# What Knox Achieved: Estimated effects of tuition-free community college on attainment and earnings[1]

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## Abstract

We examine the effect of a last-dollar "free community college" program on college credit accumulation, college completion, and medium-term labor-market outcomes. Knox Achieves pledged tuition-free community college to any Knox County, Tennessee high school graduate and served as the model for the statewide Tennessee Promise program as well as local and state initiatives across the U.S. We find that Knox Achieves eligibility led to a 24% higher likelihood of attaining an associate's degree within nine years of high school, alongside positive but insignificant changes in the likelihood of attaining a bachelor's degree, and negative but insignificant changes in in-state earnings.

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## I. Introduction

After decades of rising tuition and uneven growth in financial aid, U.S. colleges and universities have more of a "high tuition, high aid" model than in the mid-20th century, when large subsidies afforded low tuition at most public institutions (Turner, 2018). Grants and scholarships exceed community college tuition, on average, and account for two-thirds of four-year university tuition (Ma & Pender, 2021). Differentiated pricing can theoretically equalize access to higher education (Hansen & Weisbrod, 1969), assuming that students have a clear understanding of the cost of college. But in practice, students obtain financial aid through a diffuse patchwork of public, nonprofit, and institutional programs. Their net tuition bill is typically unknown until long after they have applied to college, and it may fluctuate unpredictably from year to year after that. Recent field experiments show that prospective students value and respond to unconditional certainty in the price of college (Dynarski et al., 2021; Burland et al., 2022).

In the midst of high tuition and high but uncertain aid, over 200 communities[2] and a growing number of states have launched "free college" or "promise" programs. Many share a similar core design: A locality makes a promise to cover tuition and required fees, often in conjunction with other services, for students who meet noncompetitive eligibility requirements in addition to living and attending secondary school in the location. Promise programs exhibit great variety beyond this shared core, with many differences regarding the amount of aid, student GPA and residency requirements, and the type and number of institutions covered. Very few, including the El Dorado Promise, commit to cover costs at any college or university in the country (Swanson & Ritter, 2020). Others, such as the Kalamazoo Promise, limit benefits to institutions within a state (Bartik et al., 2021), or to one sector of institutions in a state (House & Dell, 2020). Still others, such as Tulsa Achieves, are limited to one institution (Gándara & Li, 2021). Promise scholarships attract students to eligible schools and give them more certainty over their tuition bill, both before they think about enrolling, and year to year as they navigate college. Many such programs lean heavily on the high-aid component of U.S. higher education pricing, in that they cover the "last-dollar" gap between tuition and a student's other grants and scholarships.

[2] See the Upjohn Institute *Promise Database* here: https://www.upjohn.org/promise/ (Miller-Adams et al., 2017).

Between 2014 and 2022, over 20 U.S. states introduced tuition-free college promise scholarships whose foremost eligibility criteria was residency rather than family income, high school GPA, or college entrance exam scores (Mishory & Granville, 2019; Campaign for Free College Tuition, 2022). No two of these programs were identical. But on key components – where aid could be used and whether the amount of aid depended on a student's other grants – most of them resembled a last-dollar "free community college" program introduced in Knox County, Tennessee, in 2009, which later expanded statewide and inspired two federal proposals.[3]

We evaluate how the Knox County program affected college completion and earnings up to nine years after high school, relying on student outcomes in other counties and earlier cohorts to quantify the counterfactual. We find that Knox County's model of tuition-free community college raised associate degree attainment by 24% for eligible students (0.8 percentage points on top of a 3.3-point control mean) but had inconclusive effects on bachelor's degree attainment and in-state earnings. Our preferred 95% confidence interval for bachelor's degrees ranges from a 1.1 percentage-point decline to a 3.1 percentage point increase, or from a 6% decrease relative to the mean up to a 17% increase. This counters but does not rule out a leading concern with Promise programs focused on community colleges, i.e., that they divert bachelor's-intending students away from four-year schools where they are more likely to succeed. Our 95% confidence interval for 9$^{th}$-year earnings is also very wide, ranging from -14.0% to +6.6%. Modest program costs may easily be recovered by projected long-term returns to associate degrees alone, but future and unobserved benefits would need to exceed imprecise negative returns to UI-covered earnings over the 9 years after high school.

We add to what is known about college financial aid in general, and promises of free college in particular, in three ways. First, we provide the first insights on how a last-dollar scholarship affects college attainment several years after high school. Most related to our work are recent studies by Bartik et al. (2021) and Swanson and Ritter (2020), who study the effect of promise scholarships on degree completion in, respectively, Kalamazoo, Michigan and El

[3] In 2015, Then-President Obama proposed "America's College Promise" at Pellissippi State Community College in Knoxville (Boehnke, 2015). President Biden later included free community college in the "Build Back Better" package. Neither initiative moved forward.

Dorado, Arkansas. Both programs offered students "first-dollar" promise scholarships, which grant the value of tuition irrespective of other grants.

Our second contribution is to study how a promise scholarship limited to community college affects success in that sector as well as bachelor's degree attainment. Students benefitting from first-dollar programs in Kalamazoo and El Dorado could use their promise scholarships at two-year or four-year schools. Community colleges serve students with many different goals, including older students seeking new skills (Jepsen et al., 2014; Carruthers & Sanford, 2018) and students without ready access to four-year universities. But they also divert some students from what researchers have found to be a surer path to bachelor's attainment and higher earnings (Rouse, 1995; Reynolds, 2012; Boatman & Soliz, 2018; Mountjoy, 2022).

And finally, we provide some of the first insights on how a scholarship like Knox Achieves affects employment, earnings, and industries of occupation up to nine years after high school. We join Hershbein et al. (2021) as one of the first studies to examine labor-market effects of promise forms of financial aid.

Summarizing what we add to the discussion, we find that a last-dollar promise program limited to community colleges had considerably smaller effects on college attainment than what the related literature has found for first-dollar aid. Associate's attainment increased by 0.8 percentage points (24%) for eligible Knox County students, and bachelor's attainment increased by an imprecise 1.1 percentage points. Kalamazoo and El Dorado Promise programs, by contrast, increased bachelor's degree receipt by 7-9 percentage points (Swanson & Ritter, 2020; Bartik et al., 2021). Last-dollar program costs, however, are also much lower. Knox Achieves spent $246 per eligible student over 2.5 years, versus $17,620 over six years for Kalamazoo Promise. Second, our findings may help to assuage concerns about tuition-free community college and delayed or forgone bachelor's attainment; we do not find that eligibility lowered bachelor's attainment. Finally, we find no significant effects on labor-market outcomes up to 9 years after high school, aside from suggestive evidence that Knox Achieves eligibility led to work in lower-paying industries and less attrition from in-state work. These estimated effects of last-dollar Knox Achieves on college completion and earnings may foreshadow what will come from

similar programs in Tennessee[4] and across the country. Our findings are particularly useful for policymakers and funders considering similar last-dollar programs where first-dollar alternatives are prohibitively expensive.

## II. Policy Background[5] and Related Research

In July 2008, Knox County and Shelby County mayors proposed last-dollar scholarships and free community college for high school graduates in their respective counties (Ferrar, 2008). Knox and Shelby are home to Knoxville and Memphis, two of the state's largest cities. The Shelby County program did not come into fruition that year, but Knox Achieves launched in the fall. Initially a public-private partnership, Knox Achieves committed up to $2,000 a year in last-dollar community college scholarships to students in the 2008-2009 class of Knox County 12th graders. Full-time tuition at local two-year schools was $2,364 at the time, and fees added another $263-294. Given the extent of aid from other sources,[6] the program emphasized the typical bottom line to students—free tuition and fees—and ultimately lifted the cap so that no participant had to pay. The program operated out of the county mayor's office at first, and later as a standalone nonprofit. Local business leaders and anonymous donors contributed funds for scholarships and operating costs. Knox Achieves marketed the scholarship directly to high school counselors and students in their schools. County Mayor Ragsdale and program director Krissy DeAlejandro visited each of the county's high schools in person, spoke with counselors, distributed posters, and held assemblies with students. This outreach helped to lend the program legitimacy and spread the message widely.

Any public high school senior in the county was eligible, although targeted beneficiaries were lower-income students, lower-achieving students, and students who would be the first in

[4] There are reasons to think, however, that Tennessee Promise will have different effects than the early years of Knox Achieves. In the years since 2011, when our study population completed high school, many statewide efforts have evolved in parallel to the expansion of tuition-free community college. These include K-12 reforms stemming from Race to the Top, the "Drive to 55" postsecondary attainment goal, and a statewide system of transfer articulation agreements between two-year and four-year schools. More recently, programs such as Knox Promise and Nashville GRAD have emerged to assist community college students with additional advising, non-tuition assistance for books and supplies, and emergency grants for living expenses.

[5] In addition to cited media reports, our review of program history and implementation details benefitted from several conversations with Krissy DeAlejandro (President and CEO of tnAchieves) and Jackie MacDonald (Chief Operating Officer of tnAchieves).

[6] According to IPEDS, the average amount of grant and scholarship aid in 2008-2009 to full-time, first-time undergraduates was $3,528 – 4,398.

their families to attend college (Alapo, 2008). Interested students signed up for Knox Achieves in the fall of their senior year of high school. Signing up was a low-stakes commitment to learn more about the program and access supports such as mentoring and assistance with financial aid applications. Knox Achieves was popular, with 15.3% of eligible 2009-2011 cohorts taking this necessary first step.

In order to retain eligibility, participants from the fall signup lists were expected to meet with volunteer mentors (usually at their school in the evening), file a Free Application for Federal Student Aid (FAFSA) in the spring of their senior year, graduate from high school, verify their FAFSA if necessary, complete an eight-hour community service project, and then enroll in a community college for the fall term. Fifty-five percent of 12$^{th}$ grade signees did so and entered college as Knox Achieves students. Knox Achieves covered last-dollar tuition and mandatory fees for up to five semesters, conditional on full-time enrollment and maintaining a 2.0 GPA or better. Participants were also required to continue meeting with mentors during their first year in college.

After three years as a single-county initiative, the program adopted the name tnAchieves and expanded to cover 12$^{th}$ graders in over 20 counties, including Shelby. Additional expansions followed over the next two years until Tennessee introduced statewide, publicly funded Tennessee Promise for the class of 2015 forward. Tennessee Promise mirrored Knox Achieves in almost all of its key components: universal 12$^{th}$ grade eligibility (adding private and home-school seniors), required FAFSA completion, required mentoring and community service, and last-dollar aid for community college tuition and fees. tnAchieves shifted its role to become a partnering organization for Tennessee Promise and conduit for additional aid beyond tuition (Kast, 2019).

By studying Knox Achieves, we contribute to a growing literature on location-based programs that promise tuition-free college and sometimes more. Eligibility for a free-tuition, place-based scholarship tends to change students' college choice set (Andrews et al., 2010), increase enrollment at institutions where the award can be used (Gándara & Li, 2020; Bell & Gándara, 2021), and increase the likelihood that eligible students attend college at all (Carruthers and Fox, 2016; Daugherty & Gonzales, 2016; Bartik et al., 2021; Page et al., 2019). Especially relevant to our study is earlier work by Carruthers and Fox (2016) showing that Knox Achieves

increased college-going by 3-4 percentage points, or 6-9% of the East Tennessee mean. House and Dell (2020) and Bell (2021) connect the statewide successor to significantly higher enrollment at Tennessee community colleges. Tennessee 12th graders were 5.8 percentage points more likely to enroll in college after the introduction of Tennessee Promise, an unprecedented 9.9% increase (Tennessee Higher Education Commission, 2022). Carruthers and Fox (2016), Gurantz (2020), and Bell (2021) each find evidence that last-dollar free community college programs can divert some students from attending four-year universities.

The research literature on promise aid and college completion is thinner but optimistic. Two first-dollar promise programs described earlier increased bachelor's attainment among eligible high school cohorts (Swanson & Ritter, 2020; Bartik et al., 2021). Bell & Gándara (2021) likewise find higher rates of eventual bachelor's attainment among students attending Tulsa Community College who were eligible for last-dollar Tulsa Achieves. Reviews of emerging promise research conclude that this form of aid has had generally positive effects on college and community outcomes. However, there are gaps in the literature such as the effects of tuition-free college on K-12 schools, the effects of newer and less-studied programs, and the consequences of program exclusions such as first-dollar support or four-year schools (Anderson, 2021; Swanson et al., 2020).

Promise programs are often touted as inputs to local or state economic development (Miller-Adams, 2015), and in this vein, Knox Achieves was motivated as a "transformational work force development initiative" (Shelby County Mayor Wharton, quoted in Ferrar, 2008). It largely remains to be seen, however, if higher rates of college enrollment and completion will translate into better labor-market outcomes for students or communities. One empirical challenge is the scale of extramarginal college enrollment or completion that may be necessary to detect significant reduced-form effects on earnings. Enrolling in a community college rather than no college could increase individual earnings at age 30 by 18% (Mountjoy, 2022), and associate holders earn 20% more than individuals with a high school diploma (Carnevale et al., 2021). But even the most intensive college access and aid programs increase college completion by a small share of eligible cohorts (12 percentage points in Kalamazoo Promise, for example), so intent-to-treat effects may reflect a correspondingly small change in average earnings.

Hershbein et al. (2021) study the effects of Kalamazoo Promise on later earnings, finding positive but statistically insignificant effects of eligibility on in-state earnings 7-10 years after high school. Others have likewise found imprecise labor-market returns to merit-based and need-based aid (Bettinger et al., 2019; Scott-Clayton and Zafar, 2019; Eng and Matsudaira, 2021). It is important to add analyses of programs like Knox Achieves to this list, because the scholarship had broader eligibility criteria than Kalamazoo Promise, no merit or income criteria, but could only be used to attend community colleges. Expected returns to this kind of program are complicated by lower returns to associate's degrees than bachelor's degrees (Reynolds, 2012) and opposing effects of democratizing higher education and diverting students from four-year universities (Mountjoy, 2022).

## III. Methods

### III.A. Data and Summary Statistics

We begin with longitudinal administrative data describing the universe of 2006-2007 through 2010-2011 high school seniors in Tennessee's public school systems, linked to their enrollment records in public two-year and four-year higher education institutions throughout the state and in-state earnings covered by Unemployment Insurance. These cohorts include two from before Knox Achieves was introduced and three who were 12$^{th}$ graders when Knox Achieves was active in Knox County, prior to its expansion under the name tnAchieves. Our analytical sample includes all 12$^{th}$ graders in these school years, including those who dropped out or repeated the grade the following year.[7] K-12 data include indicators for student gender, race, Hispanic ethnicity, grade level and school of record, free or reduced-price lunch eligibility (which we use as proxies for having low family income[8]), ACT composite and subject scores,[9] and scores on standardized end-of-course (EOC) exams in English Language Arts, Social

[7] We show in Section IV.B. that results are similar if we restrict regression samples to students in their last observed year of high school.

[8] Free or reduced-price lunch was typically determined on a student-by-student basis for the 2007-2011 cohorts under study. Later cohorts increasingly benefitted from Community Eligibility Provision, where entire schools were provided free lunch without requiring individual applications.

[9] We do not observe ACT scores for 38% of students in the analytical sample. Tennessee strongly encouraged ACT test-taking for these cohorts, subsidizing one ACT sitting and utilizing in-school days and school spaces to give the exam. The state did not require the ACT, however, until 2018. Missing ACT scores are imputed at ½ of a standard deviation below the school-cohort mean, or ½ of standard deviation below the county-cohort mean for a small number of schools with no ACT test-takers in a cohort.

Studies, Math, and Science. We normalize EOC scores to have mean equal to zero and standard deviation equal to one within test subjects and versions. We match each 12th grader's school of record[10] to the surrounding county and merge K-12 data to county-level economic indicators including unemployment, GDP, and poverty.[11]

We join these data with college enrollment details from the National Student Clearinghouse. Our Clearinghouse data do not include college credit or completion information for private colleges or out-of-state enrollees. Accordingly, we focus on postsecondary outcomes in Tennessee's public colleges and universities. The Tennessee Higher Education Commission (THEC), a coordinating body spanning the state's public university and college systems, maintains data on these students. Twenty percent of college-going students in the state do not enroll in a THEC institution, and as we describe in Section III.B, results to follow account for the plausible idea that Knox Achieves swayed some higher-achieving students to enroll in a public institution rather than a private or out-of-state institution.

