Building bridges to life after high school: Contemporary career academies and student outcomes☆

Steven W. Hemelt[a,*], Matthew A. Lenard[b], Colleen G. Paeplow[b]

[a] *University of North Carolina at Chapel Hill, United States*
[b] *Wake County Public School System, United States*

ARTICLE INFO

ABSTRACT

Career academies serve an increasingly wide range of students. This paper examines the contemporary profile of students entering career academies in a large, diverse 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. Exploiting the lottery-based admissions process of this technology-focused academy, we find that academy enrollment increases the likelihood of high school graduation by about 8 percentage points and boosts rates of college enrollment for males but not females. Analysis of intermediate outcomes suggests that effects on attendance and industry-relevant certification at least partially mediate the overall high school graduation effect.

1. Introduction

In the United States, between 15 and 20 percent of adolescents fail to finish high school (NCES, 2015). Gaps in completion by race, ethnicity, and gender persist despite marked gains made by minority students in the early 2000s – with the graduation rate for females exceeding that of males by 12 percentage points (Murnane, 2013). 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, 2013). 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 (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 policy landscape. This evolution of goals is well-documented by the leading national advocacy consortium for career

academies in its "National Standards of Practice" (NCAC, 2004 & 2013). The first set of standards, issued in 2004, argued that career academies were an essential component of the "high school reform" movement and central to engaging students who might otherwise drop out of school. Nearly a decade later, the consortium more forcefully argued that career academies served to enhance college and career opportunities for all students – not just those enrolled in potentially under-performing high schools (NCAC, 2004 & 2013).

There is scant work on the causal effects of participation in career academies. The strongest evidence comes from a lottery-based study conducted by MDRC that focused on nine academies in operation during the 1990s (Kemple, 2001, 2004; Kemple & Willner, 2008, 2011). Since that time, the foci of career academies have grown and the slate of students served by such academies has widened. Indeed, a recent, nationally representative sample of career academy enrollees included substantially higher proportions of white and male students and a lower proportion of Hispanic students, compared to the MDRC sample (Kemple & Snipes, 2000; NAF, 2017). In addition, the surrounding policy context has shifted. 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 State Standards and development of "career- and college-ready" standards for all students. Thus, our broad aim is to update the literature on career academies that was established in a limited manner during a time when education policy looked distinct from what is has for the past two decades.

In this paper, we first use rich administrative data from the Wake County Public School System in North Carolina (henceforth "Wake County") to characterize the contemporary profile of students enrolling in that district's extensive system of career academies. Wake County is the largest school district in North Carolina and resembles the nation in terms of the demographic and socioeconomic makeup of its students (Ingels et al., 2011). We begin by descriptively documenting gaps in career academy participation by gender, race and ethnicity. We then estimate the causal effects of participation in one academy, the Academy of Information Technology (AOIT) within Apex High School, by exploiting the fact that enrollees were admitted by lottery. We estimate causal effects of enrollment in this academy on a range of educational outcomes during high school as well as measures of college enrollment and choice. AOIT is a well-regarded and adequately funded academy that has garnered recognition from the National Academy Foundation (NAF, 2013, 2016). Any study that focuses on a limited setting such as one school faces a tradeoff between internal and external validity. Here, we highlight three attributes of our empirical context that enhance the value of our key findings from the lottery-based analysis. First, the counterfactual condition is exceptionally clear. In the vast majority of studies of schools of choice (e.g., charters or magnets) that exploit lottery-based admissions, the control condition is an amalgamation of various paths students who lose the lottery pursue. This is because lottery losers frequently have additional choices of which to avail themselves if they lose their top-choice lottery. This muddies subsequent interpretation of causal effects and associated policy implications. In our case, across the cohorts in our study, 92 percent of the students who lose the lottery for the career academy enroll in the regular high school track within the same school. Thus, the treatment-control contrast is crisp and our estimates will clearly represent the effect of career academy enrollment relative to enrollment in the regular high school track. Second, students who attend AOIT begin in the 9th grade, a pivotal grade in terms of future dropout risk (Neild, Stoner-Eby, & Furstenberg, 2008). This element of the treatment contrasts with MDRC's analytic sample in which nearly three-quarters of enrollees began in the 10th grade (Kemple & Rock, 1996) – and thus may influence downstream high school outcomes. Third, the career academy that operates within Apex High School focuses on information technology. While MDRC's sample of schools included two electronics academies and one video academy (Kemple & Rock, 1996), these kinds

of technology – and the era in which they operated – likely differ substantially from the context of AOIT, where the foci are web design and computer programming.

In the penultimate section of the paper, we extend and deepen our discussion of external validity. For now, the reader ought to hold in mind that the results of the lottery-based portion of our analysis flow from a well-implemented program in a relatively high-performing, well-resourced high school. Thus, these features of the setting are a part of the framework of factors that shape the treatment-control contrast and the effects that flow from it on our outcomes of interest (Cook, 2014).

To preview results, we find that recent career academy enrollees across the district 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.

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 by about 8 percentage points. Academy participation reduces 9th grade absences and markedly increases in the likelihood of earning an IT industry certification but has little effect on academic performance and rates of AP course-taking during high school. Along the postsecondary margin, we find that participation in this academy increases the likelihood of college enrollment within one year of expected, on-time high school graduation for males but not females.

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 one of the district's well-regarded academies on a range of educational outcomes. Section V describes our empirical approach to estimating those effects. Section VI presents our main findings. Section VII discusses academy costs and external validity; and Section VIII concludes.

2. Existing literature

2.1. 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 college 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 NLSY97, a recent study finds that vocational coursework is associated with lower rates of attendance at 4-year colleges, but that advanced vocational courses are associated with increased earnings, at a rate of 2 percent per advanced course (Kreisman & Stange, 2017). The authors recommend focusing policy efforts on depth of CTE-related course offerings rather than breadth.

To our knowledge, the only study to explore causal 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 (2018). He uses data from Massachusetts in the context of a regression-discontinuity approach 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 (2018) 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 percentage 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 (2018) 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; Dougherty, 2016).

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 the National Academies Foundation (NAF) in the early 1980s (Stern, Dayton, & Raby, 2010). Recent 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, Kienzl, & Karp, 2007). Recent standards promulgated by the National Career Academy Coalition highlight the capacity of modern academies to serve a range of students well and prepare students for some form of postsecondary training (NCAC, 2017). Such 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, or agricultural and natural resources). These academies tend to offer students enhanced nonacademic 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.

2.2. 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; Page, 2012).

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 suggestive 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).[1]

There has been little to no work on the causal effects of career academy participation since the MDRC studies. Given changes in the topical foci of career academies, encouragement by national associations to re-focus on the dual goal of preparing career academy participants for college and the labor market (NCAC, 2013), and shifts in surrounding education policies, 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.

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, and services). Second, we provide causal estimates of the effects of enrollment in a well-regarded career academy on a range of educational outcomes. In doing so, we leverage an exceptionally crisp treatment-control contrast and 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.[2] Third, we explore a number of candidate mediators through which any effects on high school and college-going may operate. For example, if academy enrollment increases the likelihood of high school graduation, what are the likely channels through which that effect operates? We use rich measures of intermediate outcomes to explore four plausible channels through which effects may flow: attendance and engagement, academic performance, access to advanced, college-level courses, and applied, industry-relevant knowledge.

3. Career academies in Wake County

Wake County currently operates 20 career academies in 14 high schools.[3] The district launched its first career academy, the Health

---

[1] Earlier work that used the NLSY97 to examine the effects of Tech-Prep programs on college enrollment found that Tech-Prep participants were more likely to attend 2-year colleges and less likely to enroll in 4-year institutions, relative to their counterparts who did not participate in such programs (Cellini, 2006).

