Aid for all: College coaching, financial aid, and post-secondary persistence in Tennessee

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Aid for all: College coaching, financial aid, and post-secondary persistence in Tennessee¹

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Abstract

Beginning with the high school class of 2015, Tennessee Promise will provide college coaching and last-dollar aid to every high school graduate making a seamless transition to community college. We examine the program that preceded this effort and evaluate its potential effect on college-going and college persistence. Knox Achieves originated in Knox County, Tennessee with the class of 2009. Eligibility was neither need-based nor merit-based, negating some of the application hurdles that accompany other aid vehicles. We find that program participation is strongly associated with an increased likelihood of graduating from high school and enrolling directly in college, albeit with a modestly lower chance of starting in a four-year college. The evidence suggests that aid *per se* is not the only lever by which Knox Achieves worked: college enrollment and college credit gains are largest among lower-income students who likely saw little to no scholarship aid from the program.

¹ We are grateful for discussions with Tennessee Achieves personnel (Randy Boyd, Krissy DeAlejandro, and Jackie Hartmann) that aided our understanding of the Knox Achieves program and the development of this research. Jason Fletcher, Dave Marcotte, Paco Martorell, Georg Schaur, Marianne Wanamaker, John Winters, an anonymous referee, issue editors, and seminar participants at the University of Tennessee, the 2014 Southern Economic Association meetings, and the 2015 Association for Education Finance and Policy meetings provided helpful comments and suggestions. We thank Brian Douglas and Tom Jenkins for outstanding research assistance. All errors are our own, and the opinions and findings discussed in this study do not represent the opinions of Tennessee Achieves or any Tennessee state agency.
1. Introduction

A large and varied research literature demonstrates that attending and completing college pays off in the long run, in terms of both monetary and non-monetary benefits (Card, 1999; Oreopolous & Petronijevic, 2013). And yet, many students who might benefit from a college education fail to enroll because of financial need or inadequate support throughout the application processes for admission and aid.

Why do capable students choose not to pursue college? A host of federal, state, and institutional programs exist to alleviate students’ financial need, and abundant research has shown that aid can increase enrollment. But complex eligibility criteria can hinder the very students these programs are intended to benefit (Dynarski et al., 2013), and aid programs that are conditioned on completing the FAFSA are not always successful at increasing students’ access to college (Bettinger, 2004; Bruce & Carruthers, 2014).

College coaching is premised, in part, on the notion that aid eligibility is complex or poorly publicized. It would seem, then, that a simple and transparent financial aid program combined with college coaching would be particularly well-suited to push students into college who would have otherwise deferred. With this in mind, we examine the potential impact of Knox Achieves, a college coaching and financial aid program that was made available to every graduating high school senior in Knox County, Tennessee beginning with the class of 2009. After three years, the program – renamed Tennessee Achieves – expanded to more than twenty other counties throughout the state, covering over 40 percent of Tennessee’s 2012-2013 high school graduates. The basic structure of Tennessee Achieves motivated the statewide, publicly

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2 See Deming & Dynarski (2010) for a review.
funded Tennessee Promise, which will be available to every high school graduate beginning with the class of 2015.3

Recent experimental research suggests that college coaching (mentoring, assistance with federal financial aid applications, and other non-pecuniary interventions) late in high school can improve college enrollment.4 Bundling FAFSA assistance with tax preparation increased college enrollment for families with dependent high school students (Bettinger et al., 2012). College counseling that targeted low-income students in the summer after high school graduation substantially mitigated the “summer melt” phenomenon, increasing the share of students who fulfilled their college intentions (Castleman et al., 2012). Providing high-achieving, low-income students with application fee waivers and information about net price at selective colleges increased the likelihood of application to and enrollment in these colleges, substantially improving the quality of students’ postsecondary institutions relative to the counterfactual (Hoxby & Turner, 2013).5 A college coaching field experiment in New Hampshire increased college-going among treated females by 30 percentage points (Carrell & Sacerdote, 2013). It is not clear, however, how interventions such as these would perform if scaled to cover an entire district or state. The success of even large-scale field experiments may be difficult to replicate across diverse settings. At the same time, spillover gains that may not manifest in an experimental partial equilibrium could yield dramatically larger treatment effects in a broad-

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3 Tennessee Promise, in turn, motivated “America’s College Promise,” a 2015 White House proposal to fund the first two years of a community college education with a combination of state and federal grants.

4 A notable exception is provided by Avery (2010), who shows that a college counseling pilot study in Boston had no discernible effect on the quality of students’ applications to college.

5 Some of this work highlights the importance of students’ perceptions about the price of college in forming enrollment decisions, without full information on probable out-of-pocket expenses after aid. Hoxby & Turner (2013), in particular, provide compelling evidence that students are not completely aware of institutional aid opportunities at selective four-year institutions. Though institutional grants are shallower in two-year schools than in selective universities, quasi-experimental variation in community college tuition (i.e., the sticker price most readily observed by students considering whether to enroll) has been shown to affect enrollment decisions (Martorell et al., 2014; Denning, 2014).
based aid policy. It is possible that a program like Knox Achieves changes the college-going culture of a school, affecting program non-participants as well as participants.

Knox Achieves and its descendant programs provide last-dollar scholarships – i.e., covering the gap between the direct cost of enrollment (tuition and fees) and aid from federal, state, and institutional grants – to first-year community college students making a seamless, immediate transition between high school and one of the state’s public community colleges or technology centers. Eligibility for Knox Achieves was limited only by geography, time, and age. Beginning in 2008-2009, any high school senior in Knox County was eligible, regardless of income or aptitude. Knox Achieves proved to be a very popular program: 23 percent of the Knox County high school class of 2010-2011 met with a mentor at least once, and of those, 56 percent stayed with the program through their initial entry into a community college. Though the program is generous in principle, in practice it is a surprisingly low-cost aid vehicle. Half of program participants receive no financial aid from Knox Achieves. Their tuition and fees are covered by other grants and scholarships, but they nevertheless choose to engage fully with the program.

We examine whether Knox Achieves participation is associated with greater access to college and improved college persistence. We employ difference-in-difference and propensity score matching estimators to compare postsecondary outcomes of program participants with those of non-participating students elsewhere in East Tennessee. Both methodological approaches exploit plausibly exogenous variation in the availability of Knox Achieves mentorship and support, as determined by place and time. The nature of the program, which

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6 The 2012-2013 scholarship cost per student was $971. By way of comparison, merit-based Tennessee HOPE scholarships are worth $2,000 per year for two-year schools (excluding summer terms), and Pell grants were worth as much as $5,350 in 2009.
recruits high school students early in their senior year, probably sorts more motivated and more organized students into the treatment group. We would detect no change in the college-going rates of senior classes, relative to pre-program cohorts and relative to cohorts in ineligible schools from other counties, if these students would have enrolled in college in the absence of the program. Yet difference-in-difference analyses suggest that college enrollment rates rose significantly in the wake of Knox Achieves availability, and propensity score matching results indicate that program participants were much more likely to enroll in college than non-participants. To a great extent, the matching analysis rules out within-school selection bias by pairing participants with students in nearby districts who did not have access to the program. Findings show that participants are 24.2 percentage points more likely to enroll directly in college than matched students from ineligible districts in the same metro area. Given 17.6 percent participation rates throughout eligible senior classes, the 4.3-percentage point expectation for intent-to-treat effects aligns with the high end of difference-in-difference results.

Looking beyond college enrollment *per se* to the type of college chosen, we find that Knox Achieves is strongly associated with large gains in the likelihood of enrolling in a community college, with the caveat that the propensity to enroll in a four-year college or university is somewhat lower for participants. Treatment effect estimates for college enrollment are strongest for lower-achieving and lower-income students. Substitution away from four-year colleges and universities is more apparent among higher-achieving and higher-income students.

Keeping in mind a strong sense of non-experimental caution, we conclude that participating in Knox Achieves is a significant precursor to college enrollment gains and potentially greater college persistence relative to the best counterfactual we can identify. Understanding *how* Knox Achieves wrought substantial changes in student behavior is important
since the program’s basic structure is set to expand statewide, and perhaps even further.\(^7\) Though we cannot precisely deconstruct the role of scholarship aid from that of mentoring, strong results for students with subsidized lunch – who would generally be eligible for federal Pell grants approaching or exceeding the value of community college tuition and fees – suggests that financial aid \textit{and} non-financial aspects like mentoring mattered.\(^8\) It may have been the case that mentors’ help with FAFSA applications made students aware of financial aid entitlements. At the same time, the simple message of “free community college” has proven to be a powerful one that may have fundamentally reshaped the postsecondary expectations of participants.\(^9\)

\textbf{2. Policy background}

Knox Achieves served Knox County students exclusively for three years. The non-profit program was launched in 2008 by area business and civic leaders with funding from a combination of donations and grants. The program was made available to all schools in the county at the same time. Each Knox County high school guidance counselor was made aware of Knox Achieves when it was introduced in 2008-2009, and students participated from every high school in the county. In 2011-2012, the program grew to cover twenty-two counties across the state and adopted the name Tennessee Achieves to reflect its expanded scope. Starting with the graduating class of 2015, eligibility expanded to include all 12\(^{th}\) graders in the state via publicly funded Tennessee Promise, joining the merit-based HOPE scholarship as the second major prong

\(^7\) In addition to “America’s College Promise” (a first-dollar scholarship, as proposed), Tennessee Promise legislation was quickly followed by similar proposals in twelve other states (Weeden & Hultin, 2015).

\(^8\) Students at and below current eligibility thresholds for reduced-price lunch ($44,123 for a family of four) would typically be eligible for upwards of $3,300 in federal Pell grants. Full-time undergraduate tuition and fees amounted to $3,640 in 2012-2013, on average.

