Way Station or Launching Pad? Unpacking the Returns to Adult Technical Education*

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Abstract

We estimate returns to diplomas and certificates awarded to adult students by public technology centers, a niche sector of higher education that elevates occupational and competency-based education over transferable credits and traditional degrees. Technology centers cater to nontraditional students, particularly adults seeking part-time training in specific skills. Sub-associate credentials arising from Tennessee Colleges of Applied Technology increase access to new industries, particularly health, and industrial mobility explains half of the employment returns to postsecondary diplomas and at least three-quarters of the earnings returns to certificates. TCAT diploma completers earn $707 - 1,034 in additional quarterly earnings over non-completers, similar to the returns from community college diplomas. Benefits extend beyond the signal value of completion: students who leave without a credential fare significantly better than matched non-students with a similar history of earnings.

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1 Introduction

Earnings rise by 10 percent, on average, for each year of college (Oreopoulos & Petronijevic, 2013), and public subsidization indicates that governments worldwide believe higher education to be vital to economic health. More than a seamless continuation of secondary schooling, postsecondary education can also serve as an avenue for workers to gain new skills. Nontraditional adults enjoy average returns to education on par with young, traditional students (Leigh & Gill, 1997; Jacobson et al., 2005a,b). Even more than their younger counterparts, however, adults considering a four-year bachelor's degree may fear that "averages lie,"[1] i.e., that college is not a guaranteed path to secure employment. The risks of attempting college – stopping out, overestimating aptitude, or overestimating labor demand in one's chosen field – are high and costly for older students, even as the value of a terminal high school diploma falls and employers protest a lack of workers suited for middle-skilled jobs (Bessen, 2014). More practically, leaving the labor force for four or more years in pursuit a bachelor's degree education is untenable for many working-age adults.

Technical higher education focused on narrow, occupational fields is thought to be part of the solution to the so-called "skills gap" as well as a shorter education investment with more direct connections to jobs. The labor market values sub-baccalaureate higher education (Kane & Rouse, 1995; Gill & Leigh, 2003; Belfield & Bailey, 2011), including the certificates, diplomas, and associate's degrees that students can earn in two-year community colleges (Dadgar & Trimble, 2015; Jepsen et al., 2014; Stevens et al., forthcoming). But a community college education is not risk-free: only 26% of community college entrants complete a credential within five years, and

[1] Anthony Carnevale of the Georgetown University Center on Education and the Workforce, quoted in Arnold (2015).

completion rates are even lower for older, nontraditional students (U.S. Department of Education, 2011). In stark contrast, Tennessee Colleges of Applied Technology (TCATs, previously known as Tennessee Technology Centers), a 27-campus network of public postsecondary training centers, boasted 70-90% completion rates among full-time outgoing students in 2012-13 and 69-95% job placement rates among completers (Tennessee Higher Education Commission, 2013). TCATs offer certificates and diplomas in fields comparable to those offered by the state's community colleges or competing for-profit institutions,[2] but typically without transferrable college credits and in an environment that resembles a workplace more than a college campus. Most TCAT students enroll part-time; the ratio of full-time equivalent enrollment to total enrollment is just 39% in TCATs versus 64% in the state's community colleges and 85% in its public universities. The TCAT sector is fairly self-contained, and transfer between TCATs and community colleges or universities is very rare.[3] TCAT entrants from 2004-2008 tended to be older than new community college students (31 versus 27), about as likely to be eligible for need-based Pell grants (33-34%), but much less likely to have parents with a college education (24% versus 43%).[4]

Non-degree colleges like TCATs occupy a small, niche segment of public education in twenty-two states, enrolling less than one percent of all postsecondary students in 2006. The largest technology center systems – found in Alaska, Florida, Ohio, Oklahoma, and Tennessee – account for just 2-7% of public college students in their respective states and no more than 16% of students over 25. Nevertheless, public technology centers are under the spotlight in state plans

[2]The most popular TCAT programs, by tally of credentials awarded in 2011-2012, were Business Systems Technology, Industrial Maintenance, Industrial Technology, Nursing Assistant, Practical Nursing, and Welding (Tennessee Higher Education Commission, 2013).

