.043	0.043	0.311	0.249	0.215	0.226
N(students)	22,895	22,895	22,895	993	993	993	993

Notes: Analytic sample includes all first-time 8th grade students in 2013-2014 and 2014-2015 in the Wake County Public School System with non-missing test score and demographic information. All models include indicators for 8th grade cohort year. Heteroskedasticity-robust standard errors appear in parentheses for models in columns 1 and 2 and robust standard errors clustered on middle school appear in parentheses in columns 3 to 7: *** p<0.01, ** p<0.05, * p<0.1. Technology academies (7): Academy of Information Technology (2), Digital Media Technology (3), Game Art and Design (1), and IT and Cyber Security (1). Science academies (4): Academy of Environmental Studies (1), BioMed Academy (1), Health Science (1), and Medical BioScience. Engineering academies (4): Construction Technology (1), Engineering and Design (1), Engineering Academy (1), and Engineering and Advanced Manufacturing (1). Other academies (6): Academy of Finance (1), Culinary Arts (1), Design and Merchandising (1), Hospitality, Tourism and Sports Marketing (1), and Public Safety (2).

Table 3. Treatment-Control Contrast for AOIT

Dimension	*AOIT Enrollees (Treatment)*	*Apex HS Non-AOIT Enrollees (Control)*
Work-based learning; Workplace engagement	Paid internship in 11th grade year; Job shadowing and career-development day trips	Not available to non-AOIT students
Non-academic supports	Networking through local Chamber of Commerce, resume preparation, mock interviews, job shadowing, and pre-internship training	Not available to non-AOIT students
Curriculum	Cohort-based progression; project-based learning; teachers of CTE and academic courses collaborate during common, weekly planning time	No cohort-based structure to curriculum
IT Courses (required electives)	Sequence of courses that reflects one of two themes: programming or multimedia/web design (= 1/3 of content)	Limited availability to non-AOIT students (5% to 10% of course enrollees drawn from wider high school)
Bridge to postsecondary study	Students take college-level IT course (either AP or articulated) during 12th grade	No special encouragement or 12th grade course requirements

Sources: Interviews with AOIT Career Academy Career Development Coordinators and WCPSS CTE staff, AOIT webstie documents: http://www.apexaoit.com/curriculum/.

Table 4. Descriptive Statistics and Covariate Balance: AOIT

	Means			Baseline regressions
	WCPSS Public 9th Graders	Apex 9th Graders	AOIT Applicants	No controls
Variable	(1)	(2)	(3)	(4)
Demographics				
Female	0.478	0.457	0.360	0.026
				(0.046)
Black, non-Hispanic	0.282	0.081	0.051	0.019
				(0.021)
Hispanic	0.131	0.077	0.026	0.020
				(0.017)
White, non-Hispanic	0.480	0.740	0.787	-0.044
				(0.039)
Asian, non-Hispanic	0.058	0.060	0.104	0.012
				(0.029)
Special education	0.154	0.121	0.083	-0.030
				(0.026)
Limited English Proficiency (LEP)	0.067	0.026	0.000	
Academic Achievement				
8th Grade Math Score	0.001	0.490	0.833	-0.041
	(1.000)	(0.867)	(0.745)	(0.072)
8th Grade Reading Score	0.001	0.407	0.638	-0.029
	(0.999)	(0.850)	(0.738)	(0.071)
Academically Gifted (Math or Reading)	0.252	0.413	0.579	-0.042
				(0.047)
F-stat from joint test				0.64
p-value from F-test				0.76
N	47,714	2,303	469	469

Notes: Columns 1, 2, and 3 report means for each variable using values from 8th grade for the population listed atop each column. Standard deviations for continuous variables are listed in parentheses below the means. The analytic sample for columns 3-5 is restricted to AOIT applicants with baseline demographic and test score data and without siblings already in attendance at AOIT. Column 4 reports coefficients from regressions of the variable in a given row on an indicator denoting whether the student won the lottery. These models include indicators for year of application (i.e., 9th grade year). F-statistic and its associated p-value are for the null hypothesis that the relationship between all baseline variables and the likelihood of winning the lottery is zero. Heteroskedasticity-robust standard errors appear in parentheses: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5. Career Academy Participation and High School Graduation