\(^9\) That message grew stronger with the transition to the statewide Tennessee Promise. In Knox County, after five years of program experience, 30 percent of the class of 2013 signed up for the outgrowth of the program studied here. Participation rates for the class of 2015 were 80 percent during the first year of Tennessee Promise.
in the state’s postsecondary financial aid strategy.\textsuperscript{10} The analyses to follow focus on the outcomes of Knox County participants from the high school classes of 2006-2007 through 2010-2011, pre-dating these expansions, while drawing counterfactuals from ineligible students in other counties throughout the Knoxville metropolitan statistical area and East Tennessee region.

Interested high school students signed up for Knox Achieves in the fall of their senior year. There were no other initial eligibility criteria aside from 12\textsuperscript{th} grade enrollment in the county. Each applicant was assigned a volunteer mentor. With the help of mentors and Knox Achieves personnel, students then applied for federal aid early in the spring of their senior year. In order to receive Knox Achieves aid in college, they met with volunteer mentors throughout their senior year of high school and the following summer, and then seamlessly enrolled in a community college shortly after graduation. Mentors were unpaid community members who were expected to spend 10-15 annual hours interacting in person and remotely with a small group of program participants.\textsuperscript{11} To retain support while enrolled, students needed to maintain their college enrollment status, stay in contact with mentors, and complete an eight-hour community service project each semester. Knox Achieves financial aid and coaching were available for up to five continuous semesters of community college enrollment.

Nearly 500 Knox County seniors participated in the charter year of 2008-2009, and 286 went on to enroll in a public two-year community college in the state with the support of the program. Note that many of the other initial participants also went on to college, but without

\textsuperscript{10} Tennessee’s HOPE scholarship dates back to the fall of 2004. Aid from Knox Achieves and its successor programs does not crowd out HOPE scholarships, typically worth $2,000 per academic year to community college students.

\textsuperscript{11} According to program staff, mentors were matched to students primarily by proximity, i.e., by county or city of residence. This pairing may take some mentor preferences into account (for mentees of a particular gender, for instance). Mentors’ chief responsibilities are to help students navigate the logistical hurdles of applying for financial aid, applying for college, and successfully enrolling in college immediately after high school. Mentors communicate with mentees remotely (by text message, typically) and during in-person meetings that are a required component of program participation. Program staff encourage mentors to reach out to mentees every 1-2 weeks.
mentoring or aid from Knox Achieves. Participants were dropped from the program for missing a required meeting, not filing a FAFSA, or delaying college enrollment without an approved deferment. For the purposes of our study of enrollment outcomes, we define treatment as any senior-year Knox Achieves participation. Over time, Knox Achieves saw rapid growth in senior-year participation but lower take-up among entering college students: 1,382 seniors in the 2011-2012 graduating class applied to the program, and 502 went on to enroll in a community college with the support of Knox Achieves. Across Knox County senior classes, participation averaged 17.6 percent over the first three years of the program.

3. Data and summary statistics

Data for this study are drawn from two sources: Knox Achieves records of student participation and the statewide P-20 longitudinal data warehouse. P-20 data connect administrative data systems from the Tennessee Department of Education, the Tennessee Higher Education Commission (covering all public higher education institutions in the state), and the Tennessee Department of Labor and Workforce Development. Choice of college is spatially sensitive, so to a great extent, college outcomes will depend on the postsecondary landscape surrounding one’s high school. We limit our focus to East Tennessee, thereby conditioning students’ program participation and college outcomes on a broad but proximate set of higher education institutions. We observe all 2006-2007 through 2010-2011 twelfth grade students

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12 According to discussions with program staff, as the program grew it increasingly drew ex ante college-going students who used Knox Achieves to hedge against rejection at their preferred, four-year college or university. As a result, lower shares of participating students went on to enroll with Knox Achieves support.

13 Based on National Student Clearinghouse and Tennessee administrative data, we find that 78 percent of 2009-2011 college enrollees from high schools in the nine-counties including and surrounding Knox County attended one of three public colleges found within the metro area: the University of Tennessee (20 percent), Pellissippi State Community College (39 percent), and Roane State Community College (19 percent). Another 4 percent attended Walters State Community College, just outside the metro area. Even more attended private institutions in the metro area or institutions elsewhere in the East Tennessee region.

14 East Tennessee is defined here as thirty-five counties bordered by Scott, Morgan, Cumberland, Van Buren, Sequatchie, and Marion counties.
enrolled in public high schools in the 35-county East Tennessee region. Matching models and some difference-in-difference specifications focus on the nine-county area describing the Knoxville Metropolitan Statistical Area (MSA).\textsuperscript{15}

Tennessee Department of Education data are used to identify students in this target sample of seniors in the region, and then to collect a rich set of observable student characteristics: enrollment histories dating back to 8\textsuperscript{th} grade, basic demographics (gender, race, and Hispanic ethnicity), free and reduced-price lunch status dating back to 8\textsuperscript{th} grade, ACT scores, end-of-course (EOC) exam scores, and on-time regular high school completion (excluding completion via GED or repeating the 12\textsuperscript{th} grade). We consider regular high school completion to be one potential outcome of Knox Achieves participation, since students interact with the program throughout their senior year of high school. We merge in-state earnings from students’ junior and senior years of high school using administrative data on earnings covered by Unemployment Insurance. These earnings exclude income from self-employment, other states, some agricultural occupations, and federal employers.

Key outcomes of interest are seamless college enrollment (defined here as postsecondary enrollment within nine months of high school graduation\textsuperscript{16}) and cumulative earned college credits through the two years following high school. These outcomes are drawn from data maintained by the National Student Clearinghouse and the Tennessee Higher Education Commission (THEC). Available Clearinghouse records include enrollment activity for the fall term immediately following high school graduation, but not subsequent terms. THEC data on

\textsuperscript{15} The Knoxville MSA currently includes Anderson, Blount, Campbell, Grainger, Knox, Loudon, Morgan, Roane, and Union counties.
\textsuperscript{16} With rare exceptions, participants are expected to enroll in college the fall after high school graduation in order to retain eligibility. We use a nine-month window to allow for early (December) high school graduates to meet this criterion. Results are not substantially changed under narrower or wider definitions of seamless college enrollment.
student enrollment at in-state public colleges and universities are used to supplement Clearinghouse data by, for instance, identifying students who enrolled in a THEC college within our nine-month definition of seamless matriculation but after (or in some cases, before) the fall term following high school graduation. Information about students’ postsecondary persistence is available for THEC students but not for students who enrolled in private or out-of-state institutions. We identify cumulative credits earned within two years of high school graduation for students who enroll in THEC institutions at some point during the two calendar years following high school (including delayed entrants).\textsuperscript{17,18}

Table 1 contains summary statistics describing East Tennessee 12\textsuperscript{th} graders in 2008-2009 through 2010-2011 (the Knox Achieves program years) as well as Knox Achieves participants, Knox County non-participants, and Knoxville MSA non-participants in isolation. Participating students are much more likely to graduate high school than their peers at large, substantially more likely to go to a two-year college, and less likely to attend a four-year college. Note that non-participating Knox County students tend to exhibit lower high school graduation rates than the region at large, similar college-going rates overall, and higher four-year college matriculation rates. Among students who seamlessly matriculate to a THEC institution, Knox Achieves participants tend to accumulate 6 – 7 additional college credits in the two years following high school.

Table 1 also itemizes several student characteristics used in the analyses to follow. Knox Achieves participants are more likely to be female and less likely to be white than their peers in

\textsuperscript{17} Among 2009-2011 Knox County seniors going directly to college, 84.3 percent enroll in a THEC institution. Additionally, 4.7 percent of seniors do not go straight to college but enroll in a THEC institution within two years. Both pathways to THEC institutions are incorporated into our measure of accumulated credits. What we miss, however, are credits among students who enroll in non-THEC colleges and universities. See Section 5 for discussion of potential biases introduced by this censoring.

\textsuperscript{18} We hesitate to examine participants’ rates of two-year completion or transfer until enough time has passed to include bachelor’s degree completion and/or post-college earnings as potential outcomes.
the rest of the region and the rest of the county. Participants are more economically
disadvantaged than other seniors in the Knox area, but more advantaged than East Tennessee
students generally, in terms of subsidized lunch eligibility. Participants perform on par with their
Knox County peers on the ACT\textsuperscript{19} (scoring 18 out of 36, on average), but average EOC scores are
10 percent of a standard deviation below Knox County non-participants’ achievement.

4. Empirical strategy

We seek to quantify the potential impact of Knox Achieves on several student outcomes: high school graduation, seamless college enrollment, the type of college attended (two-year or four-year), and early post-enrollment persistence (credits earned through the first two calendar years after high school). The open-access nature of Knox Achieves eligibility mitigates
information and access barriers that affect take-up for other scholarships but does not motivate a
sharp identification strategy such as regression discontinuity, used by others in this literature
(e.g., Kane, 2003; Goodman, 2008; Scott-Clayton, 2011; Bruce & Carruthers, 2014; Cohodes &
Goodman, 2014). There are no performance or income thresholds that determine eligibility.
Access to the program was not introduced in a random or quasi-random fashion. Students self-
selected into the program, beginning with the graduating class of 2009. This selection renders
quasi-experimental identification very difficult to obtain, leading us to take two approaches with
complementary strengths and weaknesses.

4.a. Difference-in-difference analysis

\begin{footnote}{ACT scores are not universally available throughout the sample. Tennessee is one of several states that subsidizes
students’ ACT fees and aspires for all students to take the exam, typically in their junior year of high school.
Nevertheless, ACT scores are not observed for a large share of students, particularly in the early years of the panel
when ACT participation was less widespread. Wherever we control for ACT composite scores, we also control for
indicators that ACT data are missing. Missing ACT scores are imputed at the 25th percentile.}

11
We first exploit across-county and inter-temporal variation in the availability of Knox Achieves to estimate the difference in post-program Knox County students’ college outcomes, relative to earlier Knox cohorts, and relative to inter-cohort differences in outcomes from other counties throughout the East Tennessee region or Knoxville MSA.