Outcomes of interest include THEC accumulated credits within two and four years of high school, highest postsecondary certificate, associate's, or bachelor's degree attainment within eight years of high school (200% of the "normal time" to attain a bachelor's degree), and labor-market outcomes up to nine years after high school. For college attainment outcomes, we largely focus on results for highest attainment as of the 8th year after high school, up to a bachelor's degree. Except where noted, estimated effects on *highest* attainment are in agreement with estimated effects on *any* certificate or degree completion within the same time frame. We discuss the latter at more length in the Appendix. We derive labor-market outcomes from in-state earnings recorded in the state's Unemployment Insurance (UI) system, which covers the vast majority of earnings from work among state residents. Notable exceptions include earnings from self-employment, some agricultural or federal employers (including the military), and any earnings from working in other states. We compute earnings by fiscal year (third quarter of each calendar year through second quarter of the next calendar year) in each of the nine years

[10] If we observe a 12th grade student enrolled in a Knox County school and another county in the same year, we keep the Knox County observation. In other cases where a student enrolled in multiple schools during the same year, we first omit alternative schools, virtual schools, and schools that cannot be matched to U.S. Department of Education records. We resolve remaining student-by-year duplicates by keeping one observation at random.
[11] Sources for county economic data include the U.S. Bureau of Labor Statistics (unemployment), U.S. Bureau of Economic Analysis (GDP), U.S. Census Bureau (population, poverty).

following high school. Age-earnings profiles vary across industries and occupations, which complicates the analysis of early-career earnings. We address this issue to the extent possible by examining effects of Knox Achieves eligibility on earnings as well as an industry score, which we construct from a worker's industry (specifically, their employer's 4-digit NAICS code) and U.S. average earnings among workers covered by Unemployment Insurance. U.S. data are drawn from the Census Quarterly Workforce Indicator. For each year where a worker has in-state, UI-covered earnings, we compute their industry score as the average annual U.S. earnings in that industry that year, or as a weighted average if they worked in multiple industries. UI-covered earnings and industry scores are inflation-adjusted to fiscal year 2018-2019 dollars using the Consumer Price Index for Urban Consumers.[12]

We merge student data from K-12, higher education, and labor-market domains to Knox Achieves participant lists from the senior classes of 2009-2011. Participant lists allow us to flag all students who signaled their interest in the program in the fall of 2008-2010. We use participation indicators in the Appendix to quantify college and earnings gaps between Knox Achieves students and non-participating or ineligible students (Tables A5 and A6).

Table 1 provides descriptive statistics for all Tennessee 12$^{th}$ graders in Column 1. We separate Knox County 12$^{th}$ graders into the cohorts prior to Knox Achieves (Column 2) and the first three eligible cohorts (Column 3). Finally, in Column 4, we focus on the subset of Knox County students from Column 3 who participated in Knox Achieves. Students described by Column 4 are those who signed up to learn more about Knox Achieves in the fall of 12$^{th}$ grade, and who were subsequently matched to volunteer mentors. Knox Achieves participants accounted for 15.3% of eligible cohorts.

After the introduction of the program, Knox County students were slightly more likely to enroll immediately in college, and slightly more likely to receive two-year postsecondary credentials within 8 years, relative to previous cohorts of students in Knox County. For example, 5% of Knox County students in 2009-2011 earned an associate's degree within 8 years, compared with 3% statewide and 4% in earlier Knox County cohorts. At 20% bachelor's degree attainment, post-treatment Knox County students were similar to the statewide average (19%)

[12] https://fred.stlouisfed.org/series/CPIAUCSL

but below previous Knox County cohorts (23%). In comparison, Knox Achieves participants were much more likely than the other three groups to attend college or complete two-year postsecondary credentials, but they were noticeably less likely to complete bachelor's degrees. Nine years after high school, log in-state earnings for eligible Knox County students were equivalent to the pre-program mean (9.78) and lower than both the statewide average (9.82) and the Knox Achieves participant average (9.87).

Looking to student characteristics, Knox County had proportionately fewer Black students, and – at least in early cohorts – fewer free-lunch eligible students and more students who repeated the 12th grade. Many of the differences between the early and later cohorts of Knox County students are likely due to the Great Recession. For example, the percentage of free-lunch students increased from 20 to 27 percent, similar to the increase that occurred outside of Knox County from 24 to 35 percent. Achievement also declined in Knox County during this time period, illustrated by an increased likelihood of repeating 12th grade, lower ACT scores, and lower end-of-course test scores. Comparing Knox Achieves participants to all students eligible for Knox Achieves (Column 4 versus Column 3), participants were more likely to be female, Black, or eligible for free lunch, and they tended to have lower test scores on the ACT and on standardized end-of-course exams.

### III.B. Linear Estimation

To assess the potential impact of Knox Achieves availability on students' college and labor-market outcomes, we estimate the following student-level model for the 12th grade classes of 2007-2011, which include all eligible Knox County seniors from 2009-2011 as well as ineligible students from other counties and two pre-program cohorts:[13]

$$Y_i = \alpha_t + \alpha_c + KA_i\gamma + X_{isc}\beta + \varepsilon_{isct}, \quad (1)$$

where $Y_i$ is an outcome such as credits earned or associate degree attainment for student $I$, $KA_i$ is an indicator for Knox Achieves availability (equal to one for all Knox County seniors in the classes of 2009-2011), $\alpha_t$ is a cohort fixed effect, $\alpha_c$ is a county fixed effect, and $X_{isc}$ is a vector of

[13] In some specifications to follow, we show that results are similar if we restrict the comparison group to East Tennessee counties (as in Carruthers & Fox, 2016), or to a set of counties with a similar economic profile as Knox County.

observable features describing student *i*, their school *s*, and their county *c*. Students with no record of college enrollment have $Y_i$ coded as zero.

Student controls include continuous or binary variables describing gender, race, Hispanic ethnicity, repeating the 12th grade, free or reduced-price lunch eligibility in 12th grade, earnings during junior and senior years, the number of districts and counties attended between 8th and 12th grades, ACT composite and subject scores, standardized end-of-course exam scores (each student's average score across English and social studies exams, and their average across math and science exams), and indicators for missing data on these variables. These features are intended to characterize students' basic demographics, ability, and need, each of which are expected to be important correlates, signals, or determinants of later outcomes. School controls include cohort size and each school's race and ethnicity profile, i.e., the percent of each cohort who were Black or Hispanic. County controls include three economic measures describing the local economy during each student's 12th grade year – unemployment, the percent of the population in poverty, and GDP per capita – as well as changes in poverty and GDP per capita between 12th grade and five years later.

Equation (1) estimates the intent-to-treat effect of Knox Achieves eligibility on college outcomes and earnings several years after high school. Causal inferences rely on the assumption that Knox County cohort outcomes would have moved in parallel to the rest of the state in the absence of Knox Achieves. The intent-to-treat model represents a necessary methodological difference from some of the related literature on college and labor-market effects of access to promise scholarships. Universal place-based eligibility is a core feature of Knox Achieves and many that followed, and the effects of universal eligibility are certainly worth study. But this program design does not permit the kind of difference-in-difference or regression discontinuity identification used to evaluate programs where benefits are conditioned on GPA or how long a student lived in the qualifying city. Rather, the first conditions of Knox Achieves are (1) attending a Knox County high school as a senior, and (2) signing up for the program in the fall of senior year. We focus on the first criteria to identify effects of eligibility in our main analysis.[14]

[14] In the Appendix we turn to the second criteria (signing up) and report conditional differences in $Y_i$ outcomes between Knox Achieves participants and other students (Tables A5 and A6). These treatment-on-the-treated effect estimates rely on a strong assumption that signup was conditionally independent of influential and unobserved factors, such as inherent interest in associate programs or jobs that are well-aligned with such programs.

One threat to interpreting γ estimates as the causal effect of Knox Achieves is the possibility that the sample of students with observable college credits and degrees is itself influenced by Knox Achieves. Although we can identify the immediate college destinations of almost all 2007-11 high school graduates through the National Student Clearinghouse, we only observe credit accumulation and completion for students who enrolled in Tennessee's public universities and colleges. Since Knox Achieves emphasized community college enrollment, it is plausible that our capacity to observe a student's postsecondary progression was influenced by the program itself. Indeed, using the Equation (1) model, we find that Knox Achieves participation reduced the likelihood of enrolling in a private or out-of-state institution by 2.3 percentage points (although, not significantly), a large portion of the 9.2% share of all students who enrolled as such. Estimates of γ would overstate the effect of Knox Achieves on success in college if students who decided to enroll in a public in-state institution because of Knox Achieves were innately higher achieving, i.e., positively selected, relative to their peers.[15] To account for this possibility, main results for postsecondary outcomes are reported for a truncated sample, where we exclude 5 percent of Knox Achieves participants with the largest college credit accumulation after four years, as if participants who were convinced to enroll in one of Tennessee's public colleges or universities would have moved further toward a degree than all other program participants.[16] This modification to the estimating sample for college outcomes is in the spirit of Lee (2009) bounds and relies on a monotonicity assumption, i.e., that the program increased and did not decrease selection into THEC schools.

We do not truncate samples for labor and industry outcomes in our main results since private or out-of-state college enrollment does not necessarily affect our ability to observe UI earnings from Tennessee employers. Labor-market outcomes are subject to two other sample selection issues, however. First, we include enrolled college students in earnings regressions. If the program led students to substitute college for work in the short term, we may see eligibility associated with less work or lower earnings after high school. This is the crux of the college-work margin that students face, however, with policy implications for any program that seeks to

[15] We find support for positive selection into the analytical sample; higher-achieving students drove the lower likelihood of enrolling in a non-THEC institution. See Appendix Table A2.
[16] Our main results are robust to omitting the top 10% of participants, and to an untruncated sample. See Appendix Table A3.

expand access to college. And with a nine-year window of earnings after high school, our sample frame approaches the timeline where other researchers have detected significant effects of college or financial aid on earnings (Denning et al., 2019; Mountjoy, 2022). And second, with UI data limited to one state, results for earnings could be biased by sample attrition related to program influence (Foote and Stange, 2019). In our setting, free community college may affect labor-force participation, affect a student's out-of-state work opportunities, and more generally affect a student's earnings potential. The first two channels of UI sample selection, together, would violate the monotonicity assumption we make when applying Lee (2009) bounds to college outcomes. The third channel best describes what we would like to understand about free community college and later earnings, but we acknowledge that this effect is empirically indistinguishable from the program's effect on the extensive margin of observable earnings. Rather than impute missing earnings to be equal to zero, results to follow focus on log-earnings and industry scores among those with non-missing, UI-covered Tennessee earnings as well as the binary incidence of having any observed earnings in a given year following high school, and finally the likelihood of attrition from the UI sample. Following Grogger (2012), we define attrition from the earnings sample as the beginning of a terminal run of missing earnings. We then apply Equation (1) to the incidence of attrition 1-6 years following high school. If the program helps lower-wage students join the workforce or helps higher-wage students move out of state, then $\gamma$ estimates for observed log earnings will be biased downward.[17]

Aside from selection, another hazard of using Equation (1) to estimate the effect of Knox Achieves availability is the idea that cohort composition changed in ways that coincided with program availability as well as subsequent college and labor-market outcomes. Changes over time in Knox County students' college prospects or ability are chief examples of such factors. We respond to this threat by looking for differences in expected college behavior by Knox Achieves availability. Findings discussed in Section IV indicate some differences in expected college completion, although they work against finding positive program effects.

[17] As we show in the Appendix, estimated effects on earnings are similar under other sample constructions that address different possible scenarios for selection into and out of the earnings data (Table A2). We estimate Equation (1) omitting students who attrit from the earnings data entirely by the sixth year after leaving high school (under the assumption that they left the state), or omitting students who enrolled out of state, or omitting students in the top 5% of the earnings distribution each year after high school, or – finally – omitting students in the bottom 5% of earnings. Inferences are similar to what we report in Table 3 and Figure 1 in each iteration.

As a two-way fixed effects estimator, under the identifying assumption that successive treated and untreated cohorts would have followed the same conditional trajectory of outcomes ("common trends"), $\hat{\gamma}$ can be expressed as a weighted average of two-by-two difference-in-difference estimates between treated and untreated counties (De Chaisemartin & d'Haultfoeuille, 2020; Goodman-Bacon, 2021). If average treatment effects are heterogeneous (for example, building or tapering over time), then $\hat{\gamma}$ can be biased or even of the opposite sign as the average treatment effect across two-by-two subsets of the overall quasi-experiment. Using the procedure outlined by De Chaisemartin et al. (2019), we find that none of the weights in our application are negative.

Beyond selection and heterogeneity, interpreting the statistical significance of $\hat{\gamma}$ is not straightforward in this application. The Knox Achieves treatment affected a small number of groups: one county out of 95. Cluster-robust standard errors can severely over-reject the null when there are a small number of treated clusters (Conley and Taber, 2011; Ferman and Pinto, 2019; MacKinnon et al., 2023). Typical alternatives to cluster-robust inference are not well suited to applications with a single treated cluster – bootstrapped standard errors also tend to over-reject the null in these cases (MacKinnon et al., 2023), and randomization inference can be confounded by heteroskedasticity arising from differences in cluster size (Ferman and Pinto, 2019).[18] In results to follow, we rely on Ferman and Pinto (2019) p-values to make inferences about the statistical significance of coefficients, as well as 95% confidence intervals as applied in Ferman et al. (2021). These p-values and confidence intervals are derived from bootstrap regressions of residuals at the county-cohort level, correcting for heteroskedasticity from variation in county size (an important correction in our setting, since Knox is one of the larger counties in the state). The main drawback of taking this approach to inference is that we need to assume a specific form of heteroskedasticity, whereas with cluster-robust standard errors, we can allow for unrestricted heteroskedasticity.

## IV. Results

### IV.A. Balancing Tests

[18] Work in progress by Hagemann (2020) extends the analysis of a single treated cluster beyond the difference-in-difference framework used here.

The critical identification assumption allowing us to interpret γ estimates as causal effects of Knox Achieves is that access to the program was conditionally independent of unobserved determinants of college and employment outcomes. This assumption would be violated if, for example, post-2009 Knox County college and workforce outcomes were diverging from the rest of the state for unobserved reasons that were not well represented by $X_{isc}$ control variables.

Although these scenarios and others like them are untestable, we can utilize two pre-program cohorts to get a sense of how outcomes would have changed in Knox County in the absence of Knox Achieves. Specifically, we estimate predicted college and labor-market outcomes based on the behavior of ineligible students in pre-program cohorts and counties other than Knox, and we assess how these *ex ante* outcomes changed for eligible students with the introduction of Knox Achieves. This test is a more parametric version of common identification checks that visualize parallel trends across treatment and control groups, and it is better suited to our setting with one treated group and just two pre-program cohorts.[19]

Our balancing test begins by estimating the following for $KA_i$-ineligible students, i.e., the statewide classes of 2007 and 2008 along with the 2009, 2010, and 2011 classes of students not enrolled in Knox County:

$$Y_i = \alpha_0 + X_{isc}\beta + \varepsilon_{isct}, \qquad (2)$$

This specification includes the same student, school, and county covariates as in Equation (1), but without county fixed effects, cohort fixed effects, or the treatment indicator. We then use these estimates to compute least squares residuals, leverage values, and leave-one-out predicted outcomes $\tilde{Y}_{(-i)}$ for all students in all five classes from 2007 – 2011.[20] Finally, we estimate

[19] Event study and synthetic control techniques are other ways that we could scrutinize pre-treatment balance as well as program effects. Synthetic outcomes do not match Knox County outcomes very well before the Knox Achieves introduction (results available on request). The Appendix reports results from an event study specification that is similar to Equation (1) but replaces $KA_i$ with four indicators $Knox_i$*$Cohort_t$, where $Cohort_t$ is an indicator for the class of 2007, 2009, 2010, or 2011 (omitting pre-treatment 2008). The pattern of results – shown in Figure A1 – is similar to what we report for Equation (1), although cluster-robust inferences on the four event-time indicators do not adjust for one treated group.

[20] Leave-one-out predicted outcomes are computed as $\tilde{Y}_{(-i)} = \boldsymbol{x}_{ist}\hat{\beta} - \left(\frac{h_i}{1-h_i}\right)\hat{e}_{ist}$, where $\hat{\beta}$ and $\hat{e}_i$ are least squares coefficient and residual estimates from Equation (2), and $h_i$ are leverage values (diagonal elements of the projection matrix, or – intuitively – a measure of how unusual observation $i$ is relative to the rest of the sample). For experimental settings, Abadie et al. (2018) show that $\tilde{Y}_{(-i)}$ are less susceptible to finite sample bias from overfitting than least squares predictions $\hat{Y}_i = X_{isc}\hat{\beta}$.

Equation (1) excluding $X_{isc}$ controls and substituting leave-one-out predicted outcomes for actual outcomes of all students from 2007 to 2011.

Table 2 lists results for the pseudo-effect of Knox Achieves availability on college credit accumulation, certificate or degree attainment, and earnings. Coefficients are reported first for each outcome, followed by Ferman & Pinto (2019) p-values and 95% confidence intervals. The magnitude of coefficients suggests that *ex ante* predictions from an intent-to-treat Equation (1) specification are somewhat unbalanced. Based on observables alone, we would expect eligible students to accumulate 1.94 fewer college credits within two years of high school, attain more certificates (by 0.9 percentage points), and attain fewer bachelor's degrees (by 2.8 percentage points). These weakly significant coefficients are consistent with Knox County cohorts who were somewhat lower achieving after the introduction of Knox Achieves, as shown in Table 1. Our takeaway inference from Table 2 is that Knox Achieves entered the county at a time when four-year college attainment would have likely declined in its absence, a tendency that may push estimated program effects down.

**IV.B. Estimated Effects of Knox Achieves Eligibility**

Table 3 lists linear estimates of $\gamma$ for Equation (1), where we include the full sample of students from 2007 to 2011. The variable of interest is an intent-to-treat estimate because $KA_i$ is specified as a broad eligibility indicator. Our preferred results are in column (1) for the full sample of counties and 12$^{th}$ grade students. We find that Knox Achieves availability is associated with a countywide 1.30-credit rise in college credits two years after high school, along with a 2.20-credit rise four years after high school. Both credit estimates measure 8% of the control mean, but neither is statistically significant according to Ferman & Pinto (2019) p-values.