[2] While MDRC was able to achieve excellent response rates using surveys that included a variety of rich measures (i.e., roughly 80 percent of the full sample), those outcomes remain self-reported and subject to potential biases (e.g., recall bias). In addition, some high schools in the MDRC sample operated other programs that they termed "career academies" (Kemple & Snipes, 2000, p. ES-15), potentially muting the treatment-control contrast. Though the authors argue that, based on information collected for the MDRC studies, those other programs lacked the core components of a well-defined career academy, the researchers also split their sample of schools into "high-contrast" and "low-contrast" subsamples. The "high-contrast" subsample included high schools in which the difference between the treatment and control conditions was relatively starker: for example, "… high-contrast academies tended to have implemented a tighter school-within-a-school organization compared with the low-contrast sites" (Kemple & Snipes, 2000, p. ES-19).

[3] See Appendix Table A1 for a full list of Wake County career academies by

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.[4] 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 in Wake County reflects the 18 different occupational areas specified by the U.S. Department of Education (Levesque et al., 2008).

3.1. Profile of student participation in Wake County career academies

Fig. 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.[5] The socio-demographic makeup of Wake County is similar to the nation at large: Estimates from a nationally representative dataset that begins with 9th graders in 2009 (i.e., the HSLS:09) show that about 36 percent are black or Hispanic (Ingels et al., 2011), and the equivalent figure for Wake County 9th graders is 40 percent. The vast majority of academies in Wake County 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. This contrasts with MDRC's analytic sample in which more than half of enrollees were female and the vast majority were black or Hispanic (Kemple & Snipes, 2000). 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) may be 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 – a sentiment confirmed by successive editions of the National Standards of Practice (NCAC, 2004, 2013).

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 and achievement measures. We first estimate linear probability models via OLS that explain enrollment in any career academy. In column 1 of Table 2, we begin with the simplest specification that includes measures of a student's gender, race and ethnicity, 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.[6] 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 6, we use a multinomial logit model to examine choices among enrollees about career academies of different types, which includes the full set of covariates from the specification in column 3. The base choice category is "other," mainly non-STEM career academies such as those that focus on culinary arts, hospitality, and public safety.

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 students are about 1 percentage point less likely to enroll in a career academy, relative to their non-Hispanic, white counterparts and LEP students are about 2 percentage points less likely to do so, relative to their non-LEP counterparts. Note that students with special education needs are equally likely to attend a career academy as those without such needs, conditional on prior achievement. Findings in columns 4 through 6 indicate that conditional on enrolling in any career academy, female students are more likely to enter an academy focused on science and less likely to enter an engineering academy, relative to their male counterparts. Black and Asian, non-Hispanic students are more likely to choose academies with technology, science, and engineering foci and less likely to enter academies with largely non-STEM foci (i.e., the "other focus" reference category), relative to their white, non-Hispanic counterparts. Finally, LEP students are more likely to choose these "other," largely non-STEM career academies and less likely to enter science-focused academies, relative to their non-LEP peers.

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 High School's 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.[7] 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 enrollment.

(footnote continued)
launch year.

[4] Wake County CTE staff suggested that recent career academy expansion has been a function of hiring the district's first full-time career academy coordinator in 2010, local labor market demand in relevant sectors, and comparable career academy growth across the nation.

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

---

[6] We standardized all test scores across the district by subject, grade, and year. The traditional pathway to gifted identification in Wake County requires that students entering 3rd grade score at or above the 85th percentile on a section of the Cognitive Abilities Test (CogAT) before qualifying to take the Iowa Assessments. Students scoring at or above the 95th percentile on the CogAT or Iowa Assessments are recommended for gifted status. The district implemented additional pathways to gifted identification over the course of our study period.

[7] 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.

A. Overlaid by Census-Tract Level Median Household Income
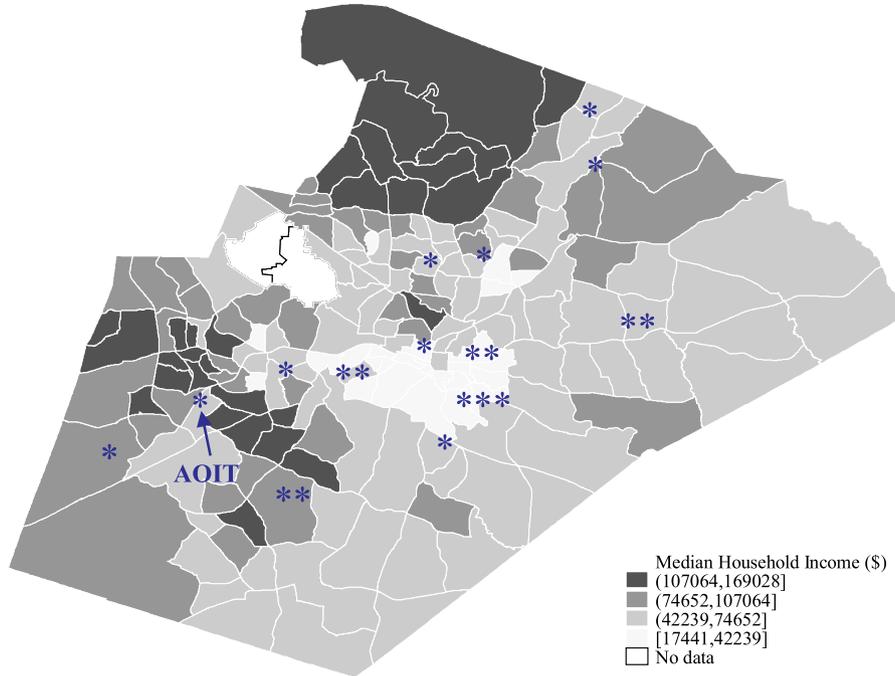
B. Overlaid by Census-Tract Level Non-White Population
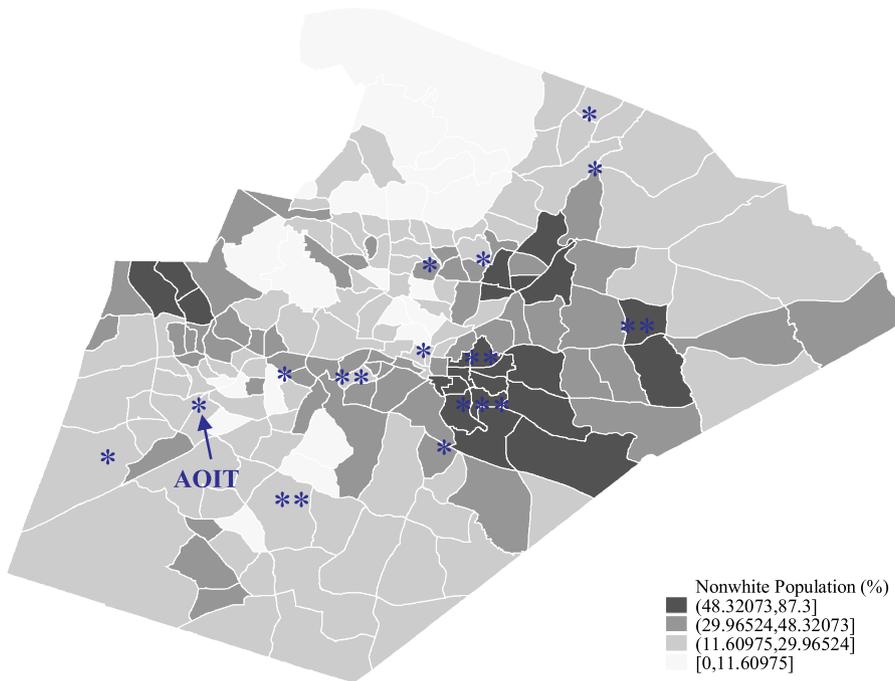
Fig. 1. Geographic Distribution of WCPSS Career Academies. A. Overlaid by Census-Tract Level Median Household Income. B. Overlaid by Census-Tract Level Non-White Population.
Sources: U.S. Census Bureau, 2011–2015 American Community Survey 5-Year Estimates (Table B19013: Median Household Income in the Past 12 Months, Table DP05: ACS Demographic and Housing Estimates) and WCPSS administrative data. WCPSS = Wake County Public School System.