[3]The demand for and rate of transfer between TCATs and other colleges is expected to grow as more traditional-aged students matriculate to TCATs with the Tennessee Promise free-tuition program.

[4]Authors' computations using administrative data described in Section 3.

to raise educational attainment and meet future workforce needs.[5] More generally, by operating at the intersection of states' postsecondary and workforce functions, technology centers can jointly serve employers' demand for skilled workers, policymakers' demand for quick and tangible employment outcomes, and nontraditional students' preference for career-oriented programs.

To date, however, little is known about the quality or persistence of the jobs that technology center alumnae find. We address this shortfall in an otherwise rich literature on returns to sub-baccalaureate education by assessing the role of Tennessee's state-run technology centers in providing marketable or course-correcting human capital to nontraditional adult students. Tennessee Colleges of Applied Technology are renowned for fast, holistic vocational training and impressive job placement records (Hoops, 2010; González, 2012), although the conditional returns to enrollment in institutions like TCATs have rarely been scrutinized closely. By focusing on specific job skills, narrow competencies, and "contact hours" rather than transferable credit hours, skills developed in TCATs may be rendered obsolete by shifting workforce needs and rapid technological development.

We examine the effect of sub-associate enrollment and credentials on near-term employment outcomes for five cohorts of adult Tennesseans who enrolled in one of the state's public technology centers between 2004 and 2008. Ours is a non-experimental setting, and the chief threat to linear regressions applied to this topic is the idea that the earnings and employment of program completers are unobservedly different, in levels and trajectories, than the outcomes of noncompleters. We address this concern with flexible specifications that condition labor outcomes on individual fixed effects and individual time trends. Our main conclusions are robust to several

[5]See, for instance, the "Oklahoma Works" strategic plan to raise educational attainment to 77% by 2025, Tennessee's "Drive to 55" initiative to raise attainment to 55% by 2025, and Ohio's "Attainment Goal 2025," which seeks to raise attainment to 65%. All three place a priority on postsecondary certificates from technology centers.

alternatives discussed in the appendix, including one specification with individual heterogeneity that is quadratic in time.

Findings indicate that technology center students who complete a diploma earn $707-1,034 more per quarter than noncompleters (13-19% of the pre-enrollment average), whereas the returns to terminal certificates are smaller and less robust. Diplomas – known as long-term certificates in states such as California, Michigan, and Washington – signify completion of a program of study (e.g., the "Diesel Technician" program), whereas shorter-term certificates are awarded for the completion of part of a program (for example, a "Diesel Engine Assembly" certificate) or for demonstration of more narrow competencies like "Manicuring." To the question of why the labor market values these credentials, we delve into two potential mechanisms. The metaphor for one mechanism is that of a launching pad, in that technology centers facilitate the transition to better jobs. Indeed, we find that TCAT credentials increase access to new industries, particularly health, and that industrial mobility explains at least half of short-term gains in employment following postsecondary diploma receipt and upwards of three-quarters of the earnings gains from technology center certificates. Industrial mobility is much smaller factor in explaining large returns to TCAT diplomas, however, suggesting that the most time-intensive form of TCAT training deepens rather than broadens industrial expertise.

Nevertheless, the fact that adults in our sample typically enter college after a marked decline in earnings and employment raises the question of whether college is little more than a way station for the temporarily unemployed. Completers may benefit more than non-completers from temporarily diverting to a technology center, but would students have been better off by not enrolling at all? Would their employment have rebounded to the same extent without college? Relative to a sample of non-student workers, both linear and matching-based empirical designs

suggest non-completers realize significantly higher earnings than non-students up to four years after starting college, suggesting that students attain something other than the signal value of completion. Candidate explanations for noncompleters' evident returns include the signal value of enrolling as well as new skills and human capital.