Turning to highest attainment within eight years of high school, we find that Knox Achieves had no significant effect on certificate attainment, increased associate's attainment by a significant 0.8 percentage points, and increased bachelor's degree attainment by an insignificant 1.1 percentage points. Estimated effects on associate's attainment are large, measuring 24% of the 3.3-percentage-point control mean, or 20% of the pre-treatment Knox County mean. Based on the 95% confidence interval for associate's degrees, we can rule out effects smaller than 0.2 percentage points and larger than 1.4 percentage points (5-35% of the pre-treatment Knox

County mean). The imprecise coefficient estimate for bachelor's degree attainment suggests that eligibility is associated with a 6% higher likelihood of completing a bachelor's degree, although the confidence interval includes zero and ranges from a 6% decline to a 17% increase. It is not clear why the program may have had a sizable effect on attainment but not credit accumulation. Taken at face value, 2.20 credits over four years is less than one additional course, and the confidence interval rules out effects larger than 5.9 credits, or about two additional courses. It is possible that the program's supplementary layer of advising and mentoring, or the requirement that students enroll full-time, helped students progress toward degrees more efficiently.[21] Our last insight from Table 3 is that higher attainment rates do not appear to have translated into higher in-state earnings. Having access to Knox Achieves as a 12th grader is associated with an insignificant 3.0% conditional *decrease* in log annual earnings nine years later. The confidence interval for 9th-year earnings is wide, ranging from a 14% decrease to a 6.6% increase.

The remaining columns of Table 3 show that our main findings are similar for alternate specifications and samples. In Column (2), we conceive of a school-level rather than county-level treatment, controlling for school fixed effects and allowing for correlated errors within schools along with unrestricted heteroskedasticity. For the remaining columns, the sample is restricted in the following ways: final-year 12th grade students in Column (3), omitting students who would subsequently repeat 12th grade; all 12th grade students in economically-similar counties for Column (4); and all 12th grade students in East Tennessee counties in Column (5). For the East Tennessee sample, we use the state's formal definition of the East Tennessee Grand Division to identify comparison counties. For the similar-county sample, we select the 47 counties that were quantitatively closest to Knox in terms of a Canberra distance. Our Canberra metric quantifies the dissimilarity between Knox and each of the other 94 counties in terms of the following variables, as of 2006 unless noted otherwise: average 12th grade ACT composite score, end-of-course achievement, county poverty rate, county GDP per capita, sales tax revenue per capita (2004), the 2006-2011 change in GDP per capita, the 2006-2011 change in poverty rate, the 2004-2009 change in sales tax revenue per capita, and the 2001-2006 change in GDP per capita and poverty. Coefficients are similar in sign and magnitude across Columns (1) – (5). Positive estimated effects on college credits are more precise with a school-level treatment

[21] We do not have course-taking data or degree progression measures to explore this possibility.

(Column 2) or in the more geographically restricted subsamples (Columns 4 and 5), and estimated effects on bachelor's degree attainment are positive and statistically significant in the East Tennessee subsample. For the remainder of the study, we focus on the broader statewide sample construction and county-level treatment construct, noting that confidence intervals from this specification generally contain the alternative Table 3 estimates.

Figure 1 illustrates the estimated effect of Knox Achieves on certificate, associate's, and bachelor's attainment over time. Each figure plots nine Equation (1) results for the binary likelihood of attaining a particular credential, and no higher degree, 1-9 years after high school. We see no change in certificate attainment (Panel I), although we show in the Appendix that access to tuition-free community college may have led to more certificate completion on the way to higher degrees (Figure A2).

Panel II of Figure I depicts positive estimated effects on associate's attainment starting 4 years after high school, rising to a 0.8-percentage-point gain over the counterfactual in year 8 before tapering to 0.6 percentage points in year 9. We might have expected program support to accelerate students toward an associate's within the first 2.5 years of college, when Knox Achieves aid could be applied toward tuition (as in Scott-Clayton and Zafar's (2019) analysis of merit-based aid in West Virginia). That does not appear to be the case here – precise effects on associate's attainment emerge after program benefits would have been exhausted.

Panel III depicts positive estimated effects on bachelor's degree completion that rise over years 5-9, up to 1.2 percentage points in year 9. Confidence intervals are large for bachelor's attainment, however, ranging from a 1.1-point decline to a 3.1-point increase. Positive and statistically insignificant effects on bachelor's degree attainment are contrary to one risk of tuition-free community college policies, i.e., the possibility that they divert bachelor's-intending students to community colleges and unintentionally lower their chances of completing a bachelor's degree. Figure 1 suggests this diversion was not the case for Knox Achieves, although we cannot rule it out completely and as we show in Appendix Tables A5 and A6, program *participants* were significantly less likely to complete bachelor's degrees than conditionally similar non-participants. Selection bias and spillover effects might reconcile this disagreement between eligibility and participation margins. Students who signaled their interest in free community college may have been inherently more inclined toward associate programs than

four-year programs, and Knox Achieves participants may have earned even fewer bachelor's degrees in the absence of the program. The implementation of Knox Achieves included school assemblies, posters, and contact with every high school counselor in the county. The statewide successor, Tennessee Promise, is said to have "changed the conversation" about college (Tamburin, 2017). Perhaps non-participating students were influenced by the program's outreach efforts, by its message about college in general, or by more college-going peers.

Figure 2 illustrates the relationship between Knox Achieves and Equation (1) $\gamma$ estimates for labor-market outcomes 1-9 years following high school. We see a fluctuating and insignificant association between Knox Achieves eligibility and log earnings that climbs from years 5-7 before tapering over years 8-9 (Panel I). The largest estimated earnings gain is 1.4% in the 7$^{th}$ year after high school, but this gain is not precise. We might be concerned that the program increased out-of-state job opportunities for inherently higher-earnings students (by increasing job opportunities in general), leading to downward bias in Panel I estimates for log earnings. But Figure 2 also shows that eligibility is not associated with a higher or lower likelihood of having UI-covered earnings in any given year (Panel II), or a higher or lower likelihood of leaving the Tennessee UI sample (Panel IV). Perhaps tuition-free community college led to similar average wages and salaries in the short term but in more lucrative sectors with higher potential earnings. Results in Panel III of Figure 2 counter that notion; we estimate that Knox Achieves had no effect on industry score 1-8 years after high school, and in fact led to significantly lower-paying industries in year 9.

What might explain higher rates of two-year college completion alongside no change in earnings or even a declining industry score? Timing may be partly responsible. Positive effects on associate's attainment come into clear view four years after high school and rise for another three years, suggesting that program effects unfold for a long time. Perhaps we would not see significantly higher returns to those degrees over the years immediately after college completion. Scale is another possibility – large returns to associate's degrees for 0.8% of eligible students might be difficult to detect countywide.

A third possibility is that program effects were countered by a more potent Great Recession for Knox County students, particularly for the first two eligible cohorts in the classes of 2009 and 2010. Murray (2013) reports that Knox County as a whole rebounded from the Great

Recession faster than much of the state, but it is possible that slow job growth differentially affected recent high school graduates. To investigate, we estimate three versions of Equation (1) for log earnings 1-9 years after high school, omitting all but one treated cohort in each specification. Figure 3 plots the results. Indeed, 2009 and 2010 cohorts had typically positive but lower $\gamma$ estimates throughout the window we observe. Estimated effects were as large as 2-3% for the 2009 and 2010 cohorts versus up to 4.3% for the 2011 cohort. But almost none of the estimates in Figure 3 are statistically significant, and all three cohorts exhibit declining earnings premia 7-9 years after high school.[22]

Looking across Table 3 and Figures 1-3, we conclude that access to the Knox Achieves promise of tuition-free community college likely helped students complete more associate's degrees than they would have otherwise. Bachelor's degree attainment rates did not suffer, nor did they increase by an exceptional amount. Effects of last-dollar aid on two-year attainment did not manifest as higher UI-covered earnings, however, or employment in better-paying industries. These findings raise questions about the individual and social payoff to broadening access to college through last-dollar aid. In Section IV.C we explore cost-benefit ratios more formally, focusing on our comparatively short-run estimated changes in UI-covered earnings as well as more speculative long-term returns to associate degrees.

Tables 4-6 report Equation (1) results for different subsamples of students by income, high school achievement, race, and ethnicity. We tend to lose precision when we focus on smaller populations, as evidenced by larger p-values in Tables 4-6, compared to full-sample results in Table 3. With this in mind, we focus on precision across subsample results as well as the magnitude of coefficients to understand which subgroups may have contributed more to Table 3 estimates, and thus may have been more potently affected by eligibility for Knox Achieves.

Table 4 partitions the Tennessee sample of 2007-2011 seniors into three groups: those who did not participate in the free school lunch program in 12$^{th}$ grade (Column 1), those who were eligible for reduced-price lunch (Column 2), and those who were eligible for free lunch

[22] The 2011 cohort would have experienced the COVID-19 recession in their 9$^{th}$ year after high school. But as seen in Figure 3, their 9$^{th}$-year earnings premium was not unusual relative to what the other cohorts experienced in the same time frame.

(Column 3). Moving left to right, family income likely falls and subsamples are successively more disadvantaged, although the correspondence between subsidized lunch eligibility and family income would be stronger if we could observe eligibility over multiple years (Michelmore and Dynarski, 2017). Notably, the income ceiling for subsidized lunch among these cohorts was low enough to qualify most reduced-price-lunch and free-lunch students for Pell grants in excess of community college tuition and fees.[23] In other words, students represented by Columns 2-3 of Table 4 likely already had "free community college" through Pell grant entitlements, although they would not have known this with certainty before applying for financial aid. Any discernible treatment effect among these subpopulations may be more attributable to non-financial aspects of Knox Achieves such as mentoring, the upfront message about the cost of college for program participants, or effective targeting toward lower-income students and students who would be the first in their families to attend college.

Given the coverage of need-based aid, it is remarkable that access to Knox Achieves has the largest estimated (albeit, statistically insignificant) effect on associate's degree attainment for the lowest-income students (Column 3), both in terms of coefficients (1.3 percentage points versus 0.8 for Column 1 students) and relative to sample means (68% in Column 3 versus 21% in Column 1). Estimated effects on college credits after 4 years and bachelor's degree attainment are also largest in magnitude for free-lunch eligible students, although not statistically significant for that or any subgroup. None of the subsidized lunch subsamples had significantly different earnings than the counterfactual after 9 years. The negative 3% earnings coefficient for higher-income students is similar to the corresponding Table 3 result. Middle-income students with reduced-price lunch actually saw 11% lower earnings, and lower-income students with free lunch eligibility saw 1.5% higher earnings, although again, earnings estimates are imprecise overall and by subgroups.

Table 5 reports Equation (1) results separately for students with below-median achievement on standardized end-of-course exams (Column 1) and with above-median

[23] Household income limits in 2008-2009 were $32,560 for reduced-price lunch, for a family of three in the contiguous 48 states, and $22,880 for free lunch (Federal Register Vol. 73, No. 69, April 9, 2008). Pell grants were typically $3,543 at family incomes of $30,000 – 40,000 (authors' calculations using the 2009-2010 Federal Pell Grant End of Year Report, Table 3). Community college tuition and fees for full-time in-state students ranged from $2,889 – 2,992 for school year 2009-2010 (IPEDS).

achievement (Column 2). Many of the above-median students described by Column 2 would additionally be eligible for merit-based HOPE scholarships, which provided up to $6,000 for higher-achieving students in these cohorts to attend public four-year institutions and up to $3,000 to attend public two-year institutions. HOPE eligibility was conditioned on scoring at least 21 on the ACT or earning a 3.0 high school grade point average. The ACT criteria alone described 55% of Knox County students with non-missing ACT scores in the sample. Effects on two-year college completion were larger in absolute and relative terms for higher-achieving students, who were 1.6 percentage points more likely to attain an associate's degree within eight years (34% of the control mean). Statistically insignificant but positive effects on bachelor's degree attainment were similar for lower-achieving and higher-achieving students (1.6 and 1.8 percentage points, respectively), although point estimates represent a much larger share of the mean for lower-achieving students (24% versus 6%). Finally, we find no significant effect on 9$^{th}$-year earnings by prior achievement.

Table 6 reports results for Equation (1) estimates by race, Hispanic ethnicity, and gender. We find that estimated effects on associate's attainment are larger or more precise for white students and men (0.9 and 0.8 percentage point gains, respectively). Hispanic students accumulated 3-4 more college credits after the introduction of Knox Achieves, the largest credit gain among these five demographic groups. Other results for the Hispanic subpopulation are imprecise, which may be attributed to their small share of each cohort, but it is notable that their 1.9-point gain in bachelor's attainment is also the largest treatment effect estimate of any demographic subgroup and Hispanics are the only subgroup where the associate's attainment declines.

Results by gender and race are one place where conclusions are somewhat different when we estimate effects on *any* certificate or degree completion rather than *highest* attainment. As shown in the Appendix, Black students and women exhibited the largest gains in any associate's completion (Table A1). This finding, combined with Table 6 results for highest attainment, suggests that Black and female students (who were over-represented among Knox Achieves participants) may have been more likely to earn an associate's degree on the way to attaining a bachelor's degree, although we lack power in identifying significant effects on bachelor's attainment. Black and female students were imprecisely 1.2 percentage points more likely to earn

a bachelor's degree if they were eligible for Knox Achieves, similar to what we report in Table 6 for men and white students.

### IV.C. Benefit-cost comparison

Next, we explore how the known costs of the program measure up to its observed and potential benefits in terms of earnings. Table 7 contains estimates of the observed and potential effects of Knox Achieves eligibility on earnings, along with its estimated costs. First, for each year after high school, we transform the log earnings coefficient from Figure 2 into percentage terms and multiply by mean earnings among students with any UI-covered, in-state earnings in a given time since high school. We then sum the discounted changes in earnings – using a real discount rate of three percent – across the nine years. All but year 6-7 returns were negative, and the discounted earnings *loss* associated with Knox Achieves eligibility is $889. This is our best estimate of the direct, short-run earnings effect associated with access to tuition-free community college, but note again that we cannot reject the hypothesis that true effects were zero in any of the nine years after high school.

The direct cost to the funder of this last-dollar scholarship was around $1,000 per enrolled participant per year. We assume that this cost is in 2009 dollars, the first full year of the scholarship, an amount equal to $1,171 in 2018 dollars (as wage variables and treatment effect estimates are measured in 2018 dollars). Using the calculation that 55% of Knox Achieves participants received the scholarship and enrolled in community college, along with a maximum eligibility of five semesters (or 2.5 years),[24] and a participation rate of 15.3% among eligible students, we calculate a potential cost of $1,171 * 0.55 * 2.5 * 0.153 = $246 per eligible student. The estimated benefit-cost ratio based on 9 years of observed earnings after high school is -$889 / 246 = -3.6.

Alternatively, we consider *potential* lifetime benefits from greater college attainment, using estimated effects on certificate, associate's, and bachelor's receipt from the first column of Table 3. We estimate benefits of eligibility from the increase in lifetime earnings for each credential, as reported in Carnevale et al. (2021), relative to earnings with a high school diploma. This is $400,000 with an associate's degree and $1.6 million with a bachelor's degree. We

[24] The average duration of postsecondary enrollment for Knox Achieves students is around three years.

assume that the gains from earning a certificate are half of the gains from an associate's degree.[25] We then multiply the lifetime earnings increase with the additional likelihood of attainment for each credential. For example, $400,000 * 0.008 for associate's degrees produces a $3,200 expected premia for each eligible student via the effect of eligibility on associate's receipt. The other estimates are -$400 for certificates and $17,600 for bachelor's degrees. Adding the three premia together, we get an estimated $20,400 in additional lifetime earnings associated with Knox Achieves eligibility, 83 times greater than the $246 program cost per eligible student.

To incorporate the uncertainty of the estimated increase in educational attainment, Table 7 includes lower and upper bounds as well. For the lower bound estimate, coefficients for each attainment level are replaced by the corresponding lower bound of the 95% confidence interval from Table 3, Column 1. Similarly, the most optimistic scenario is based on the upper bound of the confidence interval for each coefficient. The range of potential gains in bachelor's degree receipt—up to 3.1 percentage points—includes all of the estimated coefficients from alternative samples and specifications arrayed in Table 3, including those that were estimated with more precision than our preferred statewide specification. The bottom line for potential returns ranges from a $19,800 net loss over one's career to a $57,600 gain, a wide and inconclusive interval driven by imprecision in bachelor's degree attainment.

The difference in benefits is stark between the observed short run and potential long run. Eligible students had insignificantly lower earnings in the 9 years after high school, but they were also more likely to complete college credentials that lead us to project large long-run returns to eligibility via higher postsecondary attainment. Higher earnings from more associate's degrees and possibly more bachelor's degrees should push lifetime earnings up by many times the value of program costs. Our estimated effects on postsecondary attainment are imprecise, however, especially for bachelor's degrees, and this leads to a wide range of potential long-run returns that encompass the $889 decline we observe from 9 years of earnings immediately following high school. In sum, our best guess is that the program is associated with a substantial

[25] The report does not explicitly state whether the earnings gain is in real or nominal dollars, so we assume that it is in 2018 dollars. Given that the estimates are from 2009-2019, any difference in value due to inflation will be trivial in relation to the estimated increase in earnings of $400,000. We view this increase in earnings as a conservative estimate. If we estimate the lifetime gains in earnings from an associate's degree using the technique in Blomquist et al. (2014) – applied to Tennessee data from the American Community Survey – the estimated gain in earnings is closer to $450,000.

gain in potential earnings via additional education. But we cannot rule out the possibility of a large net loss due to the uncertain effect on attaining a bachelor's degree worth $1.6 million gain in additional lifetime earnings. This uncertainty is underscored by negative and imprecise estimated effects on observed earnings up to 9 years after high school.