	Outcome = High school graduation (on-time, expected)							
				Subgroups by Gender		Subgroups by Baseline Math Achievement		
		All Students		Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. First Stage								
Won lottery	0.835***	0.835***	0.835***	0.818***	0.869***	0.825***	0.906***	0.760***
	(0.024)	(0.026)	(0.027)	(0.035)	(0.042)	(0.048)	(0.037)	(0.056)
B. Effect of Winning Lottery (ITT)								
Won lottery	0.062**	0.064**	0.065**	0.079**	0.043	0.031	0.107***	0.077
	(0.025)	(0.026)	(0.026)	(0.034)	(0.039)	(0.044)	(0.036)	(0.050)
C. Effect of Enrolling in Career Academy (TOT)								
Enrolled in AOIT	0.074**	0.076**	0.078***	0.097**	0.049	0.037	0.118***	0.101
	(0.030)	(0.031)	(0.029)	(0.040)	(0.045)	(0.054)	(0.040)	(0.063)
Demographic controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline achievement controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Outcome mean, control group		0.90		0.89	0.93	0.90	0.91	0.90
N(students)		469		300	169	156	159	154

Notes: All models include indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. ITT = intent to treat; TOT = treatment on the treated.

Table 6. Career Academy Participation and 9th Grade Attendance

	All Students				Outcome = Number of days absent, 9th grade				
					Subgroups by Gender		Subgroups by Baseline Math Achievement		
	Number of days absent, 9th Grade	Share of days absent, 9th Grade	Absence rate >= 50th pctile	Absence rate >= 95th pctile	Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Effect of Winning Lottery (ITT)									
Won lottery	-1.194**	-0.007**	-0.047	-0.037*	-0.874*	-1.529	-1.928	-0.940	-0.203
	(0.579)	(0.003)	(0.046)	(0.020)	(0.510)	(1.309)	(1.456)	(0.621)	(0.552)
B. Effect of Enrolling in Career Academy (TOT)									
Enrolled in AOIT	-1.430**	-0.008**	-0.056	-0.044*	-1.068	-1.759	-2.337	-1.037	-0.267
	(0.630)	(0.003)	(0.055)	(0.026)	(0.692)	(1.219)	(1.622)	(0.679)	(0.765)
Outcome mean, control group	3.78	0.02	0.61	0.07	3.51	4.27	4.99	3.61	2.71
N(students)	469	469	469	469	300	169	156	159	154

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. ITT = intent to treat; TOT = treatment on the treated.

Table 7. Career Academy Participation and Academic Performance in High School

	All Students			Subgroups by Gender					
				Males			Females		
	ACT Composite	ACT Math	ACT Reading	ACT Composite	ACT Math	ACT Reading	ACT Composite	ACT Math	ACT Reading
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Effect of Winning Lottery (ITT)									
Won lottery	0.189	0.030	0.453	-0.086	-0.349	0.161	0.705	0.707	1.040
	(0.274)	(0.304)	(0.416)	(0.327)	(0.365)	(0.493)	(0.525)	(0.558)	(0.809)
B. Effect of Enrolling in Career Academy (TOT)									
Enrolled in AOIT	0.226	0.036	0.543	-0.105	-0.426	0.197	0.811	0.814	1.196
	(0.330)	(0.352)	(0.500)	(0.418)	(0.442)	(0.628)	(0.549)	(0.590)	(0.849)
Outcome mean, control group	24.41	25.90	24.17	24.29	26.14	23.80	24.63	25.46	24.84
N(students)	469	469	469	300	300	300	169	169	169