Outcomes and controls are aggregated to the school-year level, spanning five cohorts of seniors throughout Tennessee (including two pre-program cohorts). Postsecondary outcomes for non-matriculants are coded as zero. Our estimating equation is as follows:

\[ Y_{st} = \alpha_0 + \alpha_s + \alpha_t + KA_{st}\gamma + X_{st}\beta + (Z_{st})\pi + \epsilon_{st}, \]

where \( Y_{st} \) is a college outcome of interest for school \( s \) seniors graduating in year \( t \), conditioned on school and cohort fixed effects \((\alpha_s, \alpha_t)\), time-varying cohort features \((X_{st})\), inter-cohort trends related to school characteristics as of 2006-2007 \((Z_{st})\), and exposure to Knox Achieves \((KA_{st})\).

We omit school-years with fewer than 10 twelfth graders and estimate Equation 1 with weights for schools’ average senior class size from 2007-2011. Robust standard errors are clustered by school.

Identifying variation in \( KA_{st} \) arises from inter-county and intra-Knox availability or intensity over time. In one specification, \( KA_{st} \) is a simple indicator equal to one for Knox County high schools in academic years 2009-2011. There, the point estimate for \( \gamma \) returns the average divergence in post-program Knox outcomes relative to the post-2009 divergence for the rest of the area of metro area or East Tennessee region more broadly.

This simple difference-in-difference estimate, however, will reflect the impact of Knox Achieves as well as other unseen factors unique to Knox County after 2009. With this in mind, a second specification of Equation 1 takes advantage of the fact that the footprint of Knox Achieves within schools grew considerably with each cohort, and that growth in program
participation was steeper in some schools than others. There, $KA_s$ is defined as the share of the school $s$, year $t$ senior class who participated in the program, and the parameter $\gamma$ provides an estimate of the conditional change in each outcome concurrent with an incremental, one-percentage-point increase in Knox Achieves participation.

The vector $X_{st}$ controls for observable characteristics of graduating classes describing the share of students who are white in each school’s senior class and three domains that affect the likelihood of college enrollment: aptitude, financial need, and the opportunity cost of enrolling in college. The aptitude domain is represented by average standardized end-of-course scores for the senior class. We proxy for financial need using participation rates for free lunch programs at any time since 8th grade. Average junior-year earnings serve a dual role, representing financial need as well as the opportunity cost of going to college. Annual county unemployment rates round out our characterization of the opportunity cost of college.

The untestable identification assumption underlying Equation 1 is as follows: the presence or dosage of Knox Achieves is not conditionally coincident with unobserved, heterogeneous trends in student preferences for college. Using data on two pre-program cohorts (the only pre-program cohorts for which data are uniformly available) we examined the year-to-year difference in high school classes’ postsecondary outcomes just prior to program

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20 Program penetration is not strongly associated with observable characteristics of schools. Small pairwise correlations between $X_{st}$ elements and 2010-2011 participation rates indicate that schools with more non-white students, more free-lunch-eligible students, lower junior-year earnings, and higher average EOC scores saw steeper growth, although we cannot reject the hypothesis that these cohort features are jointly insignificant in describing 2010 participation rates.

21 Results are broadly robust to an expanded set of $X_{st}$ controls (including ACT scores, ACT and EOC subject scores, gender and ethnicity composition, reduced-price lunch eligibility, senior-year earnings, and the number of schools, districts, and counties attended since 8th grade. With at most 555 school-by-year observations and up to 112 school fixed effects, we prefer the more parsimonious set of controls.

22 County unemployment rates are sourced from the Bureau of Labor Statistics series of Local Area Unemployment statistics.

23 Synthetic control identification is a more direct way to address heterogeneous trends across Knox and other counties throughout the region and even the state. With just two years of reliable pre-program data, however, we are unable to satisfactorily balance Knox and synthetic pre-program trends.
implementation, finding no evidence that very near-term preexisting trends foretell significantly higher program penetration. To further alleviate the concern that results are driven by unobserved trends that coincide with student sentiment toward community colleges, we control for $Z_{st}$, the interaction between $X_{st}$ variables measured in the first observed pre-program year (2006-2007) and a linear time trend. This allows trends in college enrollment to vary by pre-program levels of demographics, need, aptitude, and opportunity cost.\textsuperscript{24}

4.b. Propensity score matching

Difference-in-difference analysis comparing Knox County schools’ college-going rates to those of the rest of the state give us a sense of the intent-to-treat effect of Knox Achieves. If Knox Achieves does in fact increase college-going, we should also find that program participants were conditionally more likely to enroll in college than counterparts without access to Knox Achieves. To test this expectation, we estimate treatment-on-the-treated effects using propensity score matching, utilizing the same geographic variation in eligibility that motivates Section 4.a. difference-in-difference methods. The intuition is to pair each treated Knox Achieves participant with an untreated high school senior, preferably from a different county, who has roughly the same propensity to participate in the program, and then let the average difference across matched pairs represent the average treatment effect. We limit the matching analysis to the nine-county metropolitan statistical area (MSA) around and including Knox County. As we show in Section 5.b., matched pairs become significantly unbalanced in terms of observable variables when we draw counterfactuals from outside the county. Focusing on the MSA is our attempt to balance the

\textsuperscript{24} School-specific time trends yield similar results, although at a great cost to degrees of freedom.
empirical benefits of comparing participants to ineligible students against the cost of matching dissimilar students.\textsuperscript{25}

Propensity score matching has roots in work by Rosenbaum and Rubin (1983), who show that conditional independence given observables implies conditional independence given the likelihood of treatment, itself a function of observables. This reduces the dimensionality of the matching problem considerably, allowing us to match participants to non-participants along a single propensity index rather than across many variables. Matching methods have a rich tradition in applied labor economics research, beginning with Heckman, Ichimura, and Todd (1997), although more parametric methods based on ordinary least squares (OLS) identification remain the dominant nonexperimental tool to account for selection-on-observables in applied microeconomic research. At the student level, we choose to evaluate Knox Achieves by matching rather than OLS because wide differences in pretreatment covariates between participants and non-participants (as demonstrated by Table 1 summary statistics) may lead to OLS estimates that hinge on extrapolation (Imbens, 2015), whereas matching will impose common support without imposing functional form assumptions about the process generating college choices. Our preferred matching model draws counterfactual outcomes entirely from counties other than Knox, exploiting the same plausibly exogenous variation in Knox Achieves availability that motivates difference-in-difference analysis.

We begin with a participation model predicting the likelihood of signing up with the program as a high school senior. The logit specification is as follows:

\[
T_{it} = A(W_{it}'\beta),
\]  

\textsuperscript{25} The appendix discusses results using a broader reservoir spanning the East Tennessee region.
where \( \Lambda \) is the logistic distribution and \( T_{it} \) is the unobserved probability of high school seniors’ participation. One’s propensity to participate in a college preparation and scholarship program is driven by the same domains predicting college enrollment in Equation 1: aptitude, financial need, and opportunity cost. The \( W_{it} \) vector, therefore, controls for cohort indicators and all of the \( X_{st} \) covariates from Equation 1, measured at the student level rather than the school-by-year level, as well as average EOC subject scores; the number of EOC exams taken throughout high school; ACT composite scores and ACT subject scores (and an indicator for missing ACT data); an indicator for repeating the 12th grade; gender and Hispanic ethnicity indicators; reduced-price lunch eligibility; senior-year earnings; and the number of schools, districts, and counties attended since 8th grade.

Equation 2 is estimated for the likelihood of signing up with Knox Achieves in the fall of one’s senior year of high school, a very low-stakes measure of engagement with the highest degree of attrition (46 percent among eligible cohorts). Parameter estimates are used to predict \( \hat{T}_{it} \) for each individual in the Knoxville MSA. Each treated participant \( i \) is matched to her nearest neighbor in terms of \( \hat{T}_{it} \) from one of three control reservoirs: all Knox County non-participating seniors, all Knoxville MSA seniors, and all Knoxville MSA seniors excluding Knox County non-participants. Nearest neighbor matching enables us to directly model the central source of omitted variable bias: self-selection into treatment. Matches are drawn with replacement and within a 0.02-percentage point window of \( i \)’s propensity. We omit regions of \( \hat{T}_{it} \) without common support and we omit the top one percent of the treated population where the control density of \( \hat{T}_{it} \) is thinnest. After matching each Knox Achieves participant to one student with nearly the same propensity to participate in the program, we compute the average treatment
effect on treated students (the ATT) as the difference in enrollment and post-enrollment outcomes across matched pairs.

The propensity score matching estimator is consistent if, in the absence of Knox Achieves, those in the treatment group would have been expected to have had the same collegiate outcomes as those in the control group, conditional on \( T(W,V) \), the propensity to participate as a function of observable factors \( W \) and unobservable factors \( V \). But in practice, we must rely on a less flexible mean-independence condition that omits conditional independence of unobserved \( V \). The assumption that counterfactual outcomes are independent of treatment given \( T(W) \) is violated if selection into the program is dependent on unobservable characteristics represented by \( V \). A plausible selection story is one where students who find their way to Knox Achieves during their senior year are intent on attending a community college, even more so than otherwise similar peers with the same estimated propensity to participate in such a program. This is a particularly acute concern because the program’s advertised benefits – financial aid – are contingent on the college enrollment behavior we are interested in assessing. Unobserved preferences of this nature would bias matching estimates in favor of community college enrollment, and in favor of college enrollment \( \text{per se} \), if this same component of \( V \) drives postsecondary intentions more generally. We cannot rule out this form of selection in any evaluation of the Knox Achieves program, but we can mitigate bias by including a rich set of student controls \( W \) in the participation logit model and by drawing the control group from a set of students who had no access to the program.