An important caveat is that many potential costs and benefits are omitted from the analysis. We ignore costs to the state government of providing additional funding to community colleges as well as individuals' direct and indirect costs not covered by the program. Nonmonetary benefits of higher education are also omitted. Furthermore, individual and aggregate benefits may depend on heterogeneous returns to college by ability, major, and income (Webber, 2016; Carnevale et al., 2022). All of the true costs and heterogeneous benefits of the program are not known, and these additional considerations further cloud our expectations about the net return to Knox Achieves participation.

## V. Conclusion

We estimate the medium-term effects of a low-cost, last-dollar scholarship on college completion and in-state, UI-covered earnings up to nine years after high school. Key elements of Knox Achieves – universal place-based eligibility and last-dollar support toward tuition-free community college – match local and statewide programs that followed in Tennessee and elsewhere throughout the United States.

Estimated effects vary in magnitude across different approaches, but a consistent story emerges where the introduction of Knox Achieves led to a higher rate of associate's degree attainment of up to 0.8 percentage points from a mean of 3.3%. Given that Knox Achieves is associated with gains in college attendance of 3-4 percentage points (Carruthers and Fox, 2016), the inferred extramarginal completion rate is around 20-27%, similar to 26-29% six-year graduation rates at Tennessee's community colleges during this time period (Tennessee Higher Education Commission, 2016). Although the program did not induce students to continue in school to complete bachelor's degrees at significantly higher rates in our preferred specification (Column 1 of Table 3), two caveats bear repeating. Confidence intervals and some alternate estimates suggest we should not rule out positive results for bachelor's completion, and Knox

Achieves started in the midst of a slight downward trajectory in bachelor's attainment in Knox County relative to elsewhere in Tennessee.

This pattern of results is not unexpected given the program's focus solely on community college. When looking at student subgroups, it appears that lower-income students and higher-achieving students experienced larger gains in associate's and bachelor's attainment than their counterparts, but the precision of these coefficients is mixed. These students were also most likely to receive other sources of aid, be it need based or merit based. Thus, messaging likely matters: students may have been particularly influenced by the guarantee of free community college, either because they were unaware of likely sources of aid or were uncertain of their ability to obtain such aid.

Our findings also suggest that money matters, when we consider estimated effects of Knox Achieves alongside the rest of the literature. More generous first-dollar scholarship programs that cover four-year schools as well as community colleges increase college attainment by much more than Knox Achieves. Kalamazoo Promise increased the likelihood of earning a postsecondary credential within 6 years of high school by 11.6 percentage points, including a 7.4-point gain in bachelor's attainment (Bartik et al., 2021). El Dorado Promise increased the likelihood of receiving a bachelor's degree within 6 years by 8.8 percentage points (Swanson and Ritter, 2020). The costs of guaranteeing college or university tuition from the first dollar, however, are much higher than comparable costs from last-dollar Knox Achieves and its successor the Tennessee Promise. In a meta-analysis of 43 empirical studies on financial aid and college completion, Nguyen et al. (2019) find that each additional $1,000 in annual grant aid (their Table 6, in 2014 dollars), per participant, raises degree completion by 1.8-2.2 percentage points.[26] On those terms, Kalamazoo Promise and Knox Achieves each raised college attainment by roughly 1.3-1.4 percentage points per $1,000 in additional aid.[27]

[26] Most studies in Nguyen et al.'s (2019) review estimated the effect of aid on college completion conditional on enrolling at all. This differs from our analysis of high school cohorts, 55% of whom did not immediately enroll in college. Nevertheless, Nguyen et al. (2019) report similar "delayed" completion effects, i.e., more than normal time, for study populations that were and were not conditioned on college enrollment (their Table 3).

[27] We convert $8,000 per participant-year in Kalamazoo and $1,000 per participant-year in Knox to 2018 dollars (note that Nguyen et al. (2019) study costs per participant-year, not total, multi-year program costs per eligible student as we do in Section IV.C). We then divide estimated percentage-point gains in any credential (summing Table 3 certificate, associate's, and bachelor's coefficients for Knox Achieves) by average annual participant grants. The expression is 11.6/8.72 for Kalamazoo Promise and 1.67/1.17 for Knox Achieves.

Turning to earnings, we find no gains in earnings for eligible students up to nine years after high school. Although such a finding seems inconsistent with the notable gains in associate's degree completion, recent work similarly finds imprecise effects of merit-based aid, need-based aid, and place-based aid on later earnings (Scott-Clayton and Zafar, 2019; Bartik et al., 2021; Eng and Matsudaira, 2021). Despite having near-population data for Tennessee high school graduates, our setting may be underpowered for what could be small intent-to-treat effects on earnings. If Knox Achieves increased two-year college going by 5 percentage points among eligible cohorts (the upper end of what Carruthers and Fox (2016) reported), with no diversionary effect on four-year college completion, we might only expect to see 18% higher earnings (Mountjoy, 2022) for 5% of eligible cohorts, or a 0.72% intent-to-treat effect on log earnings before considering any offsetting general equilibrium effects. This expectation falls within the 95% confidence interval for 9$^{th}$-year earnings effects in Table 3, but it may be too small to detect precisely.

Projected lifetime earnings from greater associate's completion will easily cover the program's modest costs, 10-13 times over, but only if those gains are realized. Similarly, Bartik et al. (2016) find that the likely benefits from higher lifetime earnings, driven by gains in bachelor's degree receipt, outweigh Kalamazoo Promise costs 4.66 times (their Table 5). Page et al. (2019) estimate a benefit-cost ratio of Pittsburgh Promise equal to 1.35 based on gains in short-term college enrollment and persistence. However, the likelihood that predicted increases in lifetime earnings can be achieved without any detectable increase in earnings in the first several years after high school is a concern that merits further study. Inconclusive wage and salary returns have economic implications for other last-dollar, free community college programs, including Tennessee Promise and several subsequent state and community initiatives. Promise programs share the premise that free college will support workforce or community development by increasing access to a college education. We conclude that this particular Promise program increased community college completion, as intended, but that progress on its ultimate workforce goals remain unclear.

**Appendix: Supplementary Figures and Results**

*Event Study Results*

Intent-to-treat results reported in the paper rely on the following simple two-way fixed effects specification,

$$Y_i = \alpha_t + \alpha_c + KA_i\gamma + X_{isc}\beta + \varepsilon_{isct}, \quad \text{(A1)}$$

where $KA_i$ is equal to one for Knox County 12th graders in 2009-2011 cohorts who were eligible for Knox Achieves. Here, we discuss results from an event study extension of Equation (A1):

$$Y_i = \alpha_t + \alpha_c + \Sigma_{t\neq 2008}\, Knox_i * Cohort_t\gamma_t + X_{isc}\beta + \varepsilon_{isct}, \quad \text{(A2)}$$

where $Cohort_t = \{2007, 2009, 2010, 2011\}$, omitting 2008, the last pre-treatment cohort. Findings complement the Table 2 balancing analysis but are not directly reconcilable with Equation (2) estimates of leave-one-out predicted $\tilde{Y}_{(-i)}$. Figure A1 plots $\gamma_t$ estimates (circles) and 95% confidence intervals (vertical bars) derived from cluster-robust standard errors. Each panel helps to visualize results from one pre-treatment falsification test—for the 2007 cohort—as well as post-treatment effects for each cohort 2009-2011.

Panels I-II for credits within 2 and 4 years of high school indicate that Knox County's class of 2007 was insignificantly different from the next pre-treatment cohort. Relative to the omitted class of 2008, the first treated cohort experienced gains in credit accumulation, but confidence intervals widened over the next two cohorts. Panel III suggests that the likelihood of attaining a certificate and no higher fell with the 2010 cohort (perhaps because other degrees were more likely), but this pattern was not evident for either of the other two treated cohorts. Regarding associate's attainment, Panel IV depicts a fairly large and positive treatment effect for the first Knox Achieves cohort that subsequently tapered for the following two. Panel V suggests that Knox County's pre-treatment class of 2007 completed more bachelor's degrees than expected relative to the 2008 class. Later, eligible cohorts also completed more bachelor's degrees, although – much like what we find for associate's attainment – estimated effects tapered for the last two cohorts. Finally, Panel VI shows that log earnings 9 years after high school were insignificantly lower for Knox County students prior to Knox Achieves, remained insignificantly lower for two treated classes, and climbed to par for the 2011 cohort.

Event study results suggest that, prior to 2009, outcomes were conditionally well-balanced between Knox and other counties, with the exception of bachelor's degrees. Predicted effects on bachelor's attainment were *less* likely based on observables (Table 2) but *more* likely among one Knox County pre-treatment cohort. These insights, combined with the large magnitude of imprecise bachelor's attainment coefficients relative to associate's coefficients, lead us to discount causal inferences about effects of the program on bachelor's receipt. We do not rule out positive effects on bachelor's attainment, but the magnitude of imprecise coefficients for this outcome may be driven by imbalanced potential outcomes.

*Estimated Effects on Any Certificate or Associate's Receipt*

Our main results for college completion focus on a student's highest college attainment among certificates, associate's degrees, and bachelor's degrees. Figure A2 depicts results for *any* certificate or associate's receipt (Panels I and III) along with copies of highest attainment results for comparison (Panels II and IV, also found in Figure 1). Results suggest that Knox Achieves accelerated certificate receipt, although imprecisely. Gains in certificate attainment rose to 2.8 percentage points 3 years after high school and tapered to 1.2 percentage points thereafter (Panel I). These certificates were often earned on the way to other degrees, however, because we detect no effect on the likelihood that a student earned only a certificate (Panel II).

Estimated effects on the likelihood of any associate's attainment (Panel III) follow a similar pattern as the likelihood of highest associate's attainment (Panel IV), climbing over the 4 years following high school and then plateauing at about 1.1 percentage points for any associate's and 0.8 percentage points for highest associates. The 0.3-point gap between those two estimates suggests that most of the effect on associate's degree receipt was among students who did not go on to earn a bachelor's degree within 9 years of high school.

Table A1 reports results for any certificate and associate's receipt for each of the subgroups described by Tables 4-6. Comparing control means across the five tables gives us a sense of how often each population "stacks" these credentials. Between 4-8% of each subgroup earns a certificate (Table A1) and 3-6% earn a certificate and no higher degree. However, our estimated treatment effects on any certificate receipt versus certificate-high attainment suggest that Knox Achieves increased the likelihood of that pathway, albeit not significantly (Figure A2).

The biggest gap in any versus highest certificate attainment is for higher-achieving students – 8% earn at least a certificate whereas half that many stop with a certificate. Between 2-8% of students in each population earn an associate's degree. This degree is least common among Black students (2%) and most common among higher-achieving students (8%). The likelihood of associate's attainment without a bachelor's degree is 1-5%, again with Black students being least likely and higher-achieving students being most likely.

Regression results are in accord with our main results for highest attainment, in that positive effects on associate's degrees are more pronounced for lower-income and higher-achieving students. As noted in the main paper, there are bigger differences between any and highest associate's degrees for Black and female students. Black students were insignificantly 0.6 percentage points more likely to attain an associate's and no higher if they were eligible for Knox Achieves (Table 6), but significantly 1.4 percentage points more likely to earn an associate's degree at all (Table A1). Any associate's degree was insignificantly 1.3 percentage points more likely for women (Table A1), whereas the increased likelihood that a woman attained an associate's and no higher was only 0.8 and marginally significant (Table 6). This pattern, although imprecisely estimated, suggests that Knox Achieves may have led more Black and female students to follow an associate's to bachelor's route.

*Estimating Potential Selection into Public Postsecondary Institutions and In-State Earnings*

Table A2 applies Equation (A1) to the likelihood of enrolling in a private or out-of-state college (where we cannot observe degree outcomes) as well as the likelihood of non-missing, in-state, UI-covered earnings at selected intervals 1-9 years after high school. Columns (2)-(3) partition the samples into students with below-median and above-median achievement, respectively.

Knox Achieves eligibility reduced the likelihood of enrolling in a private or out-of-state institution by 2.3 percentage points, although this is not precise according to Ferman & Pinto (2019) p-values. Selection out of our observable degree sample could be problematic if students with a different likelihood of completing college were particularly likely to make this substitution. Columns (2)-(3) support this possibility, because lower-achieving students were not more or less likely to enroll in private or out-of-state colleges, while higher-achieving students

were 2.6 percentage points less likely to do so. Neither estimate is precise, but nevertheless we err on the side of caution in our main results, which omit 5% of Knox Achieves participants with the most college credits at 4 years. In the next section we describe results when we modify that bounding assumption.

Looking to the rest of Table A2, Knox Achieves is linked to small, imprecise, and mostly negative changes in the likelihood of having observable earnings. These changes are small, imprecise, and mostly positive when we partition by achievement (we can reconcile the change in sign from the 7-11% of students with missing achievement), and no clear pattern emerges for selection into earnings among students in one or the other achievement division.

*Addressing Potential Selection into Public Postsecondary Institutions*

Table A3 illustrates the sensitivity of our main intent-to-treat findings to different degrees of bounding for potential non-random selection into the sample of students with observable college credit and completion data. Lee (2009) addressed a similar sample selection problem in an analysis of a job training program on wages that could only be observed for workers, acknowledging that employment could itself be affected by the program. Following Lee's proposed "trimming" solution, results reported in the main body of the paper exclude the top 5% of Knox Achieves participants in terms of credit accumulation within four years of high school, accounting for an extreme form of positive sample selection. The necessary monotonicity assumption is that Knox Achieves could only *increase* the likelihood of enrolling in a public Tennessee institution, and it could not increase observability for some students but increase attrition for others. We believe that this assumption is plausible for the public college enrollment margin.[28]

Column (1) of Table A3 repeats baseline Equation (1) and (A1) findings, which can also be found in Table 3 of the main paper. Column (2) trims the participant subsample by 10% rather than 5%, resulting in smaller and still-insignificant effects of Knox Achieves availability on college credits, certificate or bachelor's degree attainment, and earnings. Estimated effects for associate's attainment are very similar in magnitude and significance. Column (3) lists estimates

[28] As noted in the main text, monotonicity is less viable on the question of attrition from observed in-state earnings covered by unemployment insurance, since the program's effects on college-going could increase the likelihood of any work as well as the likelihood of having more out-of-state opportunities for work.

with no trimming, raising some coefficients but again leaving our inferences unchanged. We conclude that omitting or including the top credit-earning Knox Achieves participants has very little bearing on results.

*Addressing Potential Selection into In-State Earnings*

Table A4 lists results for log earnings among different sample criteria that attempt to address omissions in the UI data. Column (2) regressions omit students who left the UI data as late as 6 years after high school, if not earlier. If Knox Achieves led to more out-of-state or entrepreneurial opportunities for inherently high-wage students, their selection out of the wage data might bias earnings results downward. We determine attrition from terminal runs of missing data as in Grogger (2012). For example, Column (2) coefficients are from regressions that omit students with no earnings in the $6^{th}$ – $9^{th}$ years after high school, as well as anyone who had a string of missing earnings from year $t = 2$ through $t = 9$ (students with missing earnings in all years are already excluded). Results for 1, 3, and 5 years after high school change very little. Results for years 7 and 9 are identical by design to baseline findings in Column (1). Column (3) specifications omit students who enrolled out of state, and again, coefficients and significance indicators are very similar to Column (1).

The specifications reported in Columns (4) and (5) omit the bottom and top 5%, respectively, of Knox Achieves participants in terms of their earnings as of each interval after high school. These bounding exercises are similar to that of Table A3, but under the assumption that the program helped lower-earning students gain employment in in-state, UI-covered occupations (Column 4) or influenced higher-earning students to work in these occupations (Column 5). Although each trimming assumption changes the sample by a small number of students, estimated effects on earnings are notably different in Columns (4) and (5) compared to Column (1). Omitting the lowest earning participants at each point in time increases estimated returns from 1.4% to 4.1% at year 7 and from -3.0% to -0.3% at year 9. Omitting the top earning participants, however, decreases year 7 returns to 0.1% and decreases year 9 returns to -4.2%. None of these estimated returns are precise, however, and wide degrees of unexplained variation in earnings may be responsible for these swings. Nonetheless, outmigration or selection into UI-covered jobs do not appear to be responsible for inconclusive effects of Knox Achieves on earnings.

*Treatment-on-the-Treated (TOT) Estimates*

OLS Results

Now, we turn to estimates of the effect of individual-level participation in Knox Achieves. We estimate the following:

$$Y_i = \alpha_t + \alpha_c + KAPartic_i\gamma + X_{isc}\beta + \varepsilon_{isct}, \quad \text{(A3)}$$

The "treatment" variable $KAPartic_i$ in Equation (A3) is an indicator variable equal to one for students who signed up to learn more about Knox Achieves. To make causal inferences about $\gamma$ with confidence, we rely heavily on the $X_{isc}$ vector of observable student, school, and county features to control for factors that may influence students' interest in a free community college program as well as their later outcomes. It is plausible that unobservable features affected both $KAPartic_i$ and $Y_i$ outcomes, but nevertheless, it is helpful to contextualize preferred intent-to-treat effect estimates against conditional differences in $Y_i$ between participants and other students. In addition, we explore the extent to which linear Equation (A3) results are sensitive to much more flexible functional forms alongside data-driven model selection (Hansen et al., 2014), and we gauge the potential severity of selection on unobservables using coefficient stability methods proposed by Oster (2019).