2 Related Research

Conceptually, we build on work by Leigh & Gill (1997), who extend related work by Kane & Rouse (1995) and show that adult community college students in the NLSY realize roughly the same returns to education as traditional students who make a seamless transition between high school and community college. Methodologically, our work builds directly from several recent studies using state administrative data to estimate longitudinal wage returns to two-year college credentials.[6] Belfield & Bailey (2017) summarize this literature as showing "positive but modest returns" to certificates of varying intensity, with nominal quarterly gains of null to $1,680.[7] Collectively, this research base suggests that associate's degrees increase earnings more than diplomas, which in turn increase earnings more than short-term certificates,[8] that returns to health credentials tend to dominate other fields, and that women benefit from these credentials more than men (conditional on individual heterogeneity in selection of program). These results echo related studies of nationally representative survey data, which also find small or inconsistent impacts of certificates on employment outcomes, but without the benefit of pre-college data on student

[6] Settings include Kentucky (Jepsen et al., 2014), Washington (Dadgar & Trimble, 2015), Michigan (Bahr et al., 2015), Ohio (Bettinger & Soliz, 2016), and California (Stevens et al., forthcoming), among others.

[7] A large and methodologically related literature uses administrative or register data to longitudinally examine returns to public job training programs. See, among others, Mueser et al. (2007); Andersson et al. (2013); Heinrich et al. (2013); Biewen et al. (2014). Also see Marcotte (2016) for recent evidence on the labor market returns to a community college education for traditional students making a quick transition between high school and college.

[8] In fact, estimated returns to certificates are mixed in this literature, with some specifications and subsamples returning small negative yields.

earnings to control for heterogeneous selection into diploma or certificate programs (Grubb, 1997, 2002a,b; Bailey et al., 2004; Marcotte et al., 2005).

Our study of nontraditional postsecondary technical education – which often follows job loss – is also informed by Jacobson et al. (2005a, 2005b), who study the effects of community college training on displaced workers in Washington state. They find significant labor market returns on the order of 7-13 percent per year of schooling. TCAT programs share some features with federal Workforce Investment Act (WIA) training, which have been linked to 15-30% returns in multiple states (Heinrich et al., 2013). These premia foreshadow some of the findings we report for TCAT students.

We add to existing research in three ways. First, we focus on students who move through sub-associate technology centers, a setting with a high degree of investment in students' workforce success but, to date, with few close examinations of returns to enrollment and completion.[9] Second, we partially deconstruct the returns to adults' technology center credentials to better understand industrial mobility as one potential causal pathways. And third, we evaluate the returns to adult higher education at two margins: one separating completers from noncompleters, and one separating enrollees from other workers. Much of the research on returns to two-year credentials has not examined of the counterfactual where individuals stay away from two-year institutions completely, an omission that is due largely to the absence of data on non-students. Cellini & Turner (forthcoming) provide an important exception: they examine the returns to for-profit certificate programs relative to students and matched non-students, finding

[9]Bettinger & Soliz (2016) study the earnings premium from completing a certificate or associate's degree in one of Ohio's community colleges or technical colleges, finding significant returns to completing a credential in either sector ($1,040 - $1,250 quarterly), with some heterogeneity by gender and field. But without records of students' pre-enrollment earnings, they rely heavily on contemporaneous observable characteristics and students' self-reported intentions to characterize counterfactual outcomes. Nevertheless, their findings are generally consistent with those in the related literature reviewed by Belfield & Bailey (2017), as well as with some of our results to follow.

that the return to public college attendance dominates the return to for-profit attendance by 11%, and that for-profit student earnings are statistically indistinguishable from the earnings of matched non-students.[10] These inferences are particularly relevant for our study, since for-profit certificate programs share many of the same occupational foci as public technology centers, but at much higher cost to students and with less oversight from state governments.

To review the most pertinent evidence from other settings and help to shape priors, we note that completing a certificate or diploma program from a community colleges raises earnings by up to 30% over non-completers (Belfield & Bailey, 2017), the return on Workforce Investment Act training is 15-30% across several states (Heinrich et al., 2013), while certificate programs from for-profit colleges yield no distinguishable difference in earnings relative to the counterfactual of not attending college (Cellini & Turner, forthcoming). If non-degree institutions like TCATs perform on par with degree-granting community colleges and non-degree WIA programs, we would expect returns to completion – relative to participation without completion – of up to 30%. But *ex ante* returns to attendance are uncertain and may rival weaker results from the for-profit sector.