Knox Achieves was limited to Knox County before expanding in 2011-2012. With this in mind, our preferred approach matches treated participants to high school seniors in other counties within the nine-county Knoxville MSA. Though the Knox County school district has the
largest representation of high school seniors in the MSA, fifty percent come from districts in the other eight counties. This eliminates the sort of within-school selection bias that we would expect to affect results if participants were compared to observably similar students from the same schools who chose not to participate in the program. Nevertheless, we cannot rule out the possibility that Knox Achieves participants share an inherently different demand for community college access than the matched control group from other counties.

Propensity score matching is a complement to difference-in-difference analysis for a number of reasons. Though both methods are susceptible to some of the same omitted variable biases (chiefly, students’ proclivity toward community college), matching avoids the linear functional form assumptions embodied by Equation 1. That being said, matching results are incomplete on their own. Some of the matching results described in Section 5.b. regarding Knox Achieves participation and individual college matriculation are quite large. Individual treatment effects and school-wide participation rates are large enough that – unless the former are biased artifacts of the matching methodology – we should detect significant changes in aggregate outcomes in the wake of Knox Achieves availability and dosage.

Robustness checks described in the appendix test the sensitivity of matching results to more than one matched neighbor, a narrower caliper of \( \hat{T}_{it} \), the inclusion of Knox County non-participants (including students from earlier cohorts), a control reservoir spanning the East Tennessee region, other matching schemes (Mahalanobis, kernel), the addition of high school graduation as a control variable to proxy for unobserved motivation, and simple ordinary least squares. Estimated treatment effects are very large in each alternative method, although the magnitude of ATT estimates varies, with those from our preferred method falling between the higher and lower bounds of alternative estimates. See the appendix for more discussion.
5. Results

5.a. Difference-in-difference results: Knox Achieves and school-wide outcomes

Table 2 lists results for $\gamma$ in Equation 1. In Column 1, the treatment $KA_{st}$ from Equation 1 is represented by an indicator equal to one for Knox County high schools in 2009 and later. Column 2 utilizes the same specification of $KA_{st}$ but limits the analytical sample to the nine-county Knoxville metro area. We find that Knox County’s graduating classes sorted into community colleges at a rate 3.1 – 4.9 percentage points higher than before the introduction of Knox Achieves (11 – 17 percent of the relevant control mean), with the higher figure coming from comparisons to the Knoxville metro area rather than the entire East Tennessee region.

Seamless enrollment rates overall increased by 3.5 – 4.0 percentage points in the wake of Knox Achieves (8 – 9 percent of the control mean of 46 – 47 percent), which suggests that most affected participants would not have been in college at all.

The scholarship portion of Knox Achieves lowers the relative price of community colleges, which would tend to put pressure on interest in four-year colleges. But at the same time, mentorship components of the program – and in particular, assistance with federal financial aid applications – may benefit students regardless of their college destination and increase their tendency to enroll in all sectors of higher education, four-year universities included. Columns 1 – 2 indicate that four-year college enrollment fell up to 0.9 percentage points (4 percent of the regional base of 21 percent), although this estimate is not statistically significant at conventional levels and the confidence interval is consistent with higher degrees of substitution away from four-year schools as well as net gains in four-year enrollment.

Our second difference-in-difference identification strategy exploits a more granular measure of program penetration and rests on the idea that schools with a larger footprint of Knox
Achieves participation should see a larger shift in attainment outcomes affected by the program. Columns 3 and 4 of Table 2 list results when $KA_t$ is equal to the share of a high school senior class (measured 0 – 100) participating in the program, which averaged 17.6 percent across 2009, 2010, and 2011 Knox County cohorts. Each block of results in Columns 3 – 4 has three items. The first is the estimated intent-to-treat effect at 17.6 percent participation, i.e., the product of 17.6 and $\gamma$ estimates from Equation 1. The interpretation of these first estimates is most comparable to that of Column 1 – 2 point estimates for county-wide divergence. The second statistic for each outcome in Columns 3 – 4 is the point estimate associated with a one-percentage-point rise in cohort-wide participation, i.e., $\gamma$ itself. Lastly, standard errors for $\gamma$ are in parentheses.

Going from zero to 17.6 percent participation is associated with a statistically significant 2.3 – 2.9-percentage point gain in college-going and a 3.2 – 5.2-percentage point gain in two-year college enrollment. Comparing these results to analogous estimates in Columns 1 – 2, our inference is that linear variation in Knox Achieves participation explains 66 – 71 percent of Knox County’s relative gain in college enrollment overall, and all of the relative gain in two-year college enrollment. This is strongly suggestive evidence of a causal program impact on college enrollment. A typical dosage of Knox Achieves participation is linked to a 1.57-point decline in the likelihood of four-year college enrollment, meaning that perhaps 30 percent of the 5.2-point swell in community college enrollment (Column 4) comes from students who would

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26 Since Equation 1 estimates school-wide outcomes as a function of school-wide program participation, the explanatory power of participation growth will encompass program effects on participants as well as non-participants. The remaining 29 – 34 percent of variance in college enrollment could be explained by non-linear effects of program growth, or by unobserved factors of demand for college that affected Knox County schools at the same time as Knox Achieves.
have otherwise been in a four-year institution. We note, however, that the Column 4 estimate for four-year enrollment is measured just outside conventional boundaries of statistical significance.

Taken together, difference-in-difference results imply an intent to treat effect on community college enrollment of 3 – 5 percentage points, drawn in uncertain parts from students who would have otherwise gone to a four-year college and those who would have deferred college altogether, although the weight of the evidence favors the latter.\textsuperscript{27} Across all four specifications, we find no significant change in public in-state college credits in the wake of greater participation.

\textbf{5.b. Propensity score matching results: Knox Achieves, college enrollment, and college persistence}

Estimates from Equation 2, modeling the likelihood of program participation as a function of student demographics, aptitude, financial need, and opportunity cost, echo descriptive statistics from Table 1 in that females, non-white students, more economically disadvantaged students, and lower-achieving students are more apt to participate in Knox Achieves.\textsuperscript{28} Figure 1 illustrates common support for participation as a senior. Though the average propensity to participate is considerably lower for comparison students than for participants, the range of common support is broad and all treated students outside the top one percent of the propensity distribution (which is trimmed, by design) are successfully matched.

Table 3 lists propensity score matching results for high school graduation, matriculation outcomes, and postsecondary credit accumulation. Columns 1 – 3 utilize three different reservoirs for control students. Column 1 results are from a model that draws comparison

\textsuperscript{27} Note that the estimated effect size regarding four-year enrollment is actually larger than that for any college enrollment, since the latter is relative to a larger base.

\textsuperscript{28} The pseudo $R^2$ is 0.129. Other Equation 2 results are available on request.
students from Knox County. For the Column 2 model, we expand the set of possible comparisons to include students elsewhere in the nine-county Knoxville MSA. The Column 3 reservoir – our preferred model – excludes Knox County non-participants from the list of possible controls and retains students from the other eight MSA counties. Before turning to results, note that observed covariates (W in our earlier notation) are most balanced between participants and non-participants in the Column 1 same-county framework,\(^{29}\) where 7.8 percent of participants are matched to control students in the same school. When we broaden the control reservoir to include students in the other eight counties of the Knoxville MSA, and certainly when we exclude Knox County non-participants entirely, observables become significantly unbalanced between participants and matched non-participants. Even so, we prefer the Column 3 model, where we match Knox Achieves participants to ineligible students outside of the county.\(^{30}\) This is because our main identification concern lies with balance in V, unobservable determinants of interest in such a program, and by extension, interest in college.

Focusing on Column 3 results, we find that Knox Achieves participants are 3.4 percentage points more likely to graduate high school than matched students elsewhere in the MSA with the same propensity (but without the possibility) to participate in the program. Participants are 24.2 percentage points more likely to seamlessly enroll in college within nine

\(^{29}\) See \(\chi^2\) statistics at the bottom of Table 3 for likelihood-ratio tests of the hypothesis that parameters on all \(W\) elements are jointly equal to zero in predicting treatment.

\(^{30}\) By omitting Knox County non-participants, however, we risk exposing results to bias from the omitted fixed effect – that is, the inherent difference in graduation and postsecondary outcomes for Knox County seniors versus seniors elsewhere in East Tennessee. See the appendix, Table A1 and surrounding discussion, for a pseudo-matching analysis of pre-program students in Knox and comparison counties. We find that Knox County students are inherently less likely to graduate high school on time and more likely to enroll in a four-year university, running counter to post-program results discussed in this section.
months of graduation and 29.6 percentage points more likely to seamlessly enroll in community college.

Related work on other scholarships shows that differentially incentivizing one college sector over another leads to substitution into the incentivized sector (Kane, 2003; Cohodes & Goodman, 2014). In agreement with this literature, we find that Knox Achieves participants are 5.2 percentage points less likely to seamlessly enroll in a four-year college or university. The overall enrollment gains far dominate this substitution out of four-year colleges, but it may be the case that long-run gains from increasing the educational attainment of some students are offset to a degree by students who would have otherwise gone to a four-year college or university. At the same time, we emphasize that ATT estimates for four-year enrollment may reflect the same unobservable commitment to community college enrollment that potentially biases estimates for community college enrollment upward. A final consideration is the idea that students who are inclined to participate in Knox Achieves, who tend to be more disadvantaged and of lower ACT aptitude, would be better served by the community college system. In Section 5.c., we examine matriculation and postsecondary treatment effects by student aptitude and income, shedding light on which students substitute out of four-year schools and how they fare relative to matched counterfactuals.