Column (1) of Table A5 lists results when the $X_{isc}$ vector is limited to cohort fixed effects. This is a nearly unconditional estimate of relative college credit and accumulation gaps between Knox Achieves participants and other students. Table A5 shows that they were 3.0 percentage points more likely to earn a certificate (and no higher) than their peers in Knox County, throughout the state, and in earlier cohorts. They were 7.1 percentage points more likely to attain an associate's degree, 5.7 percentage points less likely to earn bachelor's degree, and they earned about as much as other students 9 years after high school.

Some of these gaps narrow when we add the basic set of controls used in the main paper. The Column (2) model estimates a 6.5 percentage point gain in associate's receipt versus a 7.1-point gain in Column (1). Participants' shortfall in bachelor's degree receipt widens to 6.7 percentage points, and estimated effects on 9$^{th}$ year earnings increase to a statistically significant 5% gain (Column 2). Coefficient changes combined with gains in explained variance ($R^2$) lead to

the inference that controls are informative and that a sizable degree of selection on unobservables would be necessary to explain away Column (2) conditional gaps. Estimates of Oster's (2019) δ parameter are underneath $R^2$ values in Columns (2)-(4). If the true treatment effect on associate's attainment were zero, for example, selection into Knox Achieves based on unobservable determinants of earning an associate's would have to be 7.1 times as informative as selection according to the basic $X_{isc}$ vector components.

Specifications reported in Column (3) of Table A5 expand the $X_{isc}$ vector from 30 elements to over 800 by including quadratic functions of continuous variables and interactions between and among all binary and continuous variables in $X_{isc}$. Point estimates for college credit gains are nevertheless similar under this more saturated and more flexible model, suggesting the Knox Achieves participants accumulated more credits within two years but fewer within four, which is consistent with their higher rate of two-year credential receipt and lower rate of bachelor's receipt. Between Column (2) and (3), the negative effect of participation on bachelor's receipt shrinks from 6.7 to 5.3 percentage points. Associate's attainment effects narrow somewhat from 6.5 percentage points in Column (2) to 6.2 percentage points in the saturated Column (3) model, and 9$^{th}$ year earnings effects increase from 5.0% to 6.1%. Even though we added many more observable controls to the linear model, Oster's (2019) δ indicates that proportionate selection on unobservables would still have to be quite large to completely explain treatment-on-the-treated effect estimates.

Lastly, Column (4) reports results from a specification of Equation (A3) with an intermediate degree of flexibility relative to baseline and saturated models. Specifically, we estimate Equation (A3) using a set of controls identified by least absolute shrinkage and selection (LASSO). We follow the post-double-selection method prescribed by Hansen et al. (2014) to recover interpretable Equation (A3) estimates of γ from a large, data-driven set of controls. Point estimates change little relative to the flexible Column (3) specification.

Matching Results

Table 1 of the main paper illustrates that the statistical profile of Knox Achieves participants was notably different from non-participants in terms of demographics, achievement, and family income. This difference may mean that models such as Equation (A3) will depend too

heavily on extrapolation when forming estimates of the conditional gap in outcomes between treated and untreated students (Imbens, 2015). In such cases, matching estimators can be a suitable alternative to linear models.

The intuition with matching is to pair each Knox Achieves participant with a quantitatively similar non-participant and interpret the average difference in outcomes across matched pairs as the treatment effect. We take two complementary approaches to defining similarity between treated and control students. We first pair participants to similar students in terms of several observable features in $X_{isc}$: gender, race, Hispanic ethnicity, repeating the 12th grade, free or reduced-price lunch, junior year earnings, number of counties since 8th grade, ACT composite, English and math end-of-course exam scores, schoolwide percent Black or Hispanic, and the county unemployment and poverty rates. Mahalanobis matching computes a distance metric describing the similarity of this control vector between every *i, j* pair of students and matches treated students to the untreated nearest neighbor in terms of this distance metric. For Mahalanobis treatment effect estimates, we compute standard errors according to Abadie and Imbens (2006). Figure A3 depicts the average standardized gap in observable features before and after matching Knox Achieves participants to non-participating Knox County students and students elsewhere in the state. As one would hope, matching on these covariates limits observable differences between Knox Achieves participants and comparison students.[29]

Our second matching approach is to pair Knox Achieves participants with non-participants according to their estimated likelihood of signing up for the program. We estimate this propensity by logit for seniors who had the opportunity to sign up, i.e., Knox County classes of 2009-2011. Predictive factors include all variables represented in $X_{isc}$ of Equation (1). Parameter estimates are mapped to seniors in other counties and pre-program cohorts. We use a nearest neighbor propensity score estimator where matches are constrained to be within two percentage points (i.e., a caliper of 0.02), within the range of overlap between treated and control propensity (i.e., with common support), and below the top one percent of treated students' propensity distribution. Figure A4 plots the distribution of predicted propensity by Knox

[29] Note that Mahalanobis matching minimizes the distance metric between matches without regard for which variables in the matching vector are most important for predicting college outcomes.

Achieves participation. Although participants generally had a higher propensity than non-participants, the area of common support is inclusive of them all.

Under both Mahalanobis and propensity score matching, we compute two sets of TOT estimates. The first allows Knox Achieves participants to be matched to any other 12th grader in the state, including their non-participating peers in Knox County. This technique could introduce bias from selection on unobservables, so in a second model we restrict the control reservoir to counties outside of Knox. The latter approach may lead to weaker matches on observables and cannot rule out omitted variable bias among Knox Achieves participants, but it will at least restrict comparison students to those who did not have the opportunity to take-up the program.

Table A6 presents treatment-on-the-treated estimates from Mahalanobis and propensity score matching procedures. The first takeaway is that treatment effect estimates are at times different under these four matching schemes and different from linear estimates reported in Table A5 Column (2) and copied to Table A6 Column (1) for comparison. Outcomes with the least consistent TOT effect estimates are credit accumulation after four years (-2.25 in the linear model but insignificant in matching models) and 9th year earnings (5.0% higher in Column 1 but as much as 12.6% lower in Column 4). These are the same outcomes for which intent-to-treat effect estimates are most inconclusive. Unfortunately, treatment-on-the-treated effect estimates do not shed more light on how program eligibility shaped credit accumulation or 9th year earnings.

Matching results are more consistent for degree outcomes. Participant rates of certificate attainment were 1-2 percentage points higher than the counterfactual (with mixed statistical precision, much like ITT results for certificates). Associate's degree attainment was 6-8 percentage points more likely than the counterfactual, in agreement with linear treatment effect estimates. Bachelor's degree attainment was 4-5 percentage points lower among participants than matched peers, a slightly narrower gap than -6.7 in Column 1.

Comparison of Intent-to-Treat and Treatment-on-the-Treated Estimates

If countywide trends in postsecondary outcomes were driven entirely by Knox Achieves, and if spillover effects were minimal between participants and non-participants, we would expect TOT estimates to be about 6.5 times as large as intent-to-treat (ITT) estimates, based on 15.3%

participation among eligible cohorts. As described above, TOT results for credit accumulation and 9th year earnings are difficult to reconcile with themselves, much less with ITT estimates. Taking 9th year earnings, for example, ITT models estimate that Knox Achieves eligibility led to 3% lower earnings. If this was entirely driven by program participants, we would expect them to have 19.5% lower earnings than the counterfactual. This is a larger decline in earnings than we estimate in any TOT model—the closest is a 12.6% decline in Table A6 Column (4), whereas the other TOT estimates range from -3.7% (insignificant) to +5.0% (significant).

TOT effect estimates point to 6-8 percentage-point higher rates of associate's attainment, and these are consistent across OLS and matching models. These gains would imply 0.9-1.2 percentage-point gains in associate's attainment countywide, which is close to the 0.8 percentage-point effect reported in the main paper. Participants were 4-7 percentage points less likely to attain a bachelor's degree, however, which would translate to a 0.6-1.1 point *decline* in bachelor's attainment that we do not see countywide. As discussed in the main paper, we can speculate as to why we come to different conclusions for the intent-to-treat effect of eligibility on bachelor's receipt versus the participant/non-participant gap in conditional bachelor's receipt. One possibility is *ex ante* imbalance in would-be bachelor's attainment, which we see conflicting evidence of in Table 2 and Figure A1. Selection bias in TOT estimates is another explanation. Finally, there may have been spillover effects from the program's general higher education advocacy to participants and non-participants alike.

**References**


Abadie, A., Chingos, M. M., & West, M. R. (2018). Endogenous stratification in randomized experiments. *Review of Economics and Statistics*, *100*(4), 567-580.

Abadie, A., & Imbens, G. W. (2006). Large sample properties of matching estimators for average treatment effects. *Econometrica*, *74*(1), 235-267.

Alapo, L. (2008, October 29). College fund program begun. *Knoxville News Sentinel (TN)*, p. 9.

Anderson, C. (2021). Local-level, place-based scholarships: a review of the literature. *Educational Review*, *73*(5), 638-661.

Andrews, R. J., DesJardins, S., & Ranchhod, V. (2010). The effects of the Kalamazoo Promise on college choice. *Economics of Education Review*, *29*(5), 722-737.

Bartik, T. J., Hershbein, B., & Lachowska, M. (2021). The effects of the Kalamazoo Promise Scholarship on college enrollment and completion. *Journal of Human Resources*, *56*(1), 269-310.

Bartik, T. J., Hershbein, B., & Lachowska, M. (2016). The merits of universal scholarship: Benefit-cost evidence from the Kalamazoo Promise. *Journal of Benefit Cost Analysis*, 7(3), 400-433.

Bell, E. (2021). Estimating the spillover effects of the Tennessee Promise: Exploring changes in tuition, fees, and enrollment. *Journal of Student Financial Aid*, *50*(1), 4.

Bell, E., & Gándara, D. (2021). Can free community college close racial disparities in postsecondary attainment? How Tulsa Achieves affects racially minoritized student outcomes. *American Educational Research Journal*, *58*(6), 1142-1177.

Bettinger, E., Gurantz, O., Kawano, L., Sacerdote, B., & Stevens, M. (2019). The long-run impacts of financial aid: Evidence from California's Cal Grant. *American Economic Journal: Economic Policy*, *11*(1), 64-94.

Blomquist, G., Coomes, P. A., Jepsen, C., Koford, B. C., & Troske, K. R. (2014) Estimating the social value of higher education: Willingness to pay for community and technical colleges. *Journal of Benefit Cost Analysis*, 5(1), 3-42.

Boatman, A., & Soliz, A. (2018). Statewide transfer policies and community college student success. *Education Finance and Policy*, *13*(4), 449-483.

Boehnke, M. (2015, January 10). Obama's promise. *Knoxville News Sentinel (TN)*, p. 1A.

Burland, E., Dynarski, S., Michelmore, K., Owen, S., & Raghuraman, S. (2022). The power of certainty: Experimental evidence on the effective design of free tuition programs (No. w29864). National Bureau of Economic Research. Working Paper.

Campaign for Free College Tuition. (2022). *Making Public Colleges Tuition Free: A Briefing Book for State Leaders*.

Carnevale, A. P., Cheah, B., & Wenzinger, E. (2021). *The college payoff: More education doesn't always mean more earnings*. Center on Education and the Workforce, Georgetown Public Policy Institute, Georgetown University.

Carnevale, A. P., Cheah, B., & Van Der Werf, M. (2022). *The Colleges Where Low-Income Students Get the Highest ROI.* Center on Education and the Workforce, Georgetown Public Policy Institute, Georgetown University.

Carruthers, C. K., & Fox, W. F. (2016). Aid for all: College coaching, financial aid, and post-secondary persistence in tennessee. *Economics of Education Review*, *51*, 97-112.

Carruthers, C. K., & Sanford, T. (2018). Way station or launching pad? Unpacking the returns to adult technical education. *Journal of Public Economics*, *165*, 146-159.

Conley, T. G., & Taber, C. R. (2011). Inference with "difference in differences" with a small number of policy changes. *The Review of Economics and Statistics*, *93*(1), 113-125.

Daugherty, L., & Gonzalez, G. C. (2016). The impact of the New Haven Promise program on college enrollment, choice, and persistence. RAND Corporation. Working Paper.

De Chaisemartin, C., & d'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review*, 110(9), 2964-2996.

De Chaisemartin, C., X. D'Haultfoeuille, & A. Deeb. (2019). "TWOWAYFEWEIGHTS: Stata module to estimate the weights and measure of robustness to treatment effect heterogeneity attached to two-way fixed effects regressions," Statistical Software Components S458611, Boston College Department of Economics, revised 03 Nov 2019.

Denning, J. T., Marx, B. M., & Turner, L. J. (2019). ProPelled: The effects of grants on graduation, earnings, and welfare. *American Economic Journal: Applied Economics*, *11*(3), 193-224.

Dynarski, S., Libassi, C. J., Michelmore, K., & Owen, S. (2021). Closing the gap: The effect of reducing complexity and uncertainty in college pricing on the choices of low-income students. *American Economic Review*, *111*(6), 1721-56.

Eng, A., & Matsudaira, J. (2021). Pell grants and student success: Evidence from the universe of federal aid recipients. *Journal of Labor Economics*, *39*(S2), S413-S454.

Ferman, B., Torsvik, G., & Vaage, K. (2021). Skipping the doctor: Evidence from a case with extended self-certification of paid sick leave. *Journal of Population Economics*, 1-37.

Ferman, B., & Pinto, C. (2019). Inference in differences-in-differences with few treated groups and heteroskedasticity. *Review of Economics and Statistics*, *101*(3), 452-467.

Ferrar, R. (2008, July 16). Free tuition planned for community colleges. *Knoxville News Sentinel (TN)*.

Foote, A., & Stange, K. (2019). Attrition from administrative data: Problems and solutions with an application to higher education. Working Paper.

Gandara, D., & Li, A. (2020). Promise for whom? "Free-college" programs and enrollments by race and gender classifications at public, 2-year colleges. *Educational Evaluation and Policy Analysis*, *42*(4), 603-627.

Goodman-Bacon, A. (2021). Difference-in-differences with variation in treatment timing. *Journal of Econometrics*, *225*(2), 254-277.

Grogger, J. (2012). Bounding the effects of social experiments: Accounting for attrition in administrative data. *Evaluation Review*, *36*(6), 449-474.

Gurantz, O. (2020). What does free community college buy? Early impacts from the Oregon Promise. *Journal of Policy Analysis and Management*, *39*(1), 11-35.

Hansen, C., Chernozhukov, V., & Belloni, A. (2014). Inference on treatment effects after selection among high-dimensional controls. *The Review of Economic Studies*, *81*(2), 608-650.

Hansen, W. L., & Weisbrod, B. A. (1969). The distribution of costs and direct benefits of public higher education: The case of California. *Journal of Human Resources*, 176-191.

Hershbein, B., McMullen, I., Pittelko, B., & Timmeney, B. (2021). Beyond degrees: Longer term outcomes of the Kalamazoo Promise. Working Paper. *Available at SSRN 3889447*.

House, E., & Dell, M. (2020). Keeping the promise: Early outcomes of Tennessee's tuition-free college initiative. In L. W. Perna & E. J. Smith (Eds.), *Improving Research-Based Knowledge of College Promise Programs* (pp. 151–172). American Educational Research Association.

Imbens, G. W. (2015). Matching methods in practice: Three examples. *Journal of Human Resources*, *50*(2), 373-419.

Jepsen, C., Troske, K., & Coomes, P. (2014). The labor-market returns to community college degrees, diplomas, and certificates. *Journal of Labor Economics* 32(1), 95-121.

Kast, M. (2019, June 20). Knox Promise to help fulfill college dreams - Program's goal is to lift students over financial obstacles. *Knoxville News Sentinel (TN)*, p. A7.

Lee, D. S. (2009). Training, wages, and sample selection: Estimating sharp bounds on treatment effects. *The Review of Economic Studies*, *76*(3), 1071-1102.

Ma, J., & Pender, M. (2021). *Trends in College Pricing and Student Aid 2021*, New York: College Board.

MacKinnon, J. G., Nielsen, M. Ø., & Webb, M. D. (2023). Cluster-robust inference: A guide to empirical practice. *Journal of Econometrics 232*(2): 272-299.

Michelmore, K., & Dynarski, S. (2017). The gap within the gap: Using longitudinal data to understand income differences in educational outcomes. *AERA Open 3*(1).

Miller-Adams, M. (2015). *Promise Nation: Transforming Communities through Place-Based Scholarships*. WE Upjohn Institute. https://research.upjohn.org/up_press/235/

Miller-Adams, M., Hershbein, B., Timmeney, B., & McMullen, I. (2017). Promise Programs Database. Kalamazoo, MI: W.E. Upjohn Institute for Employment Research. Promise: Investing in Community. Updated May 2019, July 2020. Available at: https://www.upjohn.org/promise/

Mishory, J., & Granville, P. (2019). Policy design matters for rising "free college" aid. The Century Foundation: https://tcf.org/content/commentary/policy-design-matters-rising-free-college-aid/

Mountjoy, J. (2022). Community colleges and upward mobility. *American Economic Review*, *112*(8), 2580-2630.

Murray, M. N. (2013). *Fall 2013 Tennessee Business and Economic Outlook*. Center for Business and Economic Research, University of Tennessee. https://haslam.utk.edu/sites/default/files/fall13.pdf

Nguyen, T.D., Kramer, J.W., & Evans, B.J. (2019). The Effects of Grant Aid on Student Persistence and Degree Attainment: A Systematic Review and Meta-Analysis of the Causal Evidence. *Review of Educational Research 89*(6):831-874.