3 Background, Data, and Descriptive Statistics

The Tennessee Board of Regents operates 27 Tennessee Colleges of Applied Technology throughout the state. TCATs enrolled 31,366 students in 2011-2012 (Tennessee Higher Education Commission, 2013). The collective mission of the TCAT system is to offer easy access to technical training and vocational certificates and diplomas. Any state resident is within about 50 miles of a TCAT campus. In contrast to the state's system of community colleges, TCATs do not

[10] Also see Turner (2016) for a study of Colorado welfare recipients, some of whom enrolled in community colleges. Findings there indicate that returns are driven by completion alone.

have general academic programs and do not typically prepare students for transfer to degree-granting colleges. TCATs are singularly focused on training students to acquire work-ready occupational skills. The Tennessee Board of Regents also oversees 13 two-year community colleges, which enrolled about 97,000 students in the 2011-2012 academic year. Tennessee community colleges offer many of the same vocational pathways as Tennessee Colleges of Applied Technology, as well as terminal associate's programs in academic and technical disciplines and programs to facilitate transfer to four-year colleges and universities.

Although TCATs and Tennessee community colleges both offer sub-associate credentials, there are several important differences between these two sectors.[11] Foremost, technology center enrollment and credentials are measured by clock or contact hours rather than credit hours. Most TCAT hours are not transferable to community college or university systems,[12] and student transfer from a TCAT is very rare in practice.[13] Unlike most degree programs in community colleges and universities, TCAT programs of study are competency-based and are not accumulations or sequences of self-contained courses. A TCAT student chooses her program and intensity (full-time or part-time), but does not need to select courses or manage graduation requirements across multiple disciplines. A full-time program fills about 430 hours over a four-month period, or roughly six hours per day four days a week. Diploma-granting programs tend to require many more hours than certificate-granting programs or sub-programs. A small

[11] See Hoops (2010) for a longer discussion of the TCAT model. Like community colleges, TCATs require a high school diploma or equivalent secondary credential prior to admission. Some TCAT programs require background checks, physicals, and/or occupational permits prior to enrolling.

[12] TCAT diplomas can count toward 30 credits of an associate of applied science degree, a work-ready credential that cannot be converted into four-year college credits.

[13] TCAT transfer students accounted for just 2.3% of all transfers between public institutions in the state (Tennessee Higher Education Commission, 2015), versus 15% of overall enrollment. About two-thirds of TCAT students who later enroll in a community college or university are returning or readmitted students, and a small number of others are high school students taking advantage of dual enrollment programs.

core of program faculty work with students for almost all of these contact hours, typically in a lab or workfloor environment. TCAT programs of study are open to student entry and exit, with multiple cohorts working simultaneously on competencies that are assessed in terms of "theory" (technical knowledge), skills, and professionalism. TCATs and community colleges also treat remedial education differently: community college students test into and out of remedial education, whereas all but nursing TCAT students take "Technology Foundations," a self-paced, computer-aided course in basic skills whose duration varies by program but averages 30 clock hours.[14] Tennessee community colleges are accredited by the Southern Association of Colleges and Schools, along with the state's major research universities. TCATs join a mix of public and private occupational schools under the accrediting arm of the Council on Occupational Education.

Two-year technology center credentials are offered at multiple levels of attainment within fields of study. Post-secondary diplomas are awarded at the culmination of a program lasting one to two years, and short-term certificates are awarded for the successful completion of portions of those programs, sometimes within one or two trimesters. These vocational credentials signal a narrower but potentially deeper scope of human capital development.[15] Associate's degrees, by contrast, are accredited two-year degrees whose requirements include general education and major-specific coursework (which may be vocational in nature), both of which can feasibly be applied toward a four-year bachelor's degree.

We rely on student data from administrative files maintained by the Tennessee Higher

[14]Nursing programs meet accreditation requirements by having prospective students pass the HESI exam (or COMPASS, until recently) prior to admission.

[15]New vocational graduates, rich with occupation-specific human capital, may find work more rapidly than their academic counterparts, but long-term employment prospects for vocational skills are at greater risk of obsolescence from technical change. Results are mixed as to the lifetime impact of vocational versus general education (Malamud & Pop-Eleches, 2010; Hanushek et al., 2017). Many of the skilled trades that vocational students are trained for are especially sensitive to economic fluctuations.