3.2. 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 admission to AOIT, which accepts cohorts of roughly 90 students per year. To be eligible for the

lottery, students must submit an application that includes two references (an 8th grade teacher in a core subject and another middle school staff member), a statement of interest, and a signed pledge committing, if admitted, to meet AOIT's requirements over the four-year period. The entire application and selection process occurs during spring of 8th grade, with the academy director typically offering seats to lottery winners by mid-May. AOIT does not admit students after their freshman

Table 1
Profile of Enrollees at Career Academies Across Wake County, 2014–15 and 2015–16.

			Concentration Area							
			Technology		Science		Engineering		Other	
Variable	9th Graders in WCPSS	9th Grade CA Enrollees, All Career Academies	9th Grade CA Enrollees	Non-CA 9th Graders in Same High Schools	9th Grade CA Enrollees	Non-CA 9th Graders in Same High Schools	9th Grade CA Enrollees	Non-CA 9th Graders in Same High Schools	9th Grade CA Enrollees	Non-CA 9th Graders in Same High Schools
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(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)	0.066	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 (0.999)	0.417 (0.931)	0.517 (0.889)	0.005 (1.046)	0.432 (1.005)	−0.212 (1.077)	0.562 (0.902)	−0.107 (0.974)	0.112 (0.875)	−0.172 (1.014)
8th Grade Reading Score (std)	0.002 (0.999)	0.316 (0.870)	0.360 (0.873)	−0.015 (1.032)	0.402 (0.843)	−0.204 (1.070)	0.396 (0.851)	−0.108 (0.992)	0.088 (0.879)	−0.132 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. Test scores are standardized across the district by subject, grade, and year. 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).

year because it views the academy as a four-year, cohort-based commitment.[8]

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,[9] a four-year sequence of IT courses/electives (students must select one of two specialized tracks), cohort-based grouping with fellow AOIT enrollees, and soft-skills training throughout the four-year program. A key feature of AOIT is the requirement that students complete one of two curricular tracks: "Applications and Web Development" or "Computer Programming." Participants must complete five CTE courses from either track and are strongly encouraged to take some combination of network engineering or computer engineering courses in order to satisfy district-wide elective requirements. Both track and suggested elective courses based on track 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 enrollees 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 track or elective pre-requisite, which non-AOIT students are unlikely to have. Taken together, these features form the treatment-control contrast but also shape external validity.

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., 92 percent) who lose the lottery enter Apex High School in the regular track (i.e., non-career-academy program).[10] 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.

---

[8] This four-year feature of AOIT contrasts with most of MDRC's sample of career academies, which serve students in grades 10 to 12 (Kemple & Rock, 1996).

[9] AOIT takes this internship component very seriously and has developed a detailed 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: https://www.apexaoit.com/internships. Further, district records show that 95 percent of AOIT enrollees over our sample's time period completed paid internships during their junior year of high school.

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

Table 2

Student Participation in Contemporary Career Academies: Wake County, 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
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Demographics						
Female	−0.010***	−0.009***	−0.008	−0.361	0.681*	−1.072***
	(0.003)	(0.003)	(0.006)	(0.362)	(0.374)	(0.383)
Black, non-Hispanic	−0.015***	0.003	0.000	1.413***	1.682***	1.912***
	(0.003)	(0.004)	(0.005)	(0.510)	(0.538)	(0.569)
Hispanic	−0.020***	−0.008**	−0.009*	−0.159	0.936	−0.265
	(0.004)	(0.004)	(0.005)	(0.527)	(0.538)	(0.627)
Asian, non-Hispanic	0.013*	0.003	0.007	1.726**	3.079***	1.939*
	(0.006)	(0.007)	(0.010)	(0.793)	(0.620)	(1.034)
Other, non-Hispanic	−0.011*	−0.004	−0.002	0.789**	0.356	0.993**
	(0.006)	(0.006)	(0.007)	(0.397)	(0.531)	(0.388)
Limited English Proficiency (LEP)	−0.027***	−0.013***	−0.017***	−1.071	−2.468***	−2.161
	(0.004)	(0.005)	(0.004)	(1.002)	(0.952)	(1.919)
Special education	−0.010***	0.005	0.004	0.533	−0.206	−0.014
	(0.004)	(0.004)	(0.004)	(0.376)	(0.488)	(0.470)
Academic Achievement						
Academically Gifted (Math or Reading)	–	0.011**	0.009	0.046	0.477	−0.208
		(0.006)	(0.008)	(0.412)	(0.386)	(0.515)
8th Grade Math Score (std)	–	0.013***	0.013***	0.248	0.125	0.538*
		(0.002)	(0.002)	(0.282)	(0.293)	(0.280)
8th Grade Reading Score (std)	–	0.001	0.003	−0.067	0.063	−0.040
		(0.002)	(0.002)	(0.252)	(0.206)	(0.255)
Middle school fixed effects	No	No	Yes	Yes	Yes	Yes
Outcome mean	0.043	0.043	0.043	0.313	0.251	0.210
N(students)	22,895	22,895	22,895	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 6. Columns 4 to 6 report coefficients from a multinomial logit regression, indicating the relative likelihood of choosing an academy with a particular industry focus compared with the base group of "other," mainly non-STEM academies (see below). *** 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 (1). 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; 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 if space allows)
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 website documents: http://www.apexaoit.com.

4. 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.[11] Finally, we submit rosters of applicants to the National Student

---

[11] While we include the most commonly used student-level characteristics, we are unable to use 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 programs permitted

Clearinghouse (NSC) to obtain information on college-going and initial college choice.[12]

Over our study period, AOIT received nearly twice as many applications as available seats (Appendix Table A2). To construct our analytic sample, we begin with a total of 646 applications in the 9th grade 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).[13] This results in an analytic sample of 469 students.

5. 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 Fig. 1A), its enrollees are less racially and ethnically diverse than the district as a whole (see Fig. 1B). Comparisons of AOIT enrollees with the full set of 9th graders in Apex High 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:

$$Y_{ic} = \alpha + \beta_1 CA_{ic} + \varphi X_{ic} + \delta_c + \varepsilon_{ic} \qquad (1)$$

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;

(footnote continued)
to access 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). Research studies of LEA programs, such as AOIT, are not permitted to use 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).

[12] NSC data record enrollment in participating institutions of all kinds (i.e., public/private, in-state/out-of-state). The enrollment coverage rates for NSC data during our time period of study are very high in North Carolina and surrounding states (Dynarski, Hemelt, & Hyman, 2015; Shapiro, Dundar, Wakhungu, Yuan, & Harrell, 2015).

[13] 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.

Table 4
Descriptive Statistics and Covariate Balance: AOIT.

Variable	Means			Baseline regressions
	WCPSS Public 9th Graders (1)	Apex 9th Graders (2)	AOIT Applicants (3)	Coefficient on indicator denoting lottery win (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 (std)	0.001	0.490	0.833	−0.041
	(1.000)	(0.867)	(0.745)	(0.072)
8th Grade Reading Score (std)	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 and 4 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: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

and ε_{ic} 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 Eq. (1), β_1 represents the causal effect of winning the lottery on students' outcomes.

To study the effects of participating in the career academy we use lottery assignment as an instrumental variable (IV) for *enrollment* in AOIT. The intuition behind this approach is that we can exploit random variation in the choice to participate in the 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:

$$E_{ic} = \alpha + \theta_1 CA_{ic} + \gamma X_{ic} + \delta_c + \omega_{ic} \qquad (2)$$

$$Y_{ic} = \alpha + \beta_1 \widehat{E}_{ic} + \phi X_{ic} + \delta_c + \varepsilon_{ic} \qquad (3)$$

Similarly named variables and vectors in Eqs. (2) and (3) are the same as their counterparts described in Eq. (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 Eq. (2), we use lottery assignment to isolate exogenous variation in whether a student enrolls in the career academy. In Eq. (3), we then use this

remaining, exogenously determined variation in enrollment to identify the causal impact of participating in AOIT on our outcomes of interest. Specifically, β_1 represents the weighted, local average treatment effect (LATE): that is, the weighted average of outcome differences between enrollee and non-enrollee compliers[14] 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 (Angrist et al., 1996; 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). In the analytic sample focused on AOIT, the average student in the bottom third of the baseline math achievement distribution falls at the district-wide mean, whereas average performance escalates quickly for those in the second and third terciles of the baseline achievement distribution.[15] We estimate all models using heteroskedasticity-robust standard errors.