Oster, E. (2019). Unobservable selection and coefficient stability: Theory and validation. *Journal of Business and Economic Statistics 37*(2): 187-204.

Page, L. C., Iriti, J. E., Lowry, D. J., & Anthony, A. M. (2019). The promise of place-based investment in postsecondary access and success: Investigating the impact of the Pittsburgh Promise. *Education Finance and Policy*, *14*(4), 572-600.

Reynolds, C. L. (2012). Where to attend? Estimating the effects of beginning college at a two-year institution. *Economics of Education Review*, *31*(4), 345-362.

Rouse, C. E. (1995). Democratization or diversion? The effect of community colleges on educational attainment. *Journal of Business & Economic Statistics*, *13*(2), 217-224.

Scott-Clayton, J., & Zafar, B. (2019). Financial aid, debt management, and socioeconomic outcomes: Post-college effects of merit-based aid. *Journal of Public Economics*, *170*, 68-82.

Swanson, E., & Ritter, G. (2020) Start to Finish: Examining the Impact of the El Dorado Promise Program on Postsecondary Outcomes, *Journal of Student Financial Aid 49*(3): Article 2.

Swanson, E., Watson, A. R., & Ritter, G. W. (2020). Promises fulfilled?: A systematic review of the impacts of college promise programs. In L. W. Perna & E. J. Smith (Eds.), *Improving Research-Based Knowledge of College Promise Programs* (pp. 33–68). American Educational Research Association.

Tennessee Higher Education Commission. (2016). *2015 – 2016 Tennessee Higher Education Fact Book*. https://www.tn.gov/content/dam/tn/thec/bureau/research/other-research/factbook/2015-2016_Fact_Book.pdf

Tennessee Higher Education Commission. (2022). *College Going and the Class of 2021.* https://www.tn.gov/content/dam/tn/thec/bureau/research/college-going-reports/CGR-HSSO%20Report%20Draft_Final.pdf

Turner, S. (2018). The evolution of the high tuition, high aid debate. *Change: The Magazine of Higher Learning*, *50*(3-4), 142-148.

Webber, D. A. (2016). Are college costs worth it? How ability, major, and debt affect the returns to schooling. *Economics of Education Review*, *53*, 296-310.

Table 1. Student summary statistics, by Knox Achieves eligibility and participation

| Variable | (1) All Tennessee 12th Graders | (2) Knox County 2007 and 2008 12th graders | (3) Knox County 2009, 2010, and 2011 12th graders | (4) Knox Achieves Participants |
|---|---|---|---|---|
| Immediately enrolled in college (0,1) | 0.45 | 0.45 | 0.47 | 0.71 |
| Certificate attainment (0,1) | 0.05 | 0.03 | 0.04 | 0.06 |
| Associate's degree attainment (0,1) | 0.03 | 0.04 | 0.05 | 0.12 |
| Bachelor's degree attainment (0,1) | 0.19 | 0.23 | 0.20 | 0.15 |
| Log in-state earnings one year after high school | 8.27 | 8.36 | 8.24 | 8.41 |
| | (1.25) | (1.23) | (1.25) | (1.11) |
| Log in-state earnings nine years after high school | 9.82 | 9.78 | 9.78 | 9.87 |
| | (1.23) | (1.21) | (1.23) | (1.07) |
| Female (0,1) | 0.49 | 0.48 | 0.47 | 0.60 |
| Black (0,1) | 0.25 | 0.15 | 0.17 | 0.22 |
| Hispanic (0,1) | 0.03 | 0.02 | 0.03 | 0.02 |
| Reduced-price lunch in 12th grade (0,1) | 0.06 | 0.05 | 0.05 | 0.07 |
| Free lunch in 12th grade (0,1) | 0.30 | 0.20 | 0.27 | 0.39 |
| Repeating 12th grade (0,1) | 0.04 | 0.09 | 0.10 | 0.03 |
| ACT composite (out of 36) | 19.98 | 22.16 | 20.85 | 18.79 |
| | (4.95) | (4.54) | (5.30) | (4.35) |
| EOC achievement (mean 0, standard deviation 1) | -0.05 | 0.14 | 0.05 | 0.03 |
| | (0.79) | (1.04) | (0.90) | (0.60) |
| N (students) | 314,973 | 8,477 | 13,202 | 2,026 |

Notes: Standard deviations are in parentheses below continuous-valued means. The sample includes 12th grade students throughout Tennessee, academic years 2006-2007 through 2010-2011. Other variables included in the analysis: the number of schools, districts, and counties a student attended since 8th grade, junior and senior year earnings, ACT subscores, EOC subject scores, indicators for cohort, indicators for missing ACT and EOC scores (here, we report non-missing means for these achievement variables), and county economic indicators for a student's 12th grade year (unemployment, poverty, and GDP per capita), as well as the change in their county's economic profile over the next five years. For college outcomes, analytical samples exclude students who enrolled in non-THEC institutions as well as the top 5% of program participants in terms of credit accumulation.

Table 2: Balancing tests of Knox Achieves and expected outcomes

| | |
|---|---|
| Predicted THEC college credits within two years | -1.944* |
| | (0.087) |
| | [-4.036, 0.271] |
| Predicted THEC college credits within four years | -3.745* |
| | (0.076) |
| | [-8.135, 0.264] |
| Predicted certificate attainment | 0.009* |
| | (0.073) |
| | [-0.001, 0.018] |
| Predicted associate's degree attainment | -0.001 |
| | (0.740) |
| | [-0.007, 0.005] |
| Predicted bachelor's degree attainment | -0.028* |
| | (0.053) |
| | [-0.056, 2.6E-04] |
| Predicted log earnings nine years after high school | -0.033 |
| | (0.394) |
| | [-0.100, 0.034] |
| Students | 314,973 |

Notes: The table lists γ estimates from Equation (1), where observed outcomes are substituted with leave-one-out predictions from Equation (2), estimated without Knox County cohorts eligible for Knox Achieves. Specifically, we estimate Equation (2) excluding 2009-2011 Knox County 12th graders, compute least squares residuals and leverage values for all, and then compute leave-one-out predicted outcomes. Additional controls in the secondary Equation (1) model include observable student characteristics, school composition, and county economic indicators. Ferman & Pinto (2019) p-values are in parentheses, and 95% confidence intervals are in brackets.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 3: Intent-to-treat effect estimates: Knox Achieves and postsecondary outcomes

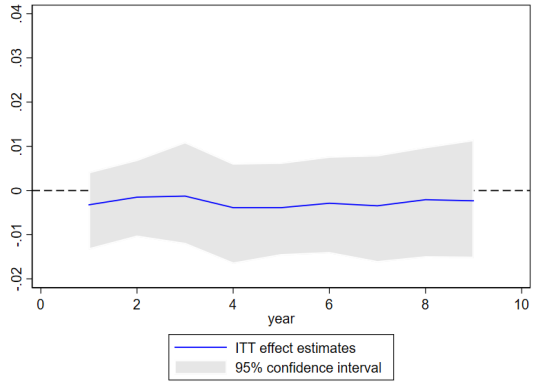
| | (1) All TN counties, all 12th graders | (2) All TN 12th graders, school FE and CRV | (3) All TN counties, final-year 12th graders | (4) All 12th graders, economically similar TN counties | (5) All 12th graders, East TN counties |
|---|---|---|---|---|---|
| THEC college credits within two years | 1.301 | 1.268* | 1.241 | 1.618** | 1.303** |
| Control mean: 15.96 | (0.263) | (0.050) | (0.238) | (0.017) | (0.043) |
| | [-0.957, 3.834] | [-0.003, 2.539] | [-1.139, 3.917] | [0.441, 2.915] | [0.025, 2.514] |
| THEC college credits within four years | 2.197 | 2.174** | 1.707 | 2.673** | 2.047 |
| Control mean: 29.29 | (0.256) | (0.031) | (0.378) | (0.022) | (0.106) |
| | [-1.888, 5.912] | [0.199, 4.149] | [-1.942, 5.957] | [0.817, 4.288] | [-1.418, 5.735] |
| Certificate attainment | -0.002 | -0.001 | -0.002 | 0.002 | -0.003 |
| Control mean: 0.047 | (0.672) | (0.776) | (0.644) | (0.632) | (0.614) |
| | [-0.015, 0.012] | [-0.005, 0.004] | [-0.016, 0.011] | [-0.007, 0.012] | [-0.013, 0.008] |
| Associate's degree attainment | 0.008*** | 0.008** | 0.008** | 0.008** | 0.008** |
| Control mean: 0.033 | (0.003) | (0.027) | (0.014) | (0.020) | (0.034) |
| | [0.002, 0.014] | [0.001, 0.015] | [0.002, 0.015] | [0.002, 0.015] | [0.001, 0.016] |
| Bachelor's degree attainment | 0.011 | 0.009 | 0.007 | 0.010 | 0.020** |
| Control mean: 0.184 | (0.355) | (0.252) | (0.571) | (0.103) | (0.032) |
| | [-0.011, 0.031] | [-0.007, 0.025] | [-0.016, 0.03] | [-0.002, 0.021] | [0.004, 0.035] |
| In-state log earnings nine years after high school | -0.030 | -0.037 | -0.014 | -0.034 | -0.012 |
| Control mean: 9.83 | (0.491) | (0.871) | (0.728) | (0.149) | (0.384) |
| | [-0.14, 0.066] | [-0.081, 0.007] | [-0.113, 0.093] | [-0.085, 0.017] | [-0.078, 0.049] |
| Treated students | 13,202 | 13,200 | 12,149 | 13,202 | 13,202 |
| All students | 314,973 | 314,960 | 304,273 | 240,341 | 113,466 |

Notes: The table lists γ estimates from Equation (1), ITT estimates of the effect of Knox Achieves availability or participation on college credits, attainment, and earnings. Coefficients represent estimated effects of Knox Achieves eligibility (i.e., being a Knox County 12th grader in 2008, 2009, or 2010) on the outcomes listed at left. Ferman & Pinto (2019) p-values are listed in parentheses in Columns (1) and (3) - (5), with 95% confidence intervals in brackets. Column (2) has cluster-robust p-values in parentheses and 95% confidence intervals in brackets, allowing for county-level correlated errors.

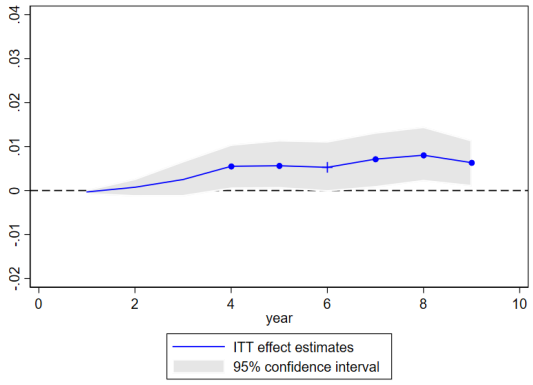
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Figure 1. Knox Achieves and highest college attainment, by years since high school

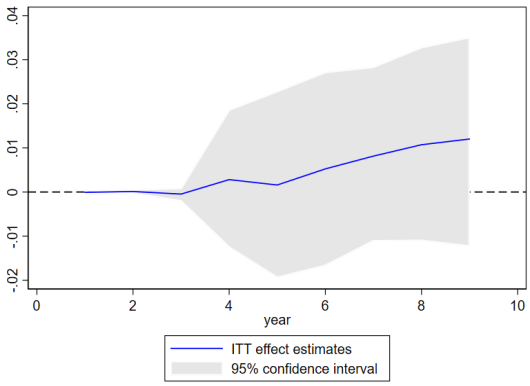
I. Certificate




II. Associate's degree




III. Bachelor's degree

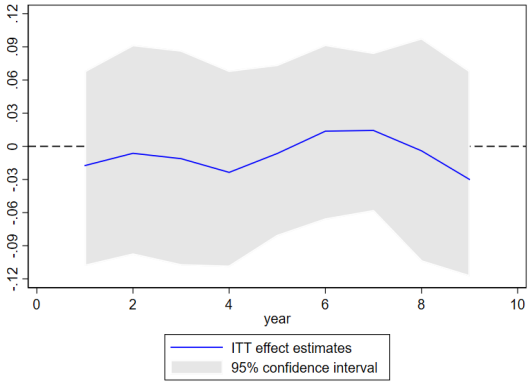



Notes: Each figure plots Equation (1) results for college credential attainment (highest certificate or degree completed), by years since high school, along with shaded 95% confidence intervals.

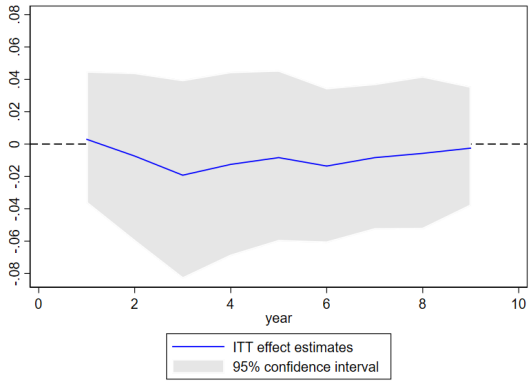
+ $p < 0.10$, ● $p < 0.05$ (Ferman & Pinto, 2019)

Figure 2. Knox Achieves and labor market outcomes, by years since high school

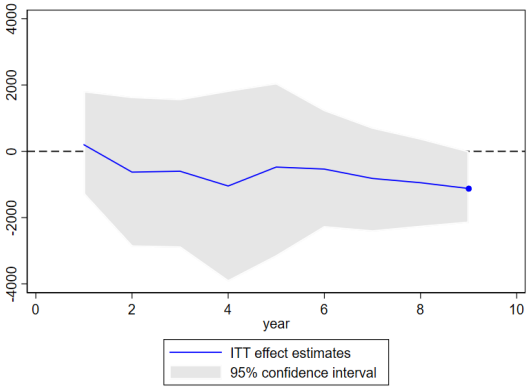
I. Log in-state earnings



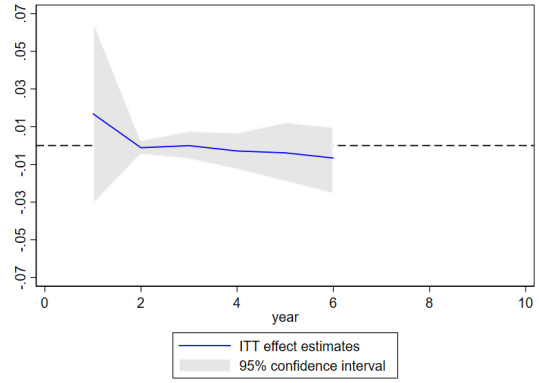

II. Any in-state earnings




III. Industry score



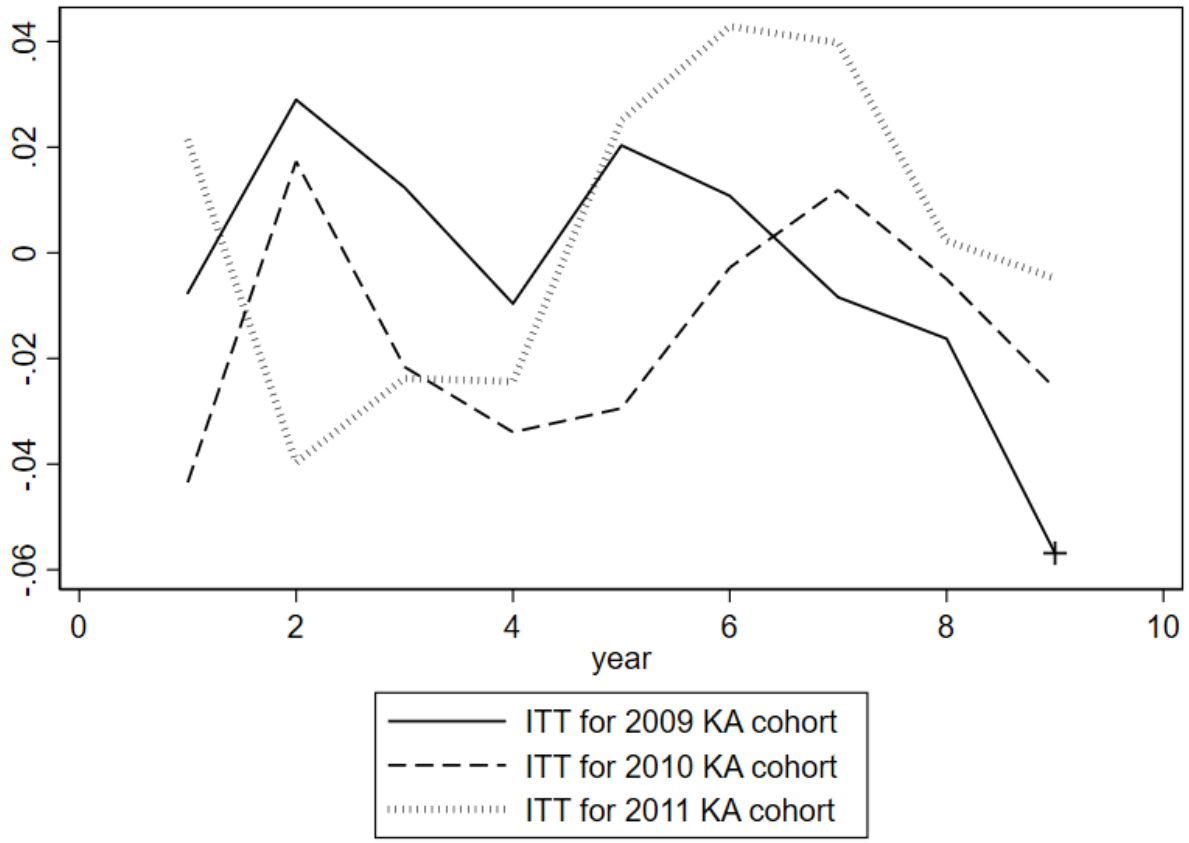

IV. Attrition from in-state earnings




Notes: Each figure plots Equation (1) results for labor market outcomes, by years since high school, along with shaded 95% confidence intervals.