Education Commission. We identify students who entered a TCAT between 2004 and 2008, and in addition to the timing of their enrollment we observe a small set of demographic and financial aid fields as well as the timing of their highest TCAT credential within a program of study.[16] We link post-secondary data to histories of in-state earnings and industries from 2001 through the second quarter of 2012. Earnings data are drawn from files maintained by the Tennessee Department of Labor and Workforce Development and include all in-state earnings covered by Unemployment Insurance. Earnings that are not covered by Tennessee's Unemployment Insurance system, and are therefore censored from the data on hand, include earnings from self-employment, some federal and agricultural occupations (e.g., military, seasonal), and earnings from employment in other states. Workers who leave the state or migrate across state boundaries to work are necessarily censored from the earnings data.[17]

Each record of quarterly earnings is associated with one or more industries, codified by the North American Industry Classification System (NAICS). We group two-digit NAICS codes into thirteen broad categories. The most common among individuals who at some point enroll in a TCAT or community college are utilities (including power, water, and waste management), manufacturing, retail, business services (including staffing contractors), education, health, and

[16]Unfortunately, we do not observe which program of study a student in these cohorts completed. Alignment between particular programs and industrial placements is a topic for future research.

[17]The limitations of administrative earnings data are not unique to this study. The internal validity of results would be threatened if, for instance, diploma and certificate recipients are differentially more or less apt to leave the state or work in occupations that are not covered by unemployment insurance, relative to TCAT students who do not complete programs of study, and moreover, if the earnings of individuals who are censored from the wage data are selectively higher or lower. A plausible selection story is one where positive returns to diplomas and certificates are biased toward zero because credentials from TCATs lead individuals to broader employment opportunities in other states. In support of this story, mobility estimates from the U.S. Census Bureau (2006) indicate that adults in the Southern region aged 25-65 with some college or an associate's-level education were more apt to move between states than adults with no more than a high school education. Findings reviewed below, however, suggest that TCAT attendance and credentials raise the likelihood of having non-missing, in-state earnings. At the same time, we do not observe the extent to which TCATs connect students to less lucrative self-employment (e.g., cosmetology or part-time contracting). Just two percent of the TCAT students we observe major in cosmetology, so that particular path of negative selection is likely to be small.

food/accommodation services.[18] We allow for participation in more than one industry at a time.

From the universe of 2004-2008 TCAT entrants, we focus on students of working age (20-60) at the time of enrollment, with non-zero earnings prior to enrollment, at least four quarters of non-zero earnings prior to TCAT entry, and no known record of attendance at a four-year college or university in the state. This allows us to eliminate young, traditional postsecondary students (who were rare among TCAT enrollees in these cohorts), focus on nontraditional adult students with prior work experience and without degree aspirations beyond a TCAT credential, and examine student earnings before, during, and after entry in the TCAT system.[19] The 20-60 age band is of particular interest in Tennessee, where legislative and programmatic efforts are underway to raise postsecondary attainment among the working-age population.[20] We extrapolate student age to terms prior to and after enrollment, omitting quarters where a student would have been under age 18 or over 64. We omit students whose college start date was left-censored, i.e., who were enrolled in the first term of the panel.[21] Within these parameters, we collect earnings and employment outcomes up to four years prior TCAT enrollment and up to four years after TCAT enrollment.

Students work and attend college year-round, but data for work and college outcomes are reported with different frequencies. Since students spend a small share of the panel enrolled, we

[18]Others include public services, construction, wholesale trade, transportation, professional services, and services not categorized elsewhere (arts, mining, forestry, and agriculture).

[19]Consistent with the Tennessee Higher Education Commission (2015) transfer report, just 5% of all 2004-2008 TCAT entrants had any record of four-year university attendance during the 2004-2012 window of higher education records that we observe, and another 2% attended a community college at some time during that window. We exclude the former group of students but not the latter.

[20]As we show in the appendix, employment gains differ somewhat by student age groups, with younger students realizing much higher earnings gains conditional on employment. For older students, a TCAT credential was more important in raising the likelihood of having any earnings.