Knox Achieves shepherds high school seniors into community colleges, and thereafter supports post-enrollment progression with renewal criteria for continuous enrollment, maintained contact with mentors, and community service. Relative to other performance-based scholarships – most notably, the Tennessee HOPE scholarship, which requires a 2.75 – 3.00 college GPA for renewal – Knox Achieves set a low performance bar for its first three cohorts of scholarship recipients but a high extra-curricular bar. The last row of results in Table 3 lists ATT estimates
for accumulated THEC credits earned within two years of graduating from high school. Relative to matched high school peers, Knox Achieves participants earn 6.8 more credits within that window, the equivalent of about two classes.

Recall that credits are unobserved for students who enroll in non-THEC institutions. If students tend to persist longer outside of the THEC system (i.e., at more selective and/or out-of-state institutions), then the possibility that Knox Achieves induces substitution away from non-THEC sectors could bias credit accumulation results upward. In an unreported analysis available on request, we find that participants who go straight to college after high school are indeed 9.0 percentage points more likely to enroll in a THEC institution than matched peers in other counties. If we omit the top 10 percent of Knox Achieves participants in terms of postsecondary credit accumulations – i.e., as if top performers would have been in a different system in the absence of Knox Achieves (following the logic of Lee (2009) bounds) – we still find highly significant matched treatment effect estimates of 4.9 credits. We take 4.9 – 6.8 to be the bounded treatment effect estimate with respect to college credits during the two years following high school.

5.c. Propensity score results by student achievement and income

Table 4 lists attainment and matriculation results by quartile of average EOC performance. To generate these estimates, we first divide the base sample – three cohorts of 12th graders throughout the Knoxville MSA – into four quartiles according to average standardized EOC performance. Then, the matching methodology is executed within each quartile. Estimates for changes in high school graduation are highest among the lowest quartile but positive (albeit imprecise) for the top three quartiles. Treatment effect estimates for seamless college enrollment
are positive and significant throughout the EOC aptitude range, but highest in the lowest quartile (28.6 percentage points), where we find positive ATT estimates for two-year and four-year college enrollment (though the latter is statistically insignificant). Substitution out of four-year colleges in response to the program becomes increasingly more likely in the upper half of the achievement distribution, where students have a larger baseline four-year matriculation rate. Relative to untreated students in the same quartile with roughly the same propensity to participate, students in the top fourth of EOC achievement are 26.8 percentage points less likely to enroll in a four-year college if they participate in Knox Achieves. Note that the effect size does not increase in proportion to the rise in point estimates since higher achieving students are inherently more likely to enroll in a four-year institution.\textsuperscript{31} Although some portion of the estimated effect on high-achieving students may be driven by unobserved commitment to community college, it is not likely that this sentiment increases with aptitude or that high-aptitude students are typically best served by community colleges. Therefore, the top panel of Table 4 on its own suggests that a portion of normative gains from greater college enrollment (including 11.5-point gains within the top quartile) are offset to an extent by mismatched high-achieving students who would have otherwise enrolled in four-year institutions.

It is not clear, however, how high-achieving Knox Achieves participants will be affected by starting in a community college. Table 4 results for credit accumulation within two years of high school indicate that participants’ transcripts measure 6 – 8 credits longer across the bottom three quartiles and 3.77 credits longer in the top quartile. Early indications, therefore, are that high-achieving students’ college persistence is modestly higher than the counterfactual,

\textsuperscript{31} Outside of Knox County (the most relevant baseline for these estimates), four-year college enrollment rates are 25 percent among students in the third quartile of achievement and 52 percent in the fourth. Treatment effects relative to these baselines, therefore, are 37 and 48 percent, respectively.
equivalent to about one additional course over two years. Impacts on longer-term outcomes like bachelor’s degree receipt and job placement are yet to be known.

Last, Table 5 examines matching results by broad categories of student income. Column 1 lists matching results when we restrict participant and control reservoirs to students who were at some point eligible for free or reduced-price lunch between 8th and 12th grades. Column 2 lists results for the subsample that were never observed with free or reduced-price lunch. Though confidence intervals overlap somewhat between Columns 1 and 2, we find that treatment effect estimates for on-time high school graduation, college enrollment overall, and credit accumulation favor lower-income students. Participants who form the treated half of Column 1 pairs likely received little to no financial aid through the program, and yet appear to be more affected by participation. Higher-income students account for all substitution away from four-year institutions.

6. Discussion

Our standout finding is that program participants exhibit substantial gains in college enrollment over matched peers. Knox Achieves participants are 24.2 percentage points more likely to go to any college and 29.6 percentage points more likely to go to a community college. These are tremendously large effect estimates, particularly when evaluated against baseline college-going of 45.5 percent throughout East Tennessee during the relevant years. It bears repeated emphasis that these are non-experimental estimates and potentially affected by factors beyond our empirical control. The chief unobservable student characteristic that we cannot control for is

32 There are a couple sources of measurement error to note in our characterization of income subsamples. First, take-up of free or reduced-price lunch among income-eligible students tends to decline through middle and high school grades. This is why we group students with any participation in subsidized lunch since 8th grade in the lower-income group. But in doing so, we include some students whose household incomes have improved between 8th and 12th grades in the lower-income group.
inherent motivation to attend college and, in particular, to attend a community college. This motivation is likely correlated with Knox Achieves participation and counterfactual enrollment, pushing enrollment ATT estimates away from zero and leading us to believe that matching estimates are likely an upper bound on the true individual treatment effect. School-level shifts in college-going are much more subtle (2.3 – 4.0 percentage points throughout a school’s senior class), but given typical program participation rates they nevertheless imply large treatment-on-the-treated estimates of 13.1 – 22.7 percentage point gains in the likelihood of seamless college enrollment.\textsuperscript{33}

The evidence on Knox Achieves and college performance is mixed: at the individual level we attribute 4.9 – 6.8-credit gains to program participation, but we do not detect significant changes in credit accumulation at the school-by-cohort level. As the program expanded to serve counties throughout the state, renewal criteria were heightened to require fulltime enrollment and 2.0 GPAs. Students have responded to the incentives inherent in performance-based scholarships in other settings (Scott-Clayton, 2011; Patel et al., 2013). It remains to be seen whether these programmatic changes will improve scholarship holders’ post-secondary persistence.

We also find evidence consistent with the idea that incentivizing community college enrollment decreases the likelihood of four-year enrollment among higher-achieving and higher-income students, although this form of substitution is less discernable at the aggregate level. This has implications for the long-run success of the program, since enrolling first at a two-year

\textsuperscript{33} Another caveat to keep in mind is that we do not – at this time – observe late enrollment in the National Student Clearinghouse, so we cannot discern the extent to which the program pulls enrollment closer to high school completion. Forty-four percent of East Tennessee seniors, excluding those in Knox County, matriculate seamlessly to college over the 2009-2011 post-program years according to National Clearinghouse records. Another 3.4 percent are observed in the THEC system within two years of high school completion. The analogous statistics for Knox County students in isolation are 51.4 percent for seamless enrollment and 2.9 percent for late THEC enrollment. Thus, accelerated enrollment likely explains little of 13.1 – 22.7 percentage-point treatment effects.
college has been shown to lower attainment (Long & Kurlaender, 2009) and reduce post-college earnings (Reynolds, 2012\textsuperscript{34}). Results here imply that there were 2 – 5 students induced to enroll in college for every one student swayed from starting at a four-year university.\textsuperscript{35} For the offsetting effects of four-year substitution to completely negate the returns to extra-marginal enrollment in aggregate, the marginal returns to starting at a four-year university over a two-year community college would have to be 2 – 5 times as large as the returns to enrolling in a community college rather than stopping with a high school diploma. Existing research does not support a premium of this magnitude.\textsuperscript{36} At the same time, we emphasize that ATT estimates for four-year enrollment may reflect the same unobservable commitment to community college enrollment that potentially biases estimates for community college enrollment upward.

Knox Achieves targets students’ financial need as well as non-financial hurdles (including incorrect perceptions about aid eligibility) between high school and college. The fact that half of participants receive no scholarship aid from the program, and that treatment effect estimates are larger for needier students (who are more likely to have federal Pell grants that negate much of the program’s last dollar aid), implies that non-financial hurdles are critical channels through which programs like Knox Achieves can work. Other interventions aimed at decreasing students’ information barriers have also yielded large gains in college enrollment (Castleman et al., 2012; Carrell & Sacerdote, 2013; Hoxby & Turner, 2013). Though we have not unbundled the relative impact of Knox Achieves components – aid, mentoring, and

\textsuperscript{34} Reynolds (2012) also notes that in light of imperfect credit markets and debt aversion, some students will find the lower near-term cost of community college adequate compensation for lower lifetime earnings.

\textsuperscript{35} Table 2, Column 4: the ratio of 2.869 (any enrollment) to -1.566 (four-year enrollment) is 1.8. The analogous computation from Table 3, Column 3, our preferred matching model, is 4.7.

\textsuperscript{36} Looking again to Reynolds (2012), evidence from the NELS88 suggests that earnings were 5 – 6 percent lower for young adults who started at two-year colleges and had intentions of completing bachelor’s degrees, although these wage gaps were not statistically significant. A survey of research on the returns to community college enrollment (and not necessarily completion) points to 9 – 13 percent gains over high school graduates (Kane & Rouse, 1999).
messaging – a potential policy implication for “Free Community College” programs in general, notably including President Obama’s 2015 proposal, is that targeted advising may serve as a strong complement to financial aid.

One key difference between Knox Achieves and related experimental evaluations is that the scale of this district-wide program has the potential to change the culture of college expectations within and across schools. Such a culture shift would manifest as program effects for non-participants, and in our empirical construct, difference-in-difference results that dominate the intent-to-treat analogs of matching results. We do not find evidence of large spillover impacts on graduating classes at large, however, since school-wide relative changes in college enrollment and other outcomes are generally smaller than individual intent-to-treat estimates from matching. Nevertheless, this does not rule out changes in baseline enrollment over a longer window of time as the program becomes more ingrained.