+ $p < 0.10$, ● $p < 0.05$ (Ferman & Pinto, 2019)

Figure 3. Knox Achieves and in-state log earnings, by cohort and years since high school




Notes: The figure displays Equation (1) point estimates for ITT estimated effects of Knox Achieves availability on log earnings, focusing on one treated cohort in each series of 9 Equation (1) results.

+ $p < 0.10$, ● $p < 0.05$ (Ferman & Pinto, 2019)

Table 4: Knox Achieves and postsecondary outcomes, by 12th grade free lunch status

| 12th grade subsidized lunch status | (1) Not eligible for subsidized lunch | (2) Reduced-price lunch eligible | (3) Free-lunch eligible |
|---|---|---|---|
| THEC college credits within two years | 1.102 | 1.860* | 1.423 |
| | (0.379) | (0.075) | (0.405) |
| | 19.458 | 13.503 | 8.845 |
| THEC college credits within four years | 2.176 | 1.321 | 3.022 |
| | (0.338) | (0.452) | (0.291) |
| | 36.204 | 23.513 | 15.407 |
| Certificate attainment | -0.006 | 0.005 | 0.007 |
| | (0.283) | (0.837) | (0.518) |
| | 0.048 | 0.057 | 0.044 |
| Associate's degree attainment | 0.008* | -0.003 | 0.013 |
| | (0.060) | (0.853) | (0.273) |
| | 0.039 | 0.033 | 0.019 |
| Bachelor's degree attainment | 0.013 | -0.018 | 0.020 |
| | (0.156) | (0.573) | (0.378) |
| | 0.238 | 0.129 | 0.079 |
| Log in-state earnings nine years after high school | -0.033 | -0.110 | 0.015 |
| | (0.578) | (0.193) | (0.739) |
| | 9.954 | 9.794 | 9.578 |
| Treated students | 9,060 | 651 | 3,509 |
| All students | 204,056 | 18,497 | 94,443 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on college credits, attainment, and earnings. Ferman and Pinto (2019) p-values are listed in parentheses. Control means are listed below p-values.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 5: Knox Achieves and postsecondary outcomes, by achievement

| | (1) | (2) |
|---|---|---|
| Achievement subsample | Below-median end-of-course achievement | Above-median end-of-course achievement |
| THEC college credits within two years | 0.967 | 1.553 |
| | (0.375) | (0.388) |
| | 8.053 | 26.401 |
| THEC college credits within four years | 2.431 | 2.844 |
| | (0.200) | (0.361) |
| | 14.08 | 48.709 |
| Certificate attainment | -0.002 | -0.003 |
| | (0.813) | (0.614) |
| | 0.056 | 0.045 |
| Associate's degree attainment | -0.004 | 0.016** |
| | (0.327) | (0.041) |
| | 0.022 | 0.047 |
| Bachelor's degree attainment | 0.016 | 0.018 |
| | (0.185) | (0.368) |
| | 0.066 | 0.327 |
| Log in-state earnings nine years after high school | 0.001 | -0.029 |
| | (0.991) | (0.381) |
| | 9.628 | 10.047 |
| Treated students | 5,244 | 6,898 |
| All students | 140,037 | 138,148 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on college persistence, attainment, and earnings. Ferman and Pinto (2019) p-values are listed in parentheses. Control means are listed below p-values.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 6: Knox Achieves and postsecondary outcomes, by race, ethnicity, and gender

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Demographic subsample | Black | Hispanic | White | Women | Men |
| THEC college credits within two years | 0.706 | 3.007* | 1.095 | 1.215 | 1.532 |
| | (0.469) | (0.070) | (0.498) | (0.294) | (0.205) |
| | 10.977 | 9.062 | 17.797 | 18.265 | 13.705 |
| THEC college credits within four years | 1.322 | 4.336 | 2.154 | 1.966 | 2.648 |
| | (0.426) | (0.203) | (0.390) | (0.400) | (0.237) |
| | 20.298 | 16.911 | 32.566 | 33.687 | 25.003 |
| Certificate attainment | 0.001 | -0.005 | -0.004 | 0.002 | -0.005 |
| | (0.703) | (0.672) | (0.604) | (0.761) | (0.500) |
| | 0.030 | 0.027 | 0.055 | 0.039 | 0.055 |
| Associate's degree attainment | 0.006 | -0.014 | 0.009*** | 0.008 | 0.008** |
| | (0.170) | (0.210) | ( < 0.001) | (0.103) | (0.018) |
| | 0.013 | 0.019 | 0.041 | 0.041 | 0.025 |
| Bachelor's degree attainment | 0.012 | 0.019 | 0.012 | 0.012 | 0.012 |
| | (0.430) | (0.538) | (0.422) | (0.416) | (0.384) |
| | 0.123 | 0.107 | 0.206 | 0.217 | 0.152 |
| Log in-state earnings nine years after high school | -0.002 | 0.033 | -0.029 | -0.039 | -0.018 |
| | (0.974) | (0.849) | (0.542) | (0.174) | (0.727) |
| | 9.576 | 9.976 | 9.928 | 9.73 | 9.94 |
| Treated students | 2,219 | 402 | 10,361 | 6,240 | 6,962 |
| All students | 77,547 | 9,953 | 224,392 | 155,255 | 159,718 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on college credits, attainment, and earnings. Ferman and Pinto (2019) p-values are listed in parentheses. Control means are listed below p-values.

*** p < 0.01, ** p < 0.05, * p < 0.10

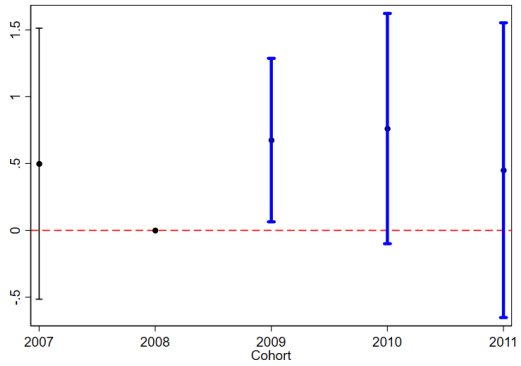
Table 7. Estimated Benefits and Costs of Knox Achieves

| Direct Earnings Benefits | | | |
|---|---|---|---|
| | Gains | Costs | |
| | -889 | 246 | |
| **Potential Earnings Gains via Increased Education** | | | |
| | Point Estimate | Lower Bound | Upper Bound |
| Gain in Certificate Receipt | -0.002 | -0.015 | 0.012 |
| Expected lifetime earnings gain | -400 | -3000 | 2400 |
| Based on lifetime earnings gain of Certificate = $200,000 | | | |
| Gain in AA Receipt | 0.008 | 0.002 | 0.014 |
| Expected lifetime earnings gain | 3200 | 800 | 5600 |
| Based on lifetime earnings gain of AA = $400,000 | | | |
| Gain in BA Receipt | 0.011 | -0.011 | 0.031 |
| Expected lifetime earnings gain | 17600 | -17600 | 49600 |
| Based on lifetime earnings gain of BA = $1,600,000 | | | |
| Total potential earnings gain | 20400 | -19800 | 57600 |

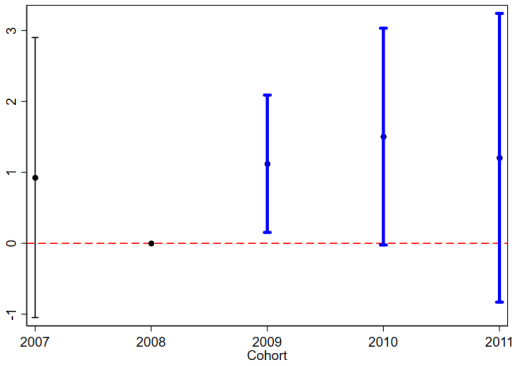
Notes: To compute direct earnings benefits, we convert Figure 2 coefficients for log wages (measured in 2018 dollars) to percentages and then multiply by mean earnings conditional on employment. We then apply a real discount rate of 3%. For potential gains, the point estimates are from Table 3, Column 1. Similarly, the lower and upper bound estimates are based on the confidence intervals from Table 3, Column 1. Lifetime earnings gains for certificates are one half the gains from associate's degrees. Gains for associate's degrees and bachelor's degrees are from Carnavale et al. (2021)

Figure A1. Event study estimates

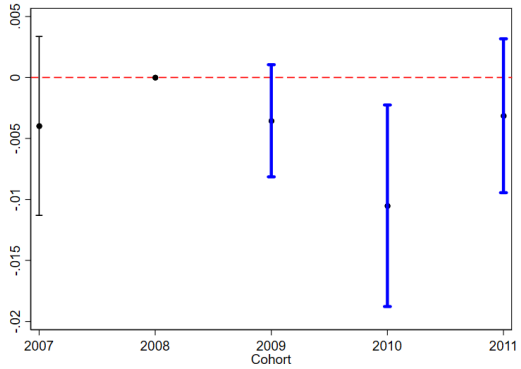
I. Credits within 2 years of high school



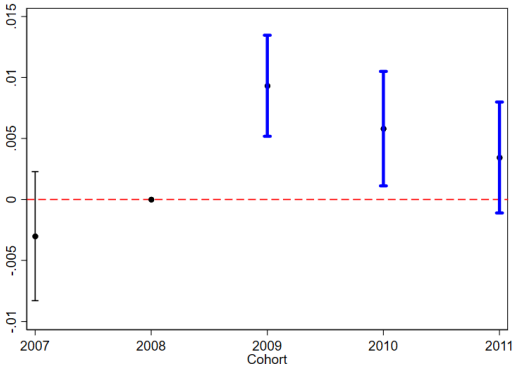

II. Credits within 4 years of high school



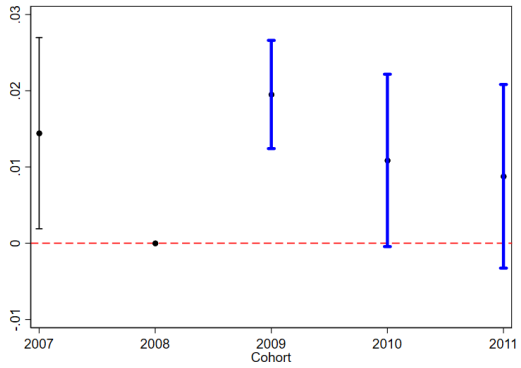

III. Certificate attainment



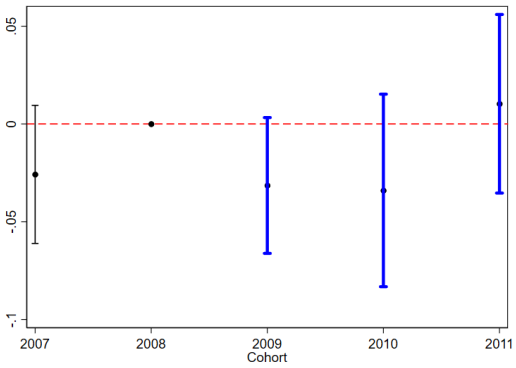

IV. Associate's degree attainment




V. Bachelor's degree attainment

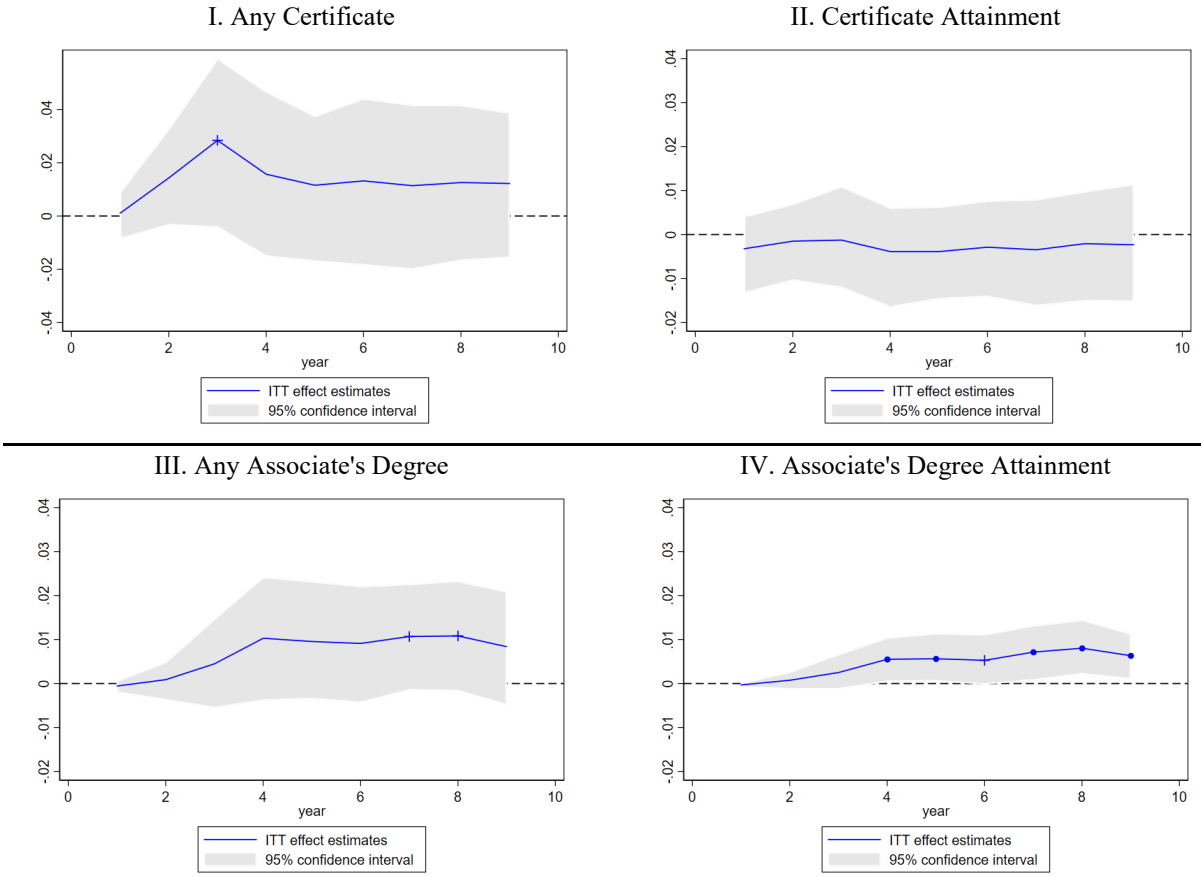



VI. Log in-state earnings nine years after high school




Notes: Each figure plots Equation (A2) event study estimates, omitting the Knox*2007 interaction, with 95% confidence intervals derived from robust standard errors that allow for clustering within counties.