6. 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 along the road to high school completion: attendance in 9th grade, academic performance and participation in advanced course-taking during high school, and industry-recognized credential attainment. We close this section with a look at the effects of involvement in AOIT on college enrollment.

6.1. Effects on high school graduation

In Table 5, we present first-stage, ITT, and LATE results related to participation in AOIT and high school graduation. First-stage estimates in Panel A indicate that lottery winners are 84 percentage points more likely to enroll in AOIT, compared to lottery losers. 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 (LATE) 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 from a public high school elsewhere in the state, our measure records this event.[16] 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 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.

6.2. Intermediate outcomes: Effects on attendance, performance, course-taking, and industry certifications 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),[17] we focus on this outcome as our measure of engagement. Panel A of Table 6 presents our main 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.

A natural next question is whether this reduction in absences is a general one or is driven by attendance changes among students with particularly high rates of baseline absence. Figs. 2 and 3 address this question. In Fig. 2, we plot distributions of 9th grade absences by treatment and control groups. Panel A contrasts distributions for lottery winners and losers. Panel B plots analogous distributions for treatment compliers (i.e., lottery winners who enrolled in the career academy) and control compliers (i.e., lottery losers who did not enroll in the academy). Across both panels, we see a pivot in the density of absences for the treatment group away from very high levels of absence (i.e., between 10 and 15 days) and toward much lower levels of absence (i.e., 0 to 5 days). Fig. 3 formalizes this analysis through the use of quantile regressions, which allow one to estimate the effect of career academy participation at different points in the distribution of 9th grade absences. The y-axis plots the ITT effect of winning the lottery at various points along this distribution. Estimates are close to zero and statistically insignificant until the top 15 to 20 percent of the distribution, where the magnitude of the effect rises sharply and becomes statistically significant at conventional levels.

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 (columns 3 and 4 of Table 6). We fail to detect statistically significant differences in effects of academy participation by terciles of baseline achievement – though the size and direction of the coefficients are suggestive of greater impacts on relatively lower-achieving students (columns 5 to 7 of Table 6).

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 (2009–10) would have reached 11th grade under this policy.[18] We explore the effects of career academy participation on composite ACT test scores as well as subject-area scores

---

[14] Since some students who lose the lottery still end up enrolling in the career academy (from the waitlist), this effect is a local average treatment effect (LATE; Angrist, Imbens, & Rubin, 1996) that applies to students who complied with their lottery status.

[15] Students in the middle third of the baseline math achievement distribution score about 0.85 standard deviations above the district-wide mean and those in the top third score an average of 1.66 standard deviations above the typical student in the wider district.

[16] 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.

[17] Allensworth and Easton (2007) argued that in addition to high rates of absence, moderate rates of absence early in high school were also problematic.

[18] Though the test was mandatory for all cohorts in our sample, 40 students are missing ACT scores even though they have full demographic and baseline 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.

Table 5
Career Academy Participation and 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)	(7)	(8)
Outcome = Enroll in career academy								
A. First-Stage Results								
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)
F-statistic	723.6	994.1	986.0	555.5	419.0	294.5	597.8	182.5
Outcome = Graduate from high school (expected, on-time)								
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 (LATE)								
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 basic baseline data. Heteroskedasticity-robust standard errors appear in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. ITT = intent to treat; LATE = local average treatment effect.

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	Males	Females	Bottom Third	Middle Third	Top Third
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Effect of Winning Lottery (ITT)							
Won lottery	−1.194**	−0.007**	−0.874*	−1.529	−1.928	−0.940	−0.203
	(0.579)	(0.003)	(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**	−1.068	−1.759	−2.337	−1.037	−0.267
	(0.630)	(0.003)	(0.692)	(1.219)	(1.622)	(0.679)	(0.765)
Outcome mean, control group	3.78	0.02	3.51	4.27	4.99	3.61	2.71
N(students)	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.

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 and the transition to some form of postsecondary training is through participation in advanced courses during high school. We explore this hypothesis using data on students' Advanced Placement (AP) course-taking during high school in Table 8. Overall, we detect little to no impact of AOIT enrollment on measures of 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. 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 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. However, the fact that we find no evidence that academy enrollment reduces academic achievement or depresses rates of advanced course-taking in late high school assuages fears that career academies must sacrifice postsecondary preparation for vocational skills.

A fourth way in which academy enrollment may influence high school completion is through the acquisition of industry-relevant knowledge. To explore this channel, we obtained student-level industry credential data. One of the few studies of high school industry credentials found that students who earned such a credential crafted stronger career plans (Castellano, Stone, & Stringfield, 2005). At the North Carolina community college level, the attainment of an "information science, communication, and design" certificate boosts the short-term likelihood of employment by 5 percentage points and quarterly earnings by more than $400 (Xu & Trimble, 2016). Wake County collects similar industry-focused credentials across a range of occupational areas, most recently administering nearly 40,000 certification exams to 17,000 unique students (roughly one-third of all high school students in the district). Certification exams are open to all students, regardless of academy membership. Technology-based credentials captured through Pearson's Certiport platform, which include

A. Intent-to-treat (ITT) Effect
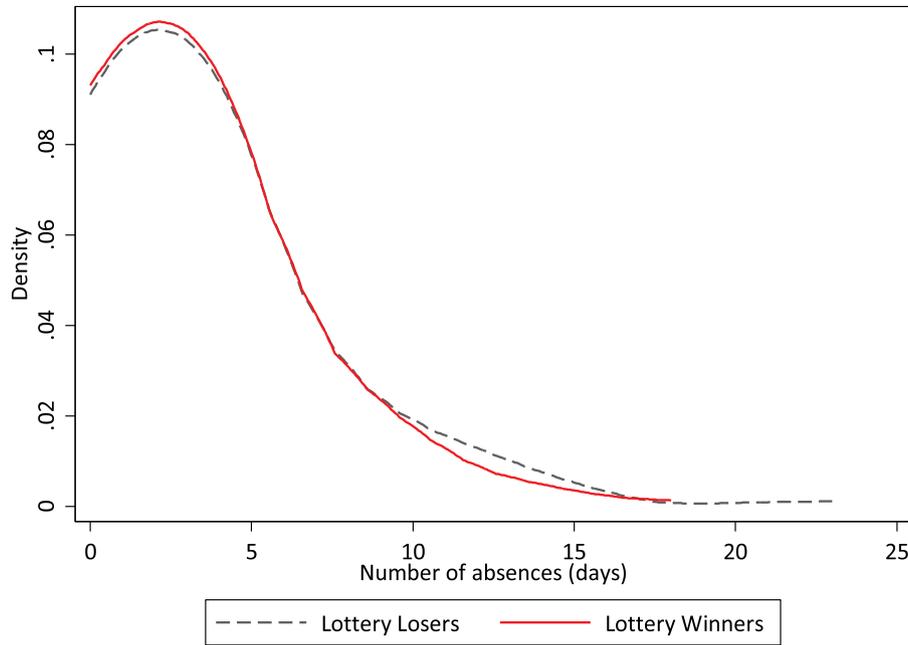
B. Local Average Treatment Effect (LATE)
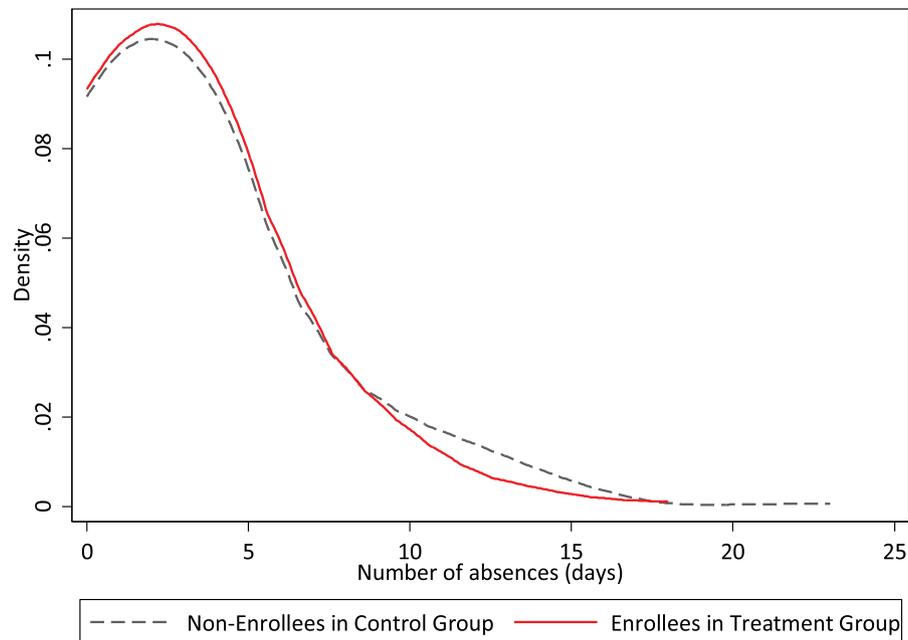
Fig. 2. AOIT Participation and 9th Grade Absences. A. Intent-to-treat (ITT) Effect. B. Local Average Treatment Effect (LATE). Notes: Figures depict kernel density plots of the outcome by treatment and control group. AOIT = Apex Academy of Information Technology.