	Subgroups by Baseline Math Achievement								
	Bottom Third			Middle Third			Top Third		
	ACT Composite	ACT Math	ACT Reading	ACT Composite	ACT Math	ACT Reading	ACT Composite	ACT Math	ACT Reading
Independent variable	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
A. Effect of Winning Lottery (ITT)									
Won lottery	0.681	0.220	1.276	0.243	-0.091	0.096	-0.142	0.344	-0.144
	(0.563)	(0.627)	(0.801)	(0.422)	(0.492)	(0.719)	(0.486)	(0.534)	(0.745)
B. Effect of Enrolling in Career Academy (TOT)									
Enrolled in AOIT	0.825	0.267	1.546	0.268	-0.101	0.105	-0.187	0.452	-0.189
	(0.645)	(0.687)	(0.936)	(0.460)	(0.531)	(0.782)	(0.652)	(0.681)	(0.963)
Outcome mean, control group	20.32	21.62	19.95	24.77	26.13	24.78	28.27	30.07	27.88
N(students)	156	156	156	159	159	159	154	154	154

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Outcomes measure performance on mandatory ACT tests taken during students' junior year of high school. Consult the text for additional information about these tests. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. ITT = intent to treat; TOT = treatment on the treated.

Table 8. Career Academy Participation and Advanced Course-taking in High School

	All Students				Outcome = Enroll in AP Math or Science Course				
					Subgroups by Gender		Subgroups by Baseline Math Achievement		
	Enroll in Any AP Course	Enroll in AP Math or Science Course	Enroll in Other AP Course	Pass Any AP Math or Science Exam	Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Effect of Winning Lottery (ITT)									
Won lottery	0.021	0.041	-0.006	0.024	0.070	-0.013	-0.031	0.066	0.093
	(0.041)	(0.038)	(0.045)	(0.035)	(0.047)	(0.065)	(0.050)	(0.073)	(0.073)
B. Effect of Enrolling in Career Academy (TOT)									
Enrolled in AOIT	0.026	0.049	-0.007	0.028	0.085	-0.015	-0.038	0.073	0.122
	(0.049)	(0.045)	(0.053)	(0.042)	(0.057)	(0.076)	(0.064)	(0.076)	(0.097)
Outcome mean, control group	0.63	0.36	0.54	0.28	0.34	0.39	0.14	0.33	0.61
N(students)	469	469	469	469	300	169	156	159	154

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Passing an AP test is defined as scoring a 3 or higher on the associated exam. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. AP = Advanced Placement. ITT = intent to treat; TOT = treatment on the treated.

Table 9. Candidate Mediators and the High School Graduation Effect of Career Academy Enrollment

	Outcome = High school graduation (on-time, expected)			
		Include controls for potential mechanisms		
	Preferred specification (Table 5, column	9th Grade Attendance	Advanced HS Course-taking	HS Test Scores
Independent variable	(1)	(2)	(3)	(4)
B. Effect of Winning Lottery (ITT)				
Won lottery	0.065***	0.053**	0.053**	0.052**
	(0.025)	(0.024)	(0.024)	(0.023)
C. Effect of Enrolling in Career Academy (TOT)				
Enrolled in AOIT	0.078***	0.063**	0.063**	0.062**
	(0.029)	(0.029)	(0.027)	(0.027)
Reduction in impact of CA enrollment:				
% explained by 9th grade absences		19		
% explained by 9th grade absences, advanced HS course-taking			19	
% explained by 9th grade absences, advanced HS course-taking, HS test scores				21
N(students)	469	469	469	469

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. HS = high school; CA = career academy; ITT = intent to treat; TOT = treatment on the treated.

Table 10. Career Academy Participation and College Enrollment

	Outcome = Enroll in college within 1 semester of on-time, expected high school graduation					
	All Students	Subgroups by Gender		Subgroups by Baseline Math Achievement		
		Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
A. Effect of Winning Lottery (ITT)						
Won lottery	0.068*	0.116**	-0.030	-0.017	0.122*	0.084
	(0.037)	(0.045)	(0.063)	(0.068)	(0.062)	(0.058)
B. Effect of Enrolling in Career Academy (TOT)						
Enrolled in AOIT	0.081*	0.142***	-0.034	-0.021	0.135*	0.111
	(0.043)	(0.054)	(0.072)	(0.082)	(0.069)	(0.078)
Outcome mean, control group	0.80	0.78	0.85	0.79	0.79	0.83
N(students)	469	300	169	156	159	154

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. ITT = intent to treat; TOT = treatment on the treated.