Figure A2. Knox Achieves and certificate/degree completion and attainment, by years since high school




Notes: Each figure plots Equation (1) results for any college certificate or degree completion (left panels) versus highest attainment (right panels, also found in Figure 1 of the main paper), by years since high school, along with shaded 95% confidence intervals

+ $p < 0.10$, ● $p < 0.05$ (Ferman & Pinto, 2019)

Table A1: Knox Achieves and any certificate or associate's receipt, by subsidized lunch, achievement, race, ethnicity, and gender

| Subsample | (1) Not eligible for subsidized lunch | (2) Reduced-price lunch eligible | (3) Free-lunch eligible | (4) Below-median EOC achievement | (5) Above-median EOC achievement |
|---|---|---|---|---|---|
| Any certificate within 8 years of high school | 0.013 | 0.007 | 0.018 | -0.003 | 0.025 |
| | (0.445) | (0.893) | (0.498) | (0.734) | (0.255) |
| | 0.073 | 0.079 | 0.056 | 0.068 | 0.076 |
| Any associate's within 8 years of high school | 0.011 | 0.002 | 0.017 | -0.008 | 0.025 |
| | (0.398) | (0.952) | (0.287) | (0.289) | (0.122) |
| | 0.070 | 0.052 | 0.031 | 0.035 | 0.084 |
| Subsample | (6) Black | (7) Hispanic | (8) White | (9) Women | (10) Men |
| Any certificate within 8 years of high school | 0.004 | 0.018 | 0.012 | 0.013 | 0.013 |
| | (0.570) | (0.359) | (0.511) | (0.485) | (0.190) |
| | 0.037 | 0.039 | 0.081 | 0.065 | 0.071 |
| Any associate's within 8 years of high school | 0.014** | 0.001 | 0.01 | 0.013 | 0.009** |
| | (0.042) | (0.942) | (0.279) | (0.163) | (0.047) |
| | 0.021 | 0.037 | 0.071 | 0.072 | 0.042 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on any certificate or associate's attainment, across 10 student subgroups. See Table 4-6 for analogous treatment effect estimates for the likelihood that students attained a certificate or associate's and no higher credential within 8 years. Ferman and Pinto (2019) p-values are listed in parentheses. Control means are listed below p-values.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A2: Knox Achieves and selection into observed college and earnings outcomes

| Subsample | (1) All TN 12th graders | (2) Below-median EOC achievement | (3) Above-median EOC achievement |
|---|---|---|---|
| Enrolled in a private or out-of-state college | -0.023 | -0.006 | -0.026 |
| | (0.278) | (0.584) | (0.440) |
| | 0.092 | 0.060 | 0.144 |
| Non-missing earnings 1 year after high school | 0.003 | 0.003 | 0.023 |
| | (0.843) | (0.915) | (0.416) |
| | 0.629 | 0.650 | 0.664 |
| Non-missing earnings 3 years after high school | -0.019 | 0.001 | -0.013 |
| | (0.465) | (0.974) | (0.698) |
| | 0.654 | 0.695 | 0.685 |
| Non-missing earnings 5 years after high school | -0.008 | 0.010 | 0.006 |
| | (0.739) | (0.685) | (0.774) |
| | 0.683 | 0.722 | 0.712 |
| Non-missing earnings 7 years after high school | -0.008 | 0.009 | 0.011 |
| | (0.760) | (0.552) | (0.531) |
| | 0.664 | 0.709 | 0.684 |
| Non-missing earnings 9 years after high school | -0.003 | 0.006 | 0.025 |
| | (0.937) | (0.742) | (0.291) |
| | 0.639 | 0.684 | 0.655 |
| Treated students (1st year) | 14,698 | 5,789 | 7,835 |
| All students (1st year) | 347,049 | 154,883 | 154,883 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on the likelihood of enrolling in private or out-of-state colleges and universities (for which we do not observe completion outcomes), and on the likelihood of having any observed in-state earnings 1-9 years after high school. Ferman and Pinto (2019) p-values are listed in parentheses. Control means are below p-values. Columns (2) - (3) exclude students with missing end-of-course achievement.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A3: Knox Achieves and postsecondary outcomes, under different sample trimming criteria

| Sample | (1) Baseline 5% trim | (2) 10% trim | (3) No trim |
|---|---|---|---|
| THEC college credits within two years | 1.301 | 1.085 | 1.489 |
| | (0.263) | (0.319) | (0.170) |
| THEC college credits within four years | 2.197 | 1.728 | 2.578 |
| | (0.256) | (0.389) | (0.181) |
| Certificate attainment | -0.002 | -0.002 | -0.002 |
| | (0.672) | (0.691) | (0.648) |
| Associate's degree attainment | 0.008*** | 0.008*** | 0.008*** |
| | (0.003) | ( < 0.001) | (0.008) |
| Bachelor's degree attainment | 0.011 | 0.006 | 0.014 |
| | (0.355) | (0.585) | (0.210) |
| Log in-state earnings nine years after high school | -0.030 | -0.034 | -0.03 |
| | (0.491) | (0.429) | (0.497) |
| Treated students | 13,202 | 13,102 | 13,275 |
| All students | 314,973 | 314,872 | 315,047 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on college persistence, attainment, and earnings. Column (1) repeats baseline estimates from Table 3, where we omit the top 5% of Knox Achieves participants in terms of college credits within four years of high school. Column (2) reports results from a specification where the top 10% of participants are omitted, and the Column (3) specification retains all Knox Achieves participants in the sample. Ferman and Pinto (2019) p-values are listed in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table A4: Knox Achieves and earnings after high school, under different assumptions about sample selection

| Subsample | (1) Baseline | (2) Without attriters | (3) Without out-of-state enrollees | (4) Without bottom 5% of participant earners | (5) Without top 5% of participant earners |
|---|---|---|---|---|---|
| In-state log earnings 1 year after high school | -0.017 | -0.036 | -0.023 | 0.007 | -0.029 |
| | (0.716) | (0.508) | (0.574) | (0.892) | (0.544) |
| In-state log earnings 3 years after high school | -0.011 | -0.017 | -0.024 | 0.018 | -0.025 |
| | (0.781) | (0.712) | (0.539) | (0.686) | (0.582) |
| In-state log earnings 5 years after high school | -0.007 | -0.015 | -0.011 | 0.020 | -0.021 |
| | (0.872) | (0.744) | (0.763) | (0.638) | (0.612) |
| In-state log earnings 7 years after high school | 0.014 | 0.014 | 0.013 | 0.041 | 0.001 |
| | (0.740) | (0.744) | (0.762) | (0.308) | (0.970) |
| In-state log earnings 9 years after high school | -0.030 | -0.030 | -0.034 | -0.003 | -0.042 |
| | (0.449) | (0.473) | (0.406) | (0.929) | (0.344) |
| Treated students (1st year) | 9,364 | 8,090 | 9,038 | 9,279 | 9,264 |
| All students (1st year) | 218,443 | 192,872 | 210,575 | 218,358 | 218,342 |

Notes: The table lists γ estimates from Equation 1, ITT estimates of the effect of Knox Achieves availability on log earnings 1-9 years after high school. Ferman and Pinto (2019) p-values are listed in parentheses. Column (1) repeats baseline results from Table 3 and Figure 2, Panel I. Column (2) omits students who left the earnings sample, i.e., who had no observed in-state earnings between six and nine years after high school. Column (3) omits students who enrolled out of state. Column (4) omits the bottom 5% of Knox Achieves participants in terms of in-state earnings, and Column (5) omits the top 5% of Knox Achieves participants in terms of in-state earnings.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

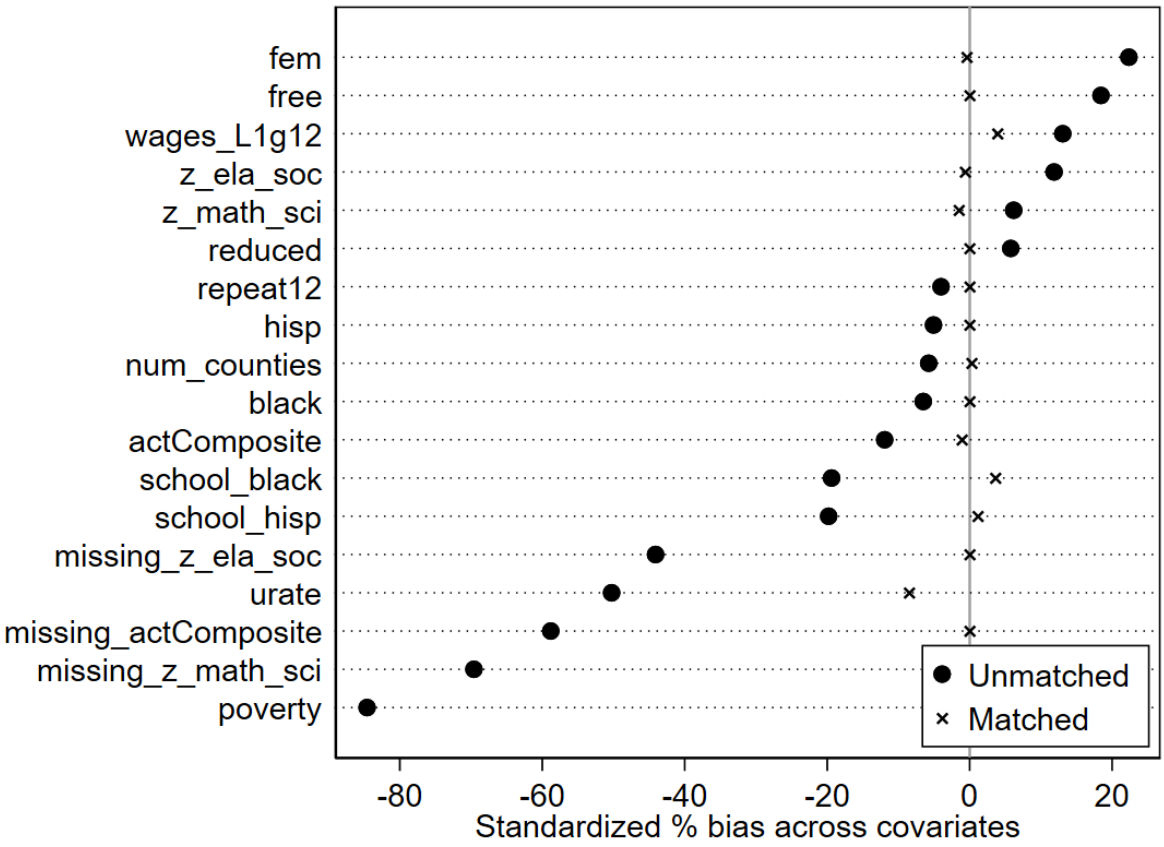
Table A5: Average treatment-on-the-treated effect estimates

| Controls | (1) Cohort fixed effects | (2) Basic | (3) Flexible | (4) Selected features among flexible set |
|---|---|---|---|---|
| THEC college credits within two years | 1.750*** | 1.297*** | 1.684*** | 1.734*** |
| | (0.276) | (0.140) | (0.180) | (0.166) |
| R-squared | 0.400 | 0.403 | 0.470 | 0.466 |
| Oster delta estimate | | 1.306 | 1.838 | 1.988 |
| THEC college credits within four years | -0.916 | -2.247*** | -1.287*** | -0.940*** |
| | (0.666) | (0.339) | (0.346) | (0.295) |
| R-squared | 0.404 | 0.407 | 0.475 | 0.471 |
| Oster delta estimate | | -1.158 | -0.761 | -0.602 |
| Certificate attainment | 0.030*** | 0.023*** | 0.022*** | 0.022*** |
| | (0.003) | (0.001) | (0.002) | (0.001) |
| R-squared | 0.021 | 0.029 | 0.037 | 0.034 |
| Oster delta estimate | | -16.172 | -20.467 | -16.796 |
| Associate's Degree Attainment | 0.071*** | 0.065*** | 0.062*** | 0.062*** |
| | (0.004) | (0.001) | (0.001) | (0.001) |
| R-squared | 0.029 | 0.034 | 0.046 | 0.043 |
| Oster delta estimate | | 7.146 | 5.614 | 6.047 |
| Bachelor's Degree Attainment | -0.057*** | -0.067*** | -0.053*** | -0.053*** |
| | (0.006) | (0.003) | (0.003) | (0.002) |
| R-squared | 0.269 | 0.271 | 0.325 | 0.321 |
| Oster delta estimate | | -6.494 | -9.151 | -8.902 |
| Log in-state earnings nine years after high school | 0.026 | 0.050*** | 0.061*** | 0.054*** |
| | (0.020) | (0.010) | (0.006) | (0.005) |
| R-squared | 0.099 | 0.103 | 0.122 | 0.117 |
| Oster delta estimate | | -14.312 | -9.448 | -11.165 |
| Treated students | 2,026 | 2,026 | 2,026 | 2,026 |
| All students | 314,973 | 314,973 | 314,973 | 314,973 |

Notes: The table lists γ estimates from variations of Equation (A3) for TOT estimates of the effect of Knox Achieves participation on college persistence, attainment, and earnings. In these specifications, $KA_i$ is a binary indicator equal to 1 for Knox Achieves participants. Robust standard errors, in parentheses below point estimates, allow for clustering by county. R-squared statistics are reported below standard errors, with Oster (2019) delta estimates below each R-squared. The Column (1) specification regresses each outcome against a KA participation indicator and cohort indicators. The Column (2) model include county and cohort fixed effects along with all $X_{isc}$ control variables used in the main ITT specification. Column (3) adds a complete set of interactions between all control variables in the Equation (1) $X_{isc}$ vector as well as squared values for continuous controls. Finally Column (4) regresses outcomes against a set of the Column (3) covariates that are selected by post-double-selection LASSO.

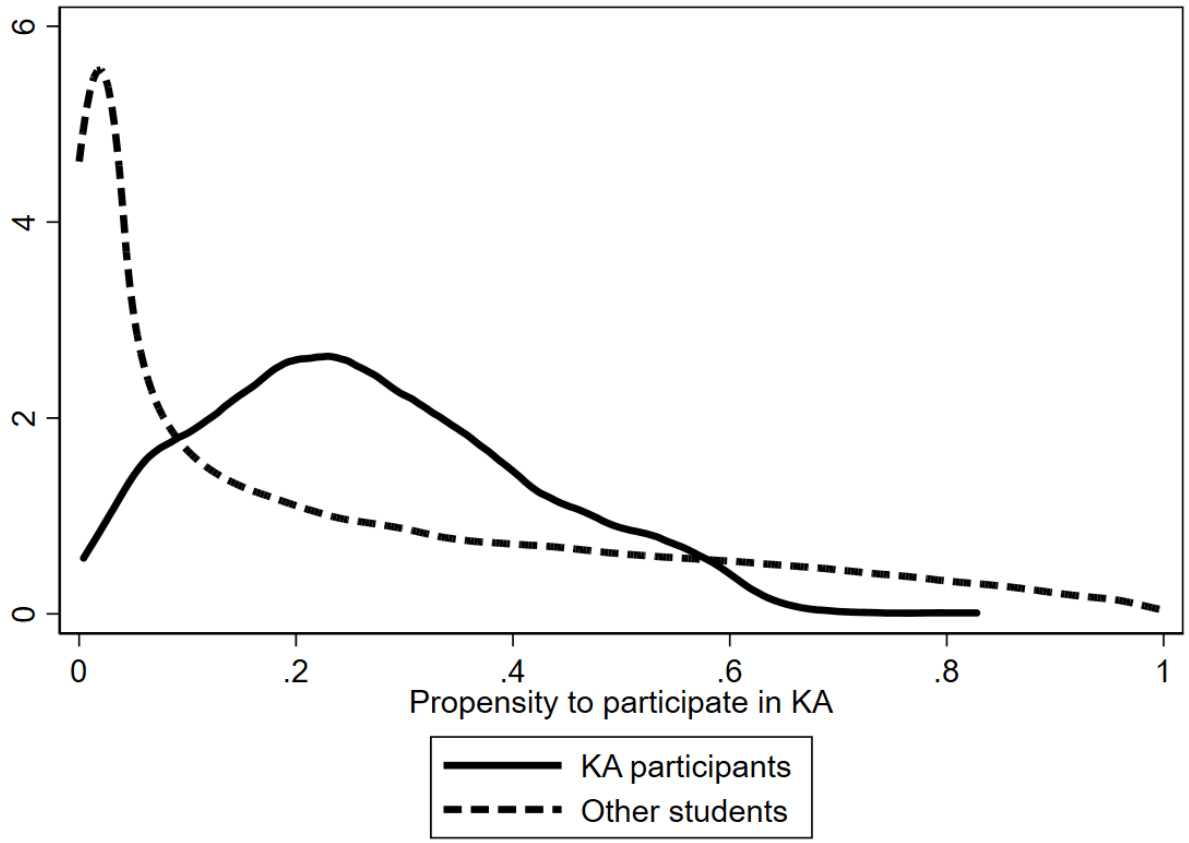
*** p < 0.01, ** p < 0.05, * p < 0.10

Figure A3. Unmatched and matched balance in student and school observable features




Notes: The figure depicts standardized differences in observed student, school, and county characteristics within unmatched (circles) and matched (x markers) samples. The donor pool includes all Tennessee 12th graders, 2007-2011. Treatment and control observations are matched by minimizing Mahalanobis distance metrics between vectors of these control variables.

Figure A4: Knox Achieves participation propensity




Notes: The figure depicts kernel densities of the estimated propensity to participate in Knox Achieves for actual participants (solid line) and ineligible non-participants (dashed line). Propensities are estimated by logit for Knox County 12th graders in the classes of 2009-2011. Factors in the logit model included $X_{isc}$ variables described under Equation (1).

Table A6. Matching results: Knox Achieves participation and postsecondary outcomes

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Control reservoir includes Knox County non-participants | | Yes | Yes | No | No |
| Method | OLS | Mahalanobis | Propensity score | Mahalanobis | Propensity score |
| THEC college credits within two years | 1.297*** | 2.613*** | 2.23*** | 2.477*** | 2.390*** |
| | (0.140) | (0.631) | (0.756) | (0.650) | (0.755) |
| THEC college credits within four years | -2.247*** | -0.453 | -0.622 | -0.948 | -0.478 |
| | (0.339) | (1.115) | (1.318) | (1.160) | (1.320) |
| Certificate Attainment | 0.023*** | 0.012 | 0.024*** | 0.014* | 0.025*** |
| | (0.001) | (0.008) | (0.007) | (0.008) | (0.007) |
| Associate's Degree Attainment | 0.065*** | 0.060*** | 0.077*** | 0.062*** | 0.079*** |
| | (0.001) | (0.009) | (0.008) | (0.009) | (0.008) |
| Bachelor's Degree Attainment | -0.067*** | -0.045*** | -0.049*** | -0.038*** | -0.052*** |
| | (0.003) | (0.011) | (0.012) | (0.012) | (0.012) |
| Log in-state earnings nine years after high school | 0.050*** | -0.037 | -0.011 | -0.126*** | -0.006 |
| | (0.010) | (0.038) | (0.039) | (0.038) | (0.039) |
| Treated students on support | 2,026 | 1,671 | 1,671 | 1,671 | 1,671 |
| All students on support | 314,973 | 221,504 | 195,144 | 213,887 | 187,533 |

Notes: The table lists Mahalanobis and propensity score matching results for postsecondary outcomes, with OLS Equation (A5, Column 2) results in Column (1) for comparison. For Column (2) – (5) models, we use a nearest-neighbor matching estimator, matching each Knox Achieves participant to one non-participant, with replacement, in terms of the Mahalanobis distance metric or the propensity score. Standard errors for Mahalanobis matching are computed according to Abadie and Imbens (2006). Propensity score estimates accommodate a 2 percentage-point caliper of participation propensity and trim the top one percent of Knox Achieves participants in terms of participation propensity.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$