Adobe, Autodesk and Microsoft certificates, are most relevant to our analyses and typically represent one-third of all credentials in the district. For this analysis, we use data on the "Microsoft Office Specialist" credential, the most prevalent in the Certiport database, representing roughly three-quarters of its credentials.[19] Table 9 presents estimates of

the effect of career academy enrollment on the likelihood of earning this particular IT certification. We find that AOIT enrollment increases the likelihood of earning such a certification by about 23 percentage points, roughly doubling the rate of credential attainment among the control group.

Taken together, our analysis of these four intermediate outcomes

---

[19] We worked directly with Pearson representatives to obtain historical credential data for our period of study. They were only able to provide historical data on Microsoft credentials and therefore we cannot explore the effects of academy enrollment on earning any technology-related industry credential.

(footnote continued)
However, Microsoft credentials constitute the vast majority of the Certiport database.
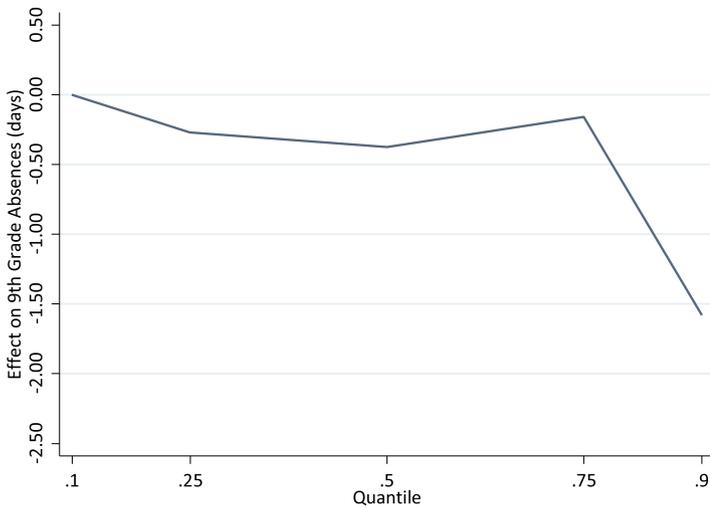
Fig. 3. Distributional Intent-to-treat Effects on 9th Grade Absences.Notes: Figure depicts coefficient estimates from simultaneous quantile regressions at various points in the distribution of 9th grade absences. Quantile regression models include student-level controls for demographics and 8th grade test scores as well as indicators for year of application (i.e., 9th grade year). The y-axis plots coefficients on the indicator variable that denotes whether a student won the admission lottery for AOIT.

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

	All Students			Subgroups by Gender					
				Males			Females		
Independent variable	ACT Composite (1)	ACT Math (2)	ACT Reading (3)	ACT Composite (4)	ACT Math (5)	ACT Reading (6)	ACT Composite (7)	ACT Math (8)	ACT Reading (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 (LATE)									
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 and SD, control group	24.41	25.90	24.17	24.29	26.14	23.80	24.63	25.46	24.84
	(4.87)	(4.85)	(6.14)	(5.05)	(4.95)	(6.38)	(4.56)	(4.65)	(5.65)
N(students)	469	469	469	300	300	300	169	169	169
Subgroups by Baseline Math Achievement									
	Bottom Third			Middle Third			Top Third		
Independent variable	ACT Composite (10)	ACT Math (11)	ACT Reading (12)	ACT Composite (13)	ACT Math (14)	ACT Reading (15)	ACT Composite (16)	ACT Math (17)	ACT Reading (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 (LATE)									
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 and SD, control group	20.32	21.62	19.95	24.77	26.13	24.78	28.27	30.07	27.88
	(3.87)	(3.67)	(5.22)	(3.20)	(3.00)	(5.04)	(3.89)	(3.60)	(5.43)
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 basic 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; LATE = local average treatment effect; SD = standard deviation.

suggests that the downstream effect on high school graduation is at least partially mediated by effects on absences and industry-relevant knowledge. That is, enrollment in AOIT appears to improve students' engagement in school, enhance industry-related competencies, and ultimately increase the likelihood of high school graduation.

6.3. 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. Indeed, the coalition behind the "national standards of practice" for career academies argues that academy participants should be enrolled in a curriculum that exceeds college entrance requirements and minimizes the likelihood of remediation upon college entry (NCAC, 2013). The wisdom of this aim is underscored by recent work that finds that those with vocational training are more likely to be employed when young but face greater obstacles later in their careers as they struggle to adapt to technological and structural changes in the economy, relative to those with general education (Hanushek, Schwerdt, Woessmann, & Zhang, 2017). These findings highlight the importance of broad education that develops general cognitive skills (Hanushek & Woessmann, 2017). Contemporary career academies like AOIT appear to be taking this charge seriously. Consider the effort AOIT exerts to facilitate an integrated curriculum for its

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

Independent variable	All Students				Outcome = Enroll in AP Math or Science Course				
					Subgroups by Gender		Subgroups by Baseline Math Achievement		
	Enroll in Any AP Course (1)	Enroll in AP Math or Science Course (2)	Enroll in Other AP Course (3)	Pass Any AP Math or Science Exam (4)	Males (5)	Females (6)	Bottom Third (7)	Middle Third (8)	Top Third (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 (LATE)									
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 basic 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; LATE = local average treatment effect.

Table 9
Career Academy Participation and Industry Credentials.

Independent variable	Outcome = Earned "Microsoft Office Specialist" Certification					
	All Students	Subgroups by Gender		Subgroups by Baseline Math Achievement		
	(1)	Males (2)	Females (3)	Bottom Third (4)	Middle Third (5)	Top Third (6)
A. Effect of Winning Lottery (ITT)						
Won lottery	0.189***	0.156***	0.263***	0.227***	0.147**	0.245***
	(0.038)	(0.047)	(0.064)	(0.065)	(0.069)	(0.073)
B. Effect of Enrolling in Career Academy (LATE)						
Enrolled in AOIT	0.227***	0.191***	0.303***	0.276***	0.162**	0.322***
	(0.044)	(0.057)	(0.069)	(0.075)	(0.075)	(0.092)
Outcome mean, control group	0.20	0.21	0.16	0.17	0.22	0.19
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 basic baseline data. See text for additional discussion of data on industry certifications. Heteroskedasticity-robust standard errors appear in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. ITT = intent to treat; LATE = local average treatment effect.

Table 10
Career Academy Participation and College Enrollment.

Independent variable	Outcome = Enroll in college within 1 year of expected, on-time high school graduation					
	All Students	Subgroups by Gender		Subgroups by Baseline Math Achievement		
	(1)	Males (2)	Females (3)	Bottom Third (4)	Middle Third (5)	Top Third (6)
A. Effect of Winning Lottery (ITT)						
Won lottery	0.037	0.070**	−0.032	0.014	0.053	0.027
	(0.030)	(0.033)	(0.054)	(0.061)	(0.051)	(0.041)
B. Effect of Enrolling in Career Academy (TOT)						
Enrolled in AOIT	0.044	0.085**	−0.036	0.016	0.059	0.036
	(0.036)	(0.043)	(0.066)	(0.073)	(0.058)	(0.060)
Outcome mean, control group	0.87	0.87	0.88	0.84	0.87	0.92
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; LATE = local average treatment effect.