Aid *per se* is not the only lever that can cost-effectively increase college enrollment. To underscore the point that the cost of college is not the only barrier to college, recall that half of Knox Achieves students receive no financial aid from the program while they are enrolled in community college, but they nevertheless continue to fulfill their obligation to meet with mentors and conduct community service projects. With direct program costs of under $1,000 per student per year, even modest impacts on college credit accumulation and college completion will fare well in cost-benefit tests of Knox Achieves, particularly when the counterfactual is an increasingly less valuable education that ends with a high school diploma.

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37 Rhetoric surrounding Tennessee Promise, the successor to Knox Achieves, often refers to “changing the culture” about postsecondary aspirations and planning. See, for instance, Morgan (2014) and Smith (2015).
Appendix: Matching robustness checks

By drawing counterfactuals entirely from other counties, estimates are vulnerable to unobserved fixed effects associated with Knox County schools. If, for instance, Knox County students were inherently more likely to enroll in college, program participants would compare favorably to non-participants from surrounding counties with or without the Knox Achieves intervention. Post-program matriculation statistics in Table 1 of the main text are not suggestive of an underlying college-going gap of this nature, but this does not rule out a conditional Knox County fixed effect that could confound treatment effect estimates. To explore potential biases from cross-county heterogeneity we estimate pseudo-matching treatment effects for two pre-program cohorts, the classes of 2007 and 2008.\textsuperscript{38} Specifically, we estimate the Equation 2 participation model for 2009-2011 Knox County cohorts, map parameter estimates to 2007 and 2008 cohorts throughout the MSA, and then match each 2007 and 2008 Knox County senior to her nearest propensity neighbor from elsewhere in the MSA.\textsuperscript{39} We limit the analysis to students whose estimated propensity falls in the top quartile of the distribution, which yields a pseudo-treatment group of 1,460 students across two cohorts. Pseudo-matching estimates for attainment and postsecondary outcomes are listed in Table A1. We find no evidence of the sort of spatial heterogeneity that would overstate program effectiveness. Running counter to our main results, Knox County pseudo-treated students were significantly less likely than matched counterparts from the rest of the MSA to graduate high school, and more likely to go to a four-year college.

\textsuperscript{38} Note that pre-program cohorts are also utilized for robustness checks described in the appendix as well as difference-in-difference analyses described in Section 4.b.

\textsuperscript{39} The participation model for this falsification exercise differs from that of our main analysis in two ways. We omit cohort indicators (whose effects cannot be mapped to pre-program years) and ACT controls (which are less available for pre-program cohorts).
Our preferred matching results are derived from nearest neighbor, one-to-one propensity score matching estimators with 0.02-percentage point calipers, with replacement, and with one-percent trimming at the high-propensity tail of the distribution. In this appendix we present results from several alternative methodologies, which generally support our main results.

Table A2 contrasts baseline results (Column 1, also found in Column 3 of Table 3) with matriculation results from ten alternative methods (Columns 2 – 11). We do not bootstrap standard errors in this array of robustness checks. Comparing Column 1 results in Table A2 to their counterparts in Table 3 illustrates that default standard errors are nearly identical to bootstrapped standard errors. We describe the motivation behind each alternative before discussing results.

Column 2 of Table A2 lists results when we narrow the propensity window within which treated students can be matched to non-treated students from 0.02 to 0.01 percentage points. A narrower caliper should reduce bias that arises from matching more distant neighbors, at some cost to precision from eliminating those distant matches from average treatment effects. Column 3 lists results from estimates with the baseline 0.02-percentage point caliper but with up to three nearest neighbor matches as opposed to one. This should increase precision but opens up the possibility of additional bias from adding outcomes that are more distant than those of the nearest neighbor. The Column 4 model samples without replacement, which should decrease the closeness of matches but potentially improve external validity as more comparison students are included in the analysis. Column 2 – 4 modifications have very little bearing on results, with ATT estimates falling well within Column 1 confidence intervals.

Column 5 lists results when we exclude the first cohort of students, i.e., those who graduated high school in 2008-2009. Discussions with Knox Achieves personnel lead us to
believe that in the charter year of the program, guidance counselors were particularly proactive in reaching out to lower-income, potentially first-generation college students. The program was marketed more widely in later years. Note that eligibility criteria were no different in the first year than in subsequent years, but it may have been the case that because of this proactive selection, first-cohort participants were differentially more or less apt to enroll in and succeed in college. Most Column 5 results are not substantially different from those of Column 1, though evident substitution away from four-year colleges and universities is small and statistically insignificant when the first cohort of eligible students is excluded.

Column 6 expands the control reservoir outward from the Knoxville MSA to include all East Tennessee 12th graders during the post-program classes of 2009 – 2011. Doing so increases our estimates of program impacts on timely high school graduation (from 3.4 to 6.3 percentage points), does not substantially change estimates for college enrollment overall, but leads to a larger estimate for community college enrollment alongside a larger estimate of outmigration from four-year schools (7.7 versus 5.2 percentage points, relative to 21 – 22 percent typical four-year matriculation in both the MSA and regional control groups).

Column 7 lists results under Epanechnikov kernel matching as opposed to nearest neighbor matching. Kernel matching compares each treated outcome to all untreated outcomes with common support, with greater weight placed on closer matches. ATT estimates are little changed from the baseline.

The fact that Knox Achieves participants are much more likely to graduate from high school may be a signal that these students are more pulled together and intent on going to college than their observationally equivalent peers. Though we prefer to treat high school graduation as an outcome of Knox Achieves treatment (since students interact with the program throughout
their senior year), in Column 8 we treat high school graduation as an additional control variable predicting Knox Achieves participation, under the notion that graduation is a signal of unobserved motivation. This moves matriculation ATT estimates toward zero, but within a standard error of baseline estimates.

Column 9 results address the missing county fixed effect in a different way by including two pre-program cohorts of Knoxville area high school seniors from 2006-2007 and 2007-2008, before Knox Achieves existed, as potential controls in addition to seniors from eight other counties in the Knoxville MSA. There, we find that ATT estimates for college enrollment and two-year college enrollment are somewhat higher than baseline estimates, and that evident substitution away from four-year colleges is noticeably smaller than suggested by main results. In practical terms this means that counterfactual Knox County comparison students are much less apt to enroll in any college (community college or four-year college) than the outside-of-Knox students who form our Column 1 counterfactual.

Column 10 approaches the question of counterfactuals from a different angle than the preferred, baseline propensity score matching methodology. For each treated student, propensity score matching identifies a near-twin in terms of the conditional likelihood of participating in the program. Another way to match students is to identify counterfactual outcomes in terms of students’ observable characteristics (as before, limited to demographics, need, aptitude, and opportunity cost) and propensity to participate in the program. With several many-valued continuous controls, we do not have the sample size necessary to match participants to non-participants with exactly the same vector of observable controls. Mahalanobis matching groups treated students to comparison students by minimizing a distance metric describing the gap

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40 We omit cohort fixed effects from the Column 9 participation model. ACT data are not available for the earliest two cohorts, so controls for achievement are limited to EOC performance.
between student $i$’s $R_i$ vector (which, here, includes the entire $W_i$ vector and the propensity score, $\hat{T}_{it}$) and student $j$’s $R_j$ vector.\footnote{The distance metric for students $i$ and $j$ is given by $M_{ij} = (R_i - R_j)'U^{-1}(R_i - R_j)$, where $U$ is the covariance matrix for $R$. Rather than matching treated students to a nearest neighbor in terms of $M_{ii}$, we employ full Mahalanobis matching (Rosenbaum, 1991), which finds the set of $n:m$ treatment-control blocks (with $n \geq 1$ treated students and $m \geq 1$ control students in each block) that minimizes the sum of $M_{ij}$. We execute this procedure using the user-written command “pmatch2” (Leuven & Sianesi, 2014) in Stata 13.1.} This is not our preferred method for evaluating Knox Achieves because Mahalanobis groups students with less regard for how much importance each $W_i$ variable should be given. Matching on the propensity score alone lets the logit model of participation determine which observable variables matter more than others. Results under Mahalanobis matching are listed in Column 10. Standard errors are computed following Abadie and Imbens (2006). Relative to baseline results, Mahalanobis treatment effect estimates imply a smaller impact on overall college enrollment (17.8 percentage points versus 24.2 in Column 1) and an 8.9-point substitution away from four-year colleges, a noticeable increase over the 5.2-point estimate in Column 1. This indicates that participants’ counterfactual outcomes in terms of the $W_i$ vector are more apt than propensity twins to enroll in four-year colleges. We note that 17.8-point impacts on college enrollment are within the range implied by difference-in-difference results (13.1 – 22.7 percentage points), and that Column 10 results are in broad agreement with our conclusion that the bulk of community college enrollment gains came from students who would not have otherwise been in college.

Last, in Column 11, we list results under a simple ordinary least squares (OLS) model predicting each matriculation and postsecondary outcome as a function of student observables and Knox Achieves participation. OLS places more importance on the $W_i$ variables’ relationship to outcomes than on their relationship to program participation. And unlike matching methods, OLS includes the outcomes of students who fall outside the region of common support and
parameter estimates may predict outcomes beyond the range of possible values. OLS results are larger in absolute value for two-year and (especially) four-year college enrollment, and the net increase in college enrollment propensity is 3.2 percentage points lower than in our baseline model.