Appendix Table A1. WCPSS Career Academies

School	Program(s)	Launch Year
Apex HS	Academy of Information Technology	2001
Apex Friendship HS	Academy of Engineering and Advanced Manufacturing	2015
Athens Drive HS (magnet)	Health Science Academy	1990
	Energy and Sustainability	2015
Broughton HS (magnet)	Hospitality, Tourism and Sports Entertainment	2013
Cary HS	Culinary Arts	2013
Enloe HS (magnet)	Medical Bioscience	1996
	Design & Merchandising Tech. Career Academy	2011
Garner HS (magnet)	Fire and Safety	2015
Heritage HS	Game Art Design	2013
Knightdale HS	Academy of Environmental Studies	2009
	Public Safety	2014
Middle Creek HS	Academy of Sustainable Energy Engineering	2013
	Digital Media	2011
Millbrook HS (magnet)	Digital Media	2014
Sanderson HS	Academy of Finance	1995
Southeast Raleigh HS (magnet)	Academy of Information Technology	2014
	Engineering Academy	2010
	Biotechnology Research	2013
Wake Forest HS	Construction Technology Career Academy	2001

Appendix Table A2. Application and Enrollment History at AOIT, 2009-10 to 2015-16

Freshman Year	Graduating Year	Seamless College Enrollment	Applications	Seats	Over-subscription Ratio	Applications – Siblings	Seats – Siblings	Sibling-Adjusted Ratio	Share of Lottery Losers Entering Apex High School
2009-10	2012-13	Fall 2013	139	75	1.9	109	46	2.4	98.6
2011-11	2013-14	Fall 2014	137	90	1.5	109	63	1.7	95.1
2011-12	2014-15	Fall 2015	208	90	2.3	169	51	3.3	98.2
2012-13	2015-16	Fall 2016	162	90	1.8	123	51	2.4	97.9
2013-14	2016-17	Fall 2017	115	90	1.3	91	66	1.4	93.6
2014-15	2017-18	Fall 2018	155	90	1.7	116	51	2.3	48.5
2015-16	2018-19	Fall 2019	112	90	1.2	76	54	1.4	N/A
	Total		1,028	615	1.7	793	382	2.1	88.5

Notes: In 2014-2015, a second career academy to which students zoned for Apex High School could apply opened (Academy of Engineering) and thus the share of students who lost the AOIT lottery and attended "regular" Apex High School dropped (because many enetered the engineering academy).

Appendix Table A3. Career Academy Participation and College Enrollment, Cohorts of 2010 to 2012

	Outcome = Enroll in college within 1 year of on-time, expected high school graduation					
		Subgroups by Gender		Subgroups by Baseline Math Achievement		
	All Students	Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
A. Effect of Winning Lottery (ITT)						
Won lottery	0.077*	0.124**	-0.022	-0.002	0.116	0.103
	(0.044)	(0.056)	(0.072)	(0.079)	(0.078)	(0.075)
B. Effect of Enrolling in Career Academy (TOT)						
Enrolled in AOIT	0.094*	0.160**	-0.024	-0.003	0.126	0.153
	(0.053)	(0.070)	(0.082)	(0.099)	(0.085)	(0.107)
Outcome mean, control group	0.78	0.75	0.83	0.77	0.77	0.80
N(students)	350	217	133	117	112	121

Notes: All models include student-level controls for demographics and 8th grade achievement as well as indicators for year of application (i.e., 9th grade year). Analytic sample excludes applicants with siblings already in attendance at AOIT as well as those without baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** p<0.01, ** p<0.05, * p<0.1. ITT = intent to treat; TOT = treatment on the treated.