Table 11
Career Academy Participation and College Choice, Male Students.

Independent variable	Location and Control of First Institution							Intensity of First Semester		
	Any in-state institution (1)	In-state Public (2)	In-state Private (3)	In-state, Public, 4-year (4)	In-state, Public, 2-year (5)	In-state, Private, 4-year (6)	In-state, Private, 2-year (7)	Full time (8)	Part time (9)	Missing Intensity (10)
A. Effect of Winning Lottery (ITT)										
Won lottery	0.084*	0.086	−0.002	0.051	0.035	0.005	−0.007	0.023	0.022	0.019
	(0.051)	(0.053)	(0.024)	(0.058)	(0.045)	(0.024)	(0.007)	(0.052)	(0.022)	(0.046)
B. Effect of Enrolling in Career Academy (LATE)										
Enrolled in AOIT	0.101*	0.105	−0.002	0.062	0.043	0.006	−0.009	0.029	0.027	0.023
	(0.061)	(0.066)	(0.031)	(0.071)	(0.054)	(0.030)	(0.008)	(0.065)	(0.025)	(0.057)
Outcome mean, control group	0.73	0.69	0.05	0.52	0.17	0.04	0.01	0.65	0.02	0.19
N(students)	300	300	300	300	300	300	300	300	300	300

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; LATE = local average treatment effect.

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 and choice in Tables 10 and 11. In terms of college enrollment, we find that career academy participation increases the likelihood of college attendance within one year of on-time, expected high school graduation for males but not females. Specifically, estimates in column 2 of Table 10 imply that a male career academy enrollee is 8.5 percentage points more likely to enroll in college within one year of expected, on-time high school graduation, compared to his counterpart who did not enroll in the academy. Further, if we estimate the effect of academy participation on college enrollment for males conditional on high school graduation, we arrive at a point estimate of 0.065 that teeters on the edge statistical significance ($p = 0.11$). This suggests that the effect of academy enrollment on college-going operates more through a change in students' propensity to attend college than through an increase in the opportunity to attend college.

Among all 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. Table 11 explores the effects of AOIT enrollment on college choice for males. The estimates in column 1 show that the boost in college-going along the extensive margin for males is entirely captured by an increase in the likelihood of attending an in-state institution. Columns 2, 4, and 5 illustrate that this in-state increase is accounted for by public institutions, roughly split between increases in the likelihood of attending an in-state public 4-year institution and an in-state public 2-year institution. We fail to detect meaningful impacts of AOIT participation on the intensity of a student's initial college enrollment (i.e., full-time versus part-time enrollment).[20]

7. Discussion: External validity and costs of AOIT

Our experimental analysis of the effects of career academy participation on a range of educational outcomes leverages a well-implemented lottery at one school. Thus, the wider applicability of

findings that flow from that analysis is necessarily limited. However, external validity is not a one-dimensional construct. The academy on which we focus, AOIT, and the high school in which it resides mirror some attributes of wider, contemporary profiles of career academies and their enrollees but differ on another set of dimensions. Thus, we use Cook's (2014) framework for thinking about external validity as a way to organize our discussion. The key dimensions of any study are the units (u), treatment (t), outcomes (o), setting (s), and time period (t_i): "utost$_i$" (Cook, 2014; Cronbach, 1982). The elements of the treatment (t) are mostly common to the career academy model (e.g., CTE coursework, cohort-based progression, work-based internships) and the topical focus is relatively more reflective of current student interests (i.e., website development and computer programming) and employer demand.[21] One treatment attribute of AOIT that is surprisingly uncommon when viewed against a recent, nationally representative survey of public school districts is the requirement that students participate in paid, work-based internships during their junior year of high school. Nationally, only 20 percent of districts reported that "most" or "all" of their CTE programs require work-based learning (Gray & Lewis, 2018). Administrators at AOIT cite the paid internship as critical to the academy's success. A second attribute of the treatment that differs from other career academies is that students must enter AOIT in the 9th grade, rather than being admitted slightly later in high school. The outcomes (o) to which one would want to generalize certainly include those studied in this paper. The time period (t_i) is more recent than prior work on the causal effects of career academies.

The setting (s) and units (u) are the two dimensions along which AOIT is more unique. The high school in which AOIT resides is a fairly high-performing school. Ninth-grade students in Apex High School scored an average of 0.49 and 0.41 standards deviations above the district mean on 8th grade math and reading tests, respectively. Applicants to the career academy within Apex's walls scored even higher. The fact that modern-day applicants are positively selected is not unique to AOIT, at least across Wake County. Table 2 confirms that higher math scores in 8th grade are positively associated with academy enrollment of any type. Relative to a recent, national portrait of career academy enrollees, AOIT applicants are more likely to be white or Asian (Sun & Spinney, 2017). An additional characteristic of the setting (s) is

---

[20] Note that intensity information tends to be missing at high rates in NSC data (Dynarski et al., 2015). In our analytic sample, about 18 percent of college enrollees are missing information on enrollment intensity.

[21] For example, the National Science Foundation (2018) summarized developments that signal increased demand for IT-based education, including an increase of 19 states from 2013 to 2017 that accept computer science credit toward high school graduation, the College Board's new AP Computer Science Principles course (launched in 2016-17), and the inclusion of computer science in the Every Student Succeeds Act's definition of a "well-rounded education."

Table 12
Costs of AOIT Operation.

	Year						
	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Expenditure Category							
Centrally allocated career and technical education (CTE) funds	$1,728	$2,873	$4,238	$20,704	$20,213	$8,324	$13,431
Career Academy Career Development Coordinator (CA-CDC)	$64,059	$65,366	$66,700	$68,062	$69,451	$70,868	$72,314
Allotments for hardware, software, and supplies	$20,834	$23,780	$37,981	$8,978	$37,023	$35,322	$31,136
Grants to Apex High School AOIT Support Team (501c3)	$8,181	$8,333	$8,333	$8,333	$8,333	$8,333	$8,333
Receipts through Apex High School AOIT Support Team (501c3)	$12,788	$16,667	$16,667	$16,667	$16,667	$16,667	$16,667
Total	$107,590	$117,020	$133,919	$122,743	$151,687	$139,514	$141,881
Cost per academy enrollee (nominal dollars)	$1,435	$1,300	$1,488	$1,364	$1,685	$1,550	$1,576
Cost per academy enrollee (constant 2016 dollars)	$1,579	$1,387	$1,555	$1,405	$1,709	$1,570	$1,576

Notes: The large jumps in CTE funds in 2012–13 and 2013–14 were due to increases in attendance at NAF workshops and its organizational fees. The CA-CDC's salary is based on the 2017–18 median salary for 10-month employees, adjusted for AOIT's 11-month position and further adjusted annually for 2% cost-of-living increases. Allotments are assigned from the district to Apex High School, which houses AOIT. We conservatively assume that all IT-related allotments are consumed at least partially by AOIT participants and, as such, we assign the full allotment to AOIT. The AOIT Academic Support Team (AST) is the academy's 501(c)(3) fundraising arm, which supports students who may not otherwise be able to fund participation in field trips or related activities. AST funds for 2009–10 were drawn from the IRS Form 990-EZ. From 2010–11 onward, AST was required to submit IRS Form 990-N (e-postcard) declaring that total funds raised were below $50,000. A former AST treasurer told us that total funds were always below $25,000, so we use that as our benchmark for these years. Thus, we assume that grants represent the 2009–10 share (one-third) of this total and receipts from that year the remainder (two-thirds). Cost per enrollee in constant 2016 dollars is calculated using the Consumer Price Index for All Urban Consumers (CPI-U).

that AOIT is adequately supported by the district and through funds raised by community stakeholders. Thus, these aspects related to the units (u) and setting (s) that are particular to AOIT also condition the relationship between academy participation and the outcomes we study, demanding care, caution, and careful thought by policymakers and practitioners as they seek to apply these findings more broadly.