Our first takeaway conclusion from Table A2 is that regardless of whether student outcomes are conditioned on participation propensity or \( W_{it} \) variables, regardless of whether results are limited to regions of common support, and regardless of whether we control for a likely outcome in order to proxy for motivation and reduce ATT estimates, these varied robustness checks support our finding that participation in Knox Achieves is strongly associated with large individual gains in college enrollment, particularly two-year college enrollment. Second, evident substitution out of four-year colleges is robust across all ten treatments. And third, the magnitude of treatment effect estimates varies meaningfully across methods. Estimates for two-year enrollment gains range from 26.6 – 34.5 percentage points, for instance, and estimates for four-year enrollment shifts range from 2.1 – 13.0 percentage points below zero. Without a better sense of why students select into Knox Achieves or cleaner identification of program access, it is not possible to pinpoint the true treatment effect. Baseline estimates lie near the midpoints of these ranges, and we maintain them as our preferred results.
References


Table 1. Student summary statistics, by Knox Achieves participation

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1) All East Tennessee 12th Graders</th>
<th>(2) Knox County Knox Achieves participants</th>
<th>(3) Knox County non-participants</th>
<th>(4) Knoxville MSA non-participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduated high school on time (%)</td>
<td>86.8</td>
<td>97.2</td>
<td>77.7</td>
<td>89.6</td>
</tr>
<tr>
<td>Seamlessly enrolled in college (%)</td>
<td>45.5</td>
<td>72.5</td>
<td>47.8</td>
<td>46.7</td>
</tr>
<tr>
<td>Seamlessly enrolled in a two-year college (%)</td>
<td>27.5</td>
<td>62.1</td>
<td>23.0</td>
<td>28.9</td>
</tr>
<tr>
<td>Seamlessly enrolled in a four-year college (%)</td>
<td>21.6</td>
<td>13.9</td>
<td>29.7</td>
<td>21.2</td>
</tr>
<tr>
<td>THEC college credits within two years of graduation 1</td>
<td>13.7</td>
<td>19.9</td>
<td>13.7</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>(17.5)</td>
<td>(15.6)</td>
<td>(18.3)</td>
<td>(16.9)</td>
</tr>
<tr>
<td>Female (%)</td>
<td>47.3</td>
<td>60.5</td>
<td>45.2</td>
<td>47.9</td>
</tr>
<tr>
<td>Hispanic (%)</td>
<td>2.8</td>
<td>2.4</td>
<td>3.0</td>
<td>2.5</td>
</tr>
<tr>
<td>White, non-Hispanic (%)</td>
<td>86.6</td>
<td>73.3</td>
<td>79.7</td>
<td>93.4</td>
</tr>
<tr>
<td>Free lunch (%)</td>
<td>48.3</td>
<td>39.6</td>
<td>25.8</td>
<td>30.5</td>
</tr>
<tr>
<td>Reduced-price lunch (%)</td>
<td>18.4</td>
<td>7.4</td>
<td>5.1</td>
<td>6.9</td>
</tr>
<tr>
<td>Senior year earnings (000s)</td>
<td>2.2</td>
<td>2.1</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>(4.3)</td>
<td>(3.6)</td>
<td>(5.8)</td>
<td>(3.3)</td>
</tr>
<tr>
<td>Junior year earnings (000s)</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>(3.0)</td>
<td>(2.3)</td>
<td>(4.1)</td>
<td>(2.1)</td>
</tr>
<tr>
<td>Number of counties since 8th grade</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>(0.4)</td>
<td>(0.3)</td>
<td>(0.4)</td>
<td>(0.5)</td>
</tr>
<tr>
<td>ACT composite</td>
<td>17.3</td>
<td>18.0</td>
<td>18.4</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>(4.2)</td>
<td>(3.7)</td>
<td>(4.5)</td>
<td>(4.4)</td>
</tr>
<tr>
<td>Average standardized EOC</td>
<td>0.054</td>
<td>-0.055</td>
<td>0.045</td>
<td>-0.048</td>
</tr>
<tr>
<td></td>
<td>(0.791)</td>
<td>(0.629)</td>
<td>(0.943)</td>
<td>(0.767)</td>
</tr>
<tr>
<td>Number of EOC records</td>
<td>2.7</td>
<td>2.7</td>
<td>2.3</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>(1.2)</td>
<td>(1.0)</td>
<td>(1.1)</td>
<td>(1.1)</td>
</tr>
<tr>
<td>N (students)</td>
<td>61,286</td>
<td>2,071</td>
<td>9,795</td>
<td>11,535</td>
</tr>
</tbody>
</table>

Notes: Standard deviations are in parentheses below continuous-valued means. The sample includes 12th grade students in the East Tennessee region, academic years 2008-2009 through 2010-2011. Other variables included in the analysis: the number of schools and districts a student attended since 8th grade, ACT subscores, EOC subject scores, an indicator for having repeated the 12th grade, indicators for cohort, indicators for missing ACT and EOC scores, and annual county unemployment rates.

1 Students who enrolled in non-THEC institutions (private and/or out-of-state) are excluded from this summary statistic. Student who did not enroll in college within two years are recorded as having zero accumulated credits.
Table 2. School-level difference-in-difference results: Knox Achieves participation shares, attainment and matriculation, and postsecondary outcomes

<table>
<thead>
<tr>
<th>Sample</th>
<th>Identification</th>
<th>(1) East Tennessee 12th grade classes</th>
<th>(2) Knoxville MSA 12th grade classes</th>
<th>(3) East Knoxville MSA 12th grade classes</th>
<th>(4) Knoxville MSA 12th grade classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knox County difference-in-difference</td>
<td>3.017 (2.397)</td>
<td>4.601** (1.900)</td>
<td>1.478 (0.082)</td>
<td>1.778 (0.067)</td>
</tr>
<tr>
<td></td>
<td>Knox County difference-in-difference</td>
<td>3.502** (1.510)</td>
<td>4.021*** (1.494)</td>
<td>2.327*** (0.049)</td>
<td>2.869*** (0.050)</td>
</tr>
<tr>
<td></td>
<td>Knox Achieves dosage: percent of seniors participating</td>
<td>0.084 (0.082)</td>
<td>0.132 (0.049)</td>
<td>0.163 (0.050)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knox Achieves dosage: percent of seniors participating</td>
<td>0.101 (0.067)</td>
<td>0.163 (0.050)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knox Achieves dosage: percent of seniors participating</td>
<td>0.084 (0.082)</td>
<td>0.132 (0.049)</td>
<td>0.163 (0.050)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knox Achieves dosage: percent of seniors participating</td>
<td>0.101 (0.067)</td>
<td>0.163 (0.050)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduated high school on time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seamlessly enrolled in college</td>
<td>3.137** (1.331)</td>
<td>4.893*** (1.471)</td>
<td>3.221*** (0.041)</td>
<td>5.157*** (0.048)</td>
</tr>
<tr>
<td></td>
<td>Seamlessly enrolled in two-year college</td>
<td>-0.112 (1.035)</td>
<td>-0.882 (1.591)</td>
<td>-0.528 (0.039)</td>
<td>-1.566 (0.057)</td>
</tr>
<tr>
<td></td>
<td>Seamlessly enrolled in four-year college</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>THEC college credits within two years</td>
<td>0.981 (0.841)</td>
<td>0.36 (1.294)</td>
<td>0.616 (0.024)</td>
<td>-0.053 (0.037)</td>
</tr>
<tr>
<td></td>
<td>School-years</td>
<td>555</td>
<td>187</td>
<td>555</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>Schools</td>
<td>112</td>
<td>38</td>
<td>112</td>
<td>38</td>
</tr>
</tbody>
</table>

Notes: The table lists γ estimates from Equation 1, difference-in-difference models of aggregate attainment and postsecondary outcomes for senior classes as a function of time-varying Knox Achieves participation, school fixed effects, cohort fixed effects, and time-varying control variables discussed in Section 4. In Columns 1 and 2, identification arises simply from within-school changes in cohort outcomes in Knox County schools versus schools elsewhere in the East Tennessee region (Column 1) or elsewhere in the Knoxville MSA (Column 2). In Columns 3 and 4, identification arises from within-school growth in the footprint of Knox Achieves participation, which is zero for schools elsewhere in the MSA or region. The estimated effect of moving from zero to 17.6% Knox Achieves participation (the mean) is listed in italics in Columns 3 and 4, with point estimates for the effect of 1-percentage point gains in participation listed below. Robust standard errors, in parentheses below point estimates, are clustered by school. Estimates are weighted by schools’ average senior class size from 2007-2011.

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent
Figure 1. Estimated propensity to participate in Knox Achieves, actual participants versus non-participant comparison students

Notes: The figure plots estimated propensity scores from Equation 2. “KA participants” are exclusively from Knox County. “Other students” are from the other eight counties in the MSA.
Table 3. Propensity score matching results: Knox Achieves participation and educational attainment

| Control reservoir includes Knox County students | (1) 0.087*** (0.010) | (2) 0.053*** (0.010) | (3) 0.034*** (0.008) |
| Control reservoir includes surrounding-county students in the Knox
| Knoxville MSA | No | Yes | Yes | |
| Graduated high school on time | | | | |
| Seamlessly enrolled in college | 0.214*** (0.020) | 0.228*** (0.017) | 0.242*** (0.015) | |
| Seamlessly enrolled in two-year college | 0.340*** (0.018) | 0.314*** (0.014) | 0.296*** (0.015) | |
| Seamlessly enrolled in four-year college | -0.135*** (0.016) | -0.088*** (0.015) | -0.052*** (0.013) | |
| THEC accumulated credits two years after graduation | 5.233*** (0.573) | 6.364*** (0.566) | 6.844*** (0.588) | |

All students on support 11,746 23,168 13,471
Treated students on support 2,048 2,051 2,051
Untreated nearest neighbors on support 1,587 1,858 1,741
Same-school matches (%) 7.8% 3.2% 0.0%
Same-county matches (%) 100.0% 39.2% 0.0%
Balancing test $\chi^2$ (p-value) 17.14 (0.928) 260.49 (0.000) 659.61 (0.000)

Notes: The table lists propensity score matching results for college enrollment outcomes and credit accumulation (average treatment on the treated, or ATT). We use a nearest-neighbor matching estimator, matching each Knox Achieves participant to one non-participant, with replacement, within a 0.02 percentage-point caliper of participation propensity. Bootstrap standard errors (50 replications) are reported in parentheses below each ATT estimate.