In Table 12, we present data on the costs of operating AOIT. Costs include funds directly allocated to AOIT from the district to support staffing, CTE courses, and supplies, as well as dollars raised by the 501(c)(3) Apex High School AOIT Support Team and reported through IRS documents (IRS, 2010, 2016). Using cohort sizes from Appendix Table A2, we calculate the per-enrollee cost in each year. Across all years, the average cost of running AOIT is $1,540 per enrollee in constant, 2016 dollars, which is in line with earlier estimates of the costs of California's Linked Learning academies (Parsi, Plank, & Stern, 2009),[22] higher than the cost to implement a school-wide gifted/talented magnet program,[23] and much lower than the costs of providing rich CTE instruction across a number of industry areas through regional vocational and technical high schools (Dougherty, 2018).[24] Given the 8 percentage-point effect of academy enrollment on high school graduation, this

implies a cost of about $19,744 (= $1,540/0.078) to induce one additional student to complete high school. The 8.5 percentage-point effect on college enrollment is concentrated among male students. Males make up about 64 percent of our analytic sample and thus the rough, implied cost to induce one additional (male) student to attend college is about $28,309 (= $1,540/[0.085*0.64]). This simple measure of cost effectiveness can be used by researchers and policymakers to compare future CTE-focused programs and initiatives aimed at improving high school completion and the path to some form of postsecondary study.

8. Conclusions and implications

In this paper, we examine the contemporary profile of students entering career academies and estimate causal effects of participation in a well-regarded, technology-focused academy 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 decade.

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 largely 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 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 for all students and college enrollment for males but not females. These findings are noteworthy for at least two reasons. First and most broadly, they illustrate the potential for 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

---

[22] Parsi, Plank, and Stern (2009) estimated the costs of operating 10 Linked Learning sites across multiple California school districts. These sites included four career academies, one of which was a NAF-affiliated information technology academy. Documented costs included start-up costs (e.g., staff time, equipment, and facilities) and the costs of ongoing staff time devoted to site-specific activities. The average annual per-student cost across the seven sites with complete cost information was $1,725, ranging from $1,111 to $2,436. Two of the four career academies had complete costs: $1,505 at Hoover Academy of Information Technology and $2,017 at Mt. Diablo Academy of Construction, Manufacturing, and Engineering.

[23] Wake County implemented seven school-wide gifted/talented magnet programs during the 2017-18 school year. These programs are funded internally through additional teacher time and supplementary resources and externally through proceeds raised by non-profit entities. The average per-pupil cost across these seven schools falls just under $500, or roughly one-third the per-pupil cost of implementing AOIT.

[24] In the working paper version of Dougherty (2018), per-student expenditures are about $6,000 greater in the regional vocational and technical high schools, compared to non-CTE high school settings in Massachusetts. Of course, the scale differs between these two settings. If we imagine a CTE-focused high school offering four "mini academies" across different industry areas, four times the per-student cost of AOIT is roughly equal to the $6,000 figure from Dougherty (2018).

otherwise would not have done so. Our findings further suggest that non-trivial mediators of this effect were attendance early in high school and industry-relevant certifications.

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 despite marked increases in SAT scores and the likelihood of taking and passing an AP exam (Angrist, Cohodes, Dynarski, Pathak, & Walters, 2016).

The second reason the findings are noteworthy is that the overall effects on educational attainment 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, Lang, & Oreopoulos, 2009; Deming, Hastings, Kane, & Staiger, 2014). For example, Deming et al. (2014) studied the public school choice lottery in the Charlotte-Mecklenburg (NC) School District. 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 were more responsive to the technology-rich, applied academic

setting of AOIT than girls. 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 different types of students in different settings. Only with such evidence can policymakers knit 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 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 that begins in 9th grade, 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 well-supported career academy with a different focus such as health services, public safety, or advanced manufacturing – or within a different setting, such as a high school that is academically struggling. As additional academies across the district move to lottery-based admissions, we plan to address such questions in future work. Similarly, as the cohorts in this study move through college and into the labor market, we hope to study the early labor market experiences of academy enrollees.[25] 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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.econedurev.2018.08.005.

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

---

[25] Labor market data, provided by the North Carolina Department of Commerce, are not currently available to researchers in the state.

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	110	46	2.4	0.88
2010–11	2013–14	Fall 2014	137	90	1.5	110	63	1.7	0.85
2011–12	2014–15	Fall 2015	208	90	2.3	168	51	3.3	0.97
2012–13	2015–16	Fall 2016	162	90	1.8	123	51	2.4	0.91
2013–14	2016–17	Fall 2017	115	90	1.3	91	66	1.4	0.94
2014–15	2017–18	Fall 2018	155	90	1.7	116	51	2.3	0.49
2015–16	2018–19	Fall 2019	112	90	1.2	76	54	1.4	N/A
Total			1,028	615	1.7	794	382	2.1	0.85

Notes: In 2014–15, a second career academy to which students zoned for Apex High School could apply opened in Apex Friendship High School (Academy of Engineering and Advanced Manufacturing) and thus the share of students who lost the AOIT lottery and attended "regular" Apex High School dropped because many entered the new academy.

References

Allensworth, E. M., & Easton, J. Q. (2007). What matters for staying on-track and graduating in chicago public high schools: A close look at course grades, failures, and attendance in the freshman year. Research report. *Consortium on Chicago School Research*, 1–61.

Anderson, M. L. (2008). Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects. *Journal of the American Statistical Association, 103*(484), 1481–1495.

Angrist, J. D., Imbens, G. W., & Rubin, D. B. (1996). Identification of causal effects using instrumental variables. *Journal of the American statistical Association, 91*(434), 445–455.

Angrist, J. D., Cohodes, S. R., Dynarski, S. M., Pathak, P. A., & Walters, C. R. (2016). Stand and deliver: Effects of Boston's charter high schools on college preparation, entry, and choice. *Journal of Labor Economics, 34*(2), 275–318.

Angrist, J. D., Lang, D., & Oreopoulos, P. (2009). Incentives and services for college achievement: Evidence from a randomized trial. *American Economic Journal: Applied Economics, 1*(1), 136–163.

Bishop, J. H., & Mane, F. (2004). The impacts of career-technical education on high school labor market success. *Economics of Education Review, 23*(4), 381–402.

Carnevale, A. P., Smith, N., & Strohl, J. (2013). Postsecondary education and economic opportunity. In L. W. Perna (Ed.). *Preparing today's students for tomorrow's jobs in metropolitan America* (pp. 93–120). University of Pennsylvania Press.

Castellano, M., Stone, J. R., III, & Stringfield, S. (2005). Earning industry-recognized credentials in high school: Exploring research and policy issues. *Journal of Career and Technical Education, 21*(2), 7–34.

Cellini, S. R. (2006). Smoothing the transition to college? The effect of Tech-Prep programs on educational attainment. *Economics of Education Review, 25*, 394–411.

Cook, T. D. (2014). Generalizing causal knowledge in the policy sciences: External validity as a task of both multi-attribute representation and multi-attribute extrapolation. *Journal of Policy Analysis and Management, 33*(2), 527–536.

Cronbach, L. J. (1982). *Designing evaluations of educational and social programs*. San Francisco, CA: Jossey-Bass.

Cullen, J. B., Jacob, B. A., & Levitt, S. D. (2005). The impact of school choice on student outcomes: An analysis of the Chicago Public Schools. *Journal of Public Economics, 89*(5-6), 729–760.

Cullen, J. B., Jacob, B. A., & Levitt, S. (2006). The effect of school choice on participants: Evidence from randomized lotteries. *Econometrica, 74*(5), 1191–1230.

Cullen, J. B., Levitt, S. D., Robertson, E., & Sadoff, S. (2013). What Can Be Done To Improve Struggling High Schools. *The Journal of Economic Perspectives, 27*(2), 133–152.

Dayton, C. (2010). *Planning guide for career academies*. Career Academy Support Network.

Dee, T. S. (2004). Are there civic returns to education? *Journal of Public Economics, 88*(9-10), 1697–1720.

Deming, D. J., Hastings, J. S., Kane, T. J., & Staiger, D. O. (2014). School choice, school quality, and postsecondary attainment. *The American Economic Review, 104*(3), 991–1013.

Dougherty, S. M. (2016,). *Career and technical education in high school: does it improve student outcomes?* Washington, DC: Thomas B. Fordham Institute. Available at: https://edexcellence.net/publications/career-and-technical-education-in-high-school-does-it-improve-student-outcomes.

Dougherty, S. M. (2018). The effect of career and technical education on human capital accumulation: Causal evidence from Massachusetts. *Education Finance and Policy, 13*(2), 119–148.

Dynarski, S. M., Hemelt, S. W., & Hyman, J. M. (2015). The missing manual: Using National Student Clearinghouse data to track postsecondary outcomes. *Educational Evaluation and Policy Analysis, 37*(1S), 413–436.

Gray, L., & Lewis, L. (2018). *Career and technical education programs in public school Districts: 2016–17: first look (NCES 2018-028)*. Washington, DC: National Center for Education Statistics U.S. Department of Education.

Hanushek, E. A., Schwerdt, G., Woessmann, L., & Zhang, L. (2017). General education, vocational education, and labor-market outcomes over the lifecycle. *Journal of*

Human Resources, 52(1), 48–87.

Hanushek, E. A., & Woessmann, L. (2017). *School resources and student achievement: A review of cross-country economic research. Cognitive abilities and educational outcomes.* Springer International Publishing149–171.

Hanushek, E. A., & Woessmann, L. (2008). The role of cognitive skills in economic development. *Journal of Economic Literature, 46*(3), 607–668.

Holzer, H. J. (2012). Good workers for good jobs: Improving education and workforce systems in the US. *IZA Journal of Labor Policy, 1*(1), 1–19.

Holzer, H. J. (2014). Proposal 8: Improving employment outcomes for disadvantaged students. *Policies to Address Poverty in America, 87*.

Ingels, S. J., Pratt, D. J., Herget, D. R., Burns, L. J., Dever, J. A., Ottem, R. et al. (2011). High school longitudinal study of 2009 (HSLS: 09): Base-year data file documentation. NCES 2011-328. National Center for Education Statistics.

Internal Revenue Service. (2010). Form 990-EZ, Short Form Return of Organization Exempt From Income Tax: Apex High School AOIT support team. 2008 Retrieved from the Foundation Center http://foundationcenter.org/find-funding/990-finder.

Internal Revenue Service. (2016). Form 990-N, Electronic Notice (e-Postcard) for Tax-Exempt Organizations: Apex High School AOIT Support Team. 2011 Retrieved from IRS Tax Exempt Organization Search https://apps.irs.gov/app/eos.

Kemple, J. J., & Rock, J. L. (1996). *Career Academies. Early implementation lessons from a 10-Site evaluation.* New York: Manpower Demonstration Research Corporation.

Kemple, J. J. (2001). *Career academies: impacts on students' initial transitions to post-secondary education and employment.* New York: Manpower Demonstration Research Corporation.

Kemple, J. J. (2004). Career academies: Impacts on labor market outcomes and educational attainment. *MDRC*, 1–106.

Kemple, J. J., & Snipes, J. C. (2000). *Career Academies: Impacts on Students' Engagement and Performance in High School.* MDRC.

Kemple, J. J., & Willner, C. J. (2008). *Career academies: Long-term impacts on labor market outcomes, educational attainment, and transitions to adulthood.* New York, NY: MDRC1–47.

Kemple, J. J., & Willner, C. J. (2011). Technical resources for "Career Academies: Long-term impacts on labor market outcomes, educational attainment, and transitions to adulthood. *MDRC*, 1–130.

Kreisman, D., & Stange, K. (2017). Vocational and Career Tech Education in American High Schools: The Value of Depth Over Breadth. *Education Finance and Policy*, 1–72.

Levesque, K., Laird, J., Hensley, E., Choy, S. P., Cataldi, E. F., & Hudson, L. (2008). Career and Technical Education in the United States: 1990 to 2005. Statistical Analysis Report. NCES 2008-035,. *National Center for Education Statistics*.

Maxwell, N. L. (2001). Step to college moving from the high school career academy through the 4-Year University. *Evaluation Review, 25*(6), 619–654.

Maxwell, N. L., & Rubin, V. (2002). High school career academies and post-secondary outcomes. *Economics of Education Review, 21*(2), 137–152.

Murnane, R. J. (2013). U.S. High School Graduation Rates: Patterns and Explanations. *Journal of Economic Literature, 51*(2), 370–422.

National Academies Foundation. (2017). National Data Card, 2016–2017.

National Academies Foundation. (2016). *Powering up.* NAF's Distinguished Academies.

National Academies Foundation. (2013). *Apex high academy wins first sanford I.* Weill Academy of Excellence Award.

National Standards of Practice for Career Academies, 2004. Nashville, TN: National Career Academy Coalition.

National Career Academy Coalition. (2013). *National standards of practice for career academies*.

National Center for Education Statistics. (2015). Digest of Education Statistics 2015. Tables 219.10 and 219.46. Access: https://nces.ed.gov/programs/coe/indicator_coi.asp.

National Science Foundation. (2018). *Science and engineering indicators 2018 (NSB-2018-1) and digest (NSB-2018-2).* Alexandria, VA: National Science Foundation, National Science Board, and National Center for Science and Engineering Statistics.

NCDPI. (2016). Disclosure of Student's Eligibility Status for Free and Reduced Price Meals: Memorandum of Agreement.

Neild, R. C., Stoner-Eby, S., & Furstenberg, F. (2008). Connecting entrance and departure: The transition to ninth grade and high school dropout. *Education and Urban Society,*

40(5), 543–569.

Neumark, D., & Rothstein, D. (2006). School-to-career programs and transitions to employment and higher education. *Economics of Education Review, 25*(4), 374–393.

Orr, M. T., Bailey, T., Hughes, K. L., Kienzl, G. S., & Karp, M. M. (2007). The National Academy Foundation's Career Academies: Shaping Postsecondary Transitions. In D. Neumark (Ed.). *Improving School-to-Work Transitions*(pp. 169–209).

Parsi, A., Plank, D., & Stern, D. (2009). *Costs of California multiple pathway programs. Policy analysis for california education (PACE)*. Berkeley: University of California.

Rabren, K., Carpenter, J., Dunn, C., & Carney, J. S. (2014). Actions against poverty the impact of career technical education. *Career Development and Transition for Exceptional Individuals, 37*(1), 29–39.

Shapiro, D., Dundar, A., Wakhungu, P. K., Yuan, X., & Harrell, A. (2015). *Transfer and Mobility: a national view of student movement in postsecondary Institutions, fall 2008 cohort (Signature report No. 9)*. Herndon, VA: National Student Clearinghouse Research Center.

Smith, J., Pender, M., & Howell, J. (2013). The full extent of student-college academic undermatch. *Economics of Education Review, 32*, 247–261.

Stern, D., Dayton, C., & Raby, M. (2010). *Career Academies: A Proven Strategy to Prepare High School Students for College and Careers.* Berkeley, CA: Career Academy Support Network1–39.

Stone, J. R., Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Enhancing high school students' math skills through career and technical education. *American Educational Research Journal, 45*(3), 767–795.

Sun, J., & Spinney, S. (2017). *Transforming the American High School Experience: NAF's Cohort Graduation Rates from 2011-2015.* Fairfax, VA: ICF International1–49.

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09), First Follow-up and High School Transcript Study Public-Use File, 2009.

Visher, M. G., Altuna, J. N., & Safran, S. (2013). *Making it Happen: How Career Academies can Build College and Career Exploration Programs.* New York, NY: MDRC1–133.

Xu, D., & Trimble, M. (2016). What about certificates? Evidence on the labor market returns to nondegree community college awards in two states. *Educational Evaluation and Policy Analysis, 38*(2), 272–292.