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent
### Table 4. Propensity score matching results: Knox Achieves participation, educational attainment, and postsecondary credits, by high school achievement quartile

<table>
<thead>
<tr>
<th>End-of-course exam quartile</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First (lowest)</td>
<td>Second</td>
<td>Third</td>
<td>Fourth (highest)</td>
</tr>
<tr>
<td>Graduated high school on time</td>
<td>0.049**</td>
<td>0.017</td>
<td>0.011</td>
<td>0.027*</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Seamlessly enrolled in college</td>
<td>0.286***</td>
<td>0.263***</td>
<td>0.186***</td>
<td>0.115***</td>
</tr>
<tr>
<td></td>
<td>(0.039)</td>
<td>(0.028)</td>
<td>(0.034)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Seamlessly enrolled in two-year college</td>
<td>0.279***</td>
<td>0.252***</td>
<td>0.248***</td>
<td>0.352***</td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>Seamlessly enrolled in four-year college</td>
<td>0.023</td>
<td>0.028</td>
<td>-0.092***</td>
<td>-0.268***</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.021)</td>
<td>(0.032)</td>
<td>(0.039)</td>
</tr>
<tr>
<td>THEC college credits within two years</td>
<td>6.665***</td>
<td>8.278***</td>
<td>5.58***</td>
<td>3.77**</td>
</tr>
<tr>
<td></td>
<td>(0.95)</td>
<td>(1.17)</td>
<td>(1.20)</td>
<td>(1.64)</td>
</tr>
<tr>
<td>All students on support</td>
<td>3,359</td>
<td>3,615</td>
<td>3,250</td>
<td>2,694</td>
</tr>
<tr>
<td>Treated students on support</td>
<td>511</td>
<td>599</td>
<td>566</td>
<td>332</td>
</tr>
<tr>
<td>Untreated nearest neighbors on support</td>
<td>442</td>
<td>503</td>
<td>484</td>
<td>287</td>
</tr>
</tbody>
</table>

Notes: The table lists propensity score matching results for college enrollment outcomes and credit accumulation (average treatment on the treated, or ATT) within four student subgroups defined by achievement quartiles. We use a nearest neighbor matching estimator, matching each Knox Achieves participant to one non-participant, with replacement, within a 0.02 percentage-point caliper of participation propensity. Bootstrap standard errors (50 replications) are reported below each ATT estimate in parentheses.

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent
Table 5. Propensity score matching results: Knox Achieves participation, educational attainment, and postsecondary credits, by free/reduced-price lunch status

<table>
<thead>
<tr>
<th>Ever qualified for free or reduced-price lunch?</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Graduated high school on time</td>
<td>0.045***</td>
<td>0.033***</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Seamlessly enrolled in college</td>
<td>0.257***</td>
<td>0.215***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Seamlessly enrolled in two-year college</td>
<td>0.252***</td>
<td>0.318***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Seamlessly enrolled in four-year college</td>
<td>0.030*</td>
<td>-0.121***</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.021)</td>
</tr>
<tr>
<td>THEC college credits within two years</td>
<td>7.83***</td>
<td>5.70***</td>
</tr>
<tr>
<td></td>
<td>(0.70)</td>
<td>(0.85)</td>
</tr>
</tbody>
</table>

All students on support                        | 5,197 | 8,274 |
Treated students on support                    | 960   | 1,091 |
Untreated nearest neighbors on support         | 788   | 934   |

Notes: The table lists propensity score matching results for college enrollment outcomes and credit accumulation (average treatment on the treated, or ATT) within two student subgroups: those who qualified for free or reduced-price lunch at some point in high school, and those who did not. We use a nearest neighbor matching estimator, matching each Knox Achieves participant to one non-participant (with replacement) within a 0.02 percentage-point caliper of participation propensity. Bootstrap standard errors (50 replications) are reported below each ATT estimate in parentheses.

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent
Table A1. Pre-program matched differences in matriculation and postsecondary outcomes, Knox County versus the rest of the Knoxville MSA

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Matched difference (st. err.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduated high school on time</td>
<td>-0.054***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
</tr>
<tr>
<td>Seamlessly enrolled in college</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
</tr>
<tr>
<td>Seamlessly enrolled in two-year college</td>
<td>-0.030</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
</tr>
<tr>
<td>Seamlessly enrolled in four-year college</td>
<td>0.039***</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
</tr>
<tr>
<td>THEC college credits within two years of graduation</td>
<td>0.435</td>
</tr>
<tr>
<td></td>
<td>(0.68)</td>
</tr>
<tr>
<td>All students on support</td>
<td>2,887</td>
</tr>
<tr>
<td>Knox students on support</td>
<td>1,460</td>
</tr>
<tr>
<td>Untreated nearest neighbors on support</td>
<td>788</td>
</tr>
</tbody>
</table>

Notes: Estimates are obtained by matching Knox County 12th graders from the classes of 2007 and 2008 (prior to the availability of Knox Achieves) to peers elsewhere in the Knoxville MSA based on their estimated propensity to participate in the program. Propensities are estimated for post-2008 Knox County seniors and mapped to the two pre-program cohorts. Students with propensities below the post-2008 75th percentile are omitted. We use a nearest-neighbor matching estimator, matching each Knox County student to a peer from another county, with replacement, within a 0.02 percentage-point caliper of participation propensity. Bootstrapped standard errors (50 replications) are reported in parentheses below each ATT estimate.

*** significant at 1 percent, ** significant at 5 percent, * significant at 10 percent
Table A2. Robustness checks: Knox Achieves participation, educational attainment, and postsecondary persistence

<table>
<thead>
<tr>
<th>Attainment outcome</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduated high school on time</td>
<td>0.034***</td>
<td>0.034***</td>
<td>0.038***</td>
<td>0.035***</td>
<td>0.037***</td>
<td>0.063***</td>
<td>0.042***</td>
<td>0.062***</td>
<td>0.041***</td>
<td>0.054***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.009)</td>
<td>(0.007)</td>
<td>(0.005)</td>
<td>(0.008)</td>
<td>(0.006)</td>
<td>(0.005)</td>
<td></td>
</tr>
<tr>
<td>Seamlessly enrolled in college</td>
<td>0.242***</td>
<td>0.242***</td>
<td>0.240***</td>
<td>0.239***</td>
<td>0.242***</td>
<td>0.246***</td>
<td>0.238***</td>
<td>0.250***</td>
<td>0.305***</td>
<td>0.178***</td>
<td>0.210***</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.016)</td>
<td>(0.013)</td>
<td>(0.012)</td>
<td>(0.019)</td>
<td>(0.015)</td>
<td>(0.011)</td>
<td>(0.016)</td>
<td>(0.016)</td>
<td>(0.016)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Seamlessly enrolled in two-year college</td>
<td>0.296***</td>
<td>0.296***</td>
<td>0.296***</td>
<td>0.296***</td>
<td>0.283***</td>
<td>0.345***</td>
<td>0.294***</td>
<td>0.302***</td>
<td>0.337***</td>
<td>0.266***</td>
<td>0.328***</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.016)</td>
<td>(0.013)</td>
<td>(0.012)</td>
<td>(0.018)</td>
<td>(0.015)</td>
<td>(0.012)</td>
<td>(0.016)</td>
<td>(0.015)</td>
<td>(0.017)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Seamlessly enrolled in four-year college</td>
<td>-0.052***</td>
<td>-0.052***</td>
<td>-0.052***</td>
<td>-0.055***</td>
<td>-0.021</td>
<td>-0.077***</td>
<td>-0.053***</td>
<td>-0.047***</td>
<td>-0.025**</td>
<td>-0.089***</td>
<td>-0.130***</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
<td>(0.010)</td>
<td>(0.009)</td>
<td>(0.014)</td>
<td>(0.012)</td>
<td>(0.009)</td>
<td>(0.013)</td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>THEC college credits within two years</td>
<td>6.84***</td>
<td>6.84***</td>
<td>6.82***</td>
<td>6.86***</td>
<td>7.05***</td>
<td>7.93***</td>
<td>6.83***</td>
<td>7.23***</td>
<td>8.45***</td>
<td>4.35***</td>
<td>5.17***</td>
</tr>
<tr>
<td></td>
<td>(0.56)</td>
<td>(0.56)</td>
<td>(0.46)</td>
<td>(0.40)</td>
<td>(0.67)</td>
<td>(0.88)</td>
<td>(0.40)</td>
<td>(0.56)</td>
<td>(0.53)</td>
<td>(0.60)</td>
<td>(0.41)</td>
</tr>
</tbody>
</table>

Notes: The table lists propensity score matching results for college enrollment outcomes (average treatment on the treated, or ATT). Baseline results in Column 1 (and Table 3) use a nearest-neighbor matching estimator, matching each Knox Achieves participant to one non-participant within a 0.02 percentage-point caliper of participation propensity, with replacement. Columns 2-9 list results under alternative propensity score matching methodologies, Column 10 lists results from full Mahalanobis matching, and Column 11 lists results from ordinary least squares. For Column 1-9 variations, default standard errors are reported in parentheses below each matching ATT estimate. Mahalanobis matching (Column 10) standard errors follow Abadie and Imbens (2006). Heteroskedasticity-robust standard errors are reported for OLS results in Column 11.