[21]Since we do not observe college entry dates, we are not able to completely identify and omit returning students. Some earn diplomas almost immediately, suggesting that they enter with existing credits. As we show in the appendix, results are robust to the exclusion of subjectively early completers.

transform trimesterly enrollment into quarterly enrollment, assigning spring/winter enrollment to the first and second quarters of the year, summer enrollment to the second and third quarters, and fall enrollment to the third and fourth quarters.

Table 1 provides descriptive statistics for the student panel prior to each individual's initial enrolled quarter. The first three variables – any earnings, quarterly earnings, and log quarterly earnings – are our primary outcomes of interest. We define "any earnings" as having non-zero, non-missing earnings in a given quarter, which describes 82 percent of the panel prior to enrollment. We define quarterly earnings to be equal to zero for quarters with missing earnings, combining the extensive and intensive margins of work for one outcome. Earnings are inflation-adjusted and expressed in 2009 dollars. Students in the panel typically earned $5,577 per quarter prior to entering a TCAT, including zero-wage quarters. This level of income corresponds with 153% of the 2009 federal poverty threshold for a two-person household ($3,643), and five out of ten students had at least one year with individual earnings below the two-person poverty line prior to enrolling.[22] Our third outcome of interest is log-transformed earnings, which is limited to non-missing, non-zero earnings. For convenience, we refer to individuals as "students" throughout the study, even though they were enrolled during just 12 percent of the 2001-2012 quarters we observe in the workforce data. Individuals were 32 years of age, on average, and enrolled in counties with 5.8 percent unemployment. The lower panel of Table 1 summarizes TCAT attainment and student demographics. The data archive each student's highest terminal TCAT attainment (i.e., we do not observe sequenced or stacked certificates), and we interpret results to follow accordingly. We find that 10.6 percent of students who entered a TCAT between

[22] We do not observe family structure or the earnings of other household members. The median Tennessee household has 2.5 members according to Census estimates, with 61% of adults in the labor force.

2004 and 2008 at either part-time or full-time intensity earned a TCAT certificate by 2011, with less than 1% earning two or more certificates from distinct programs,[23] and 26.4 percent earning a diploma. Just one percent of students attained both a TCAT certificate and diploma, likely from different programs of study. These levels of attainment are considerably lower than the system's celebrated graduation rates of 62 - 94 percent (Hoops, 2010), a consequence of the fact that we do not limit the sample to first-time, full-time students, who are a minority of the TCAT student body. Nevertheless, these broad TCAT completion rates easily exceed 26 percent attainment among first-time full-time students in the state's community colleges (Tennessee Higher Education Commission, 2013). The gender distribution among TCAT students is roughly even, and 81 percent identify as white, somewhat higher than the statewide share of 78 percent.

Sample means do not lend insight to the dynamics of student earnings prior to and following technology center attendance, nor do they allow for comparisons of TCAT students at different points of the age-earnings profile. With this in mind, we first visualize the typical path of earnings before, during, and after TCAT enrollment, conditional on time fixed effects and a limited set of observable features. Specifically, we estimate the following:

$$Y_{it} = \tau_0 + Z_{it}\theta + \tau_t + \nu_{it}, \tag{1}$$

where Y_{it} represents employment or wages, Z_{it} controls for observable student features (gender, race, and a third-degree polynomial function of age), and τ_t controls for quarter t fixed effects.

Figure 1 plots mean-smoothing polynomial residuals, ν_{it}, along with quarterly average residuals, for binary employment (panels I-II) and earnings (III-IV). There, we see clearly that TCAT students exhibit the Ashenfelter's (1978) dip common to studies of training programs, in

[23] See the appendix for estimates of returns to a rare second certificate.

that earnings decline noticeably prior to enrollment. This is suggestive of the notion that many of these nontraditional TCAT students were separated from the workforce prior to enrolling. Employment and earnings regain ground shortly after enrolling but then taper and even decline toward the end of the panel. The dip in employment and earnings is much more pronounced and more prolonged for certificate and diploma completers than it is for non-completers, whereas the post-enrollment taper is more pronounced for non-completers. Completers spend just 1-2 more quarters enrolled than non-completers,[24] indicating that non-completers are much more apt to work and attend TCATs at the same time.

On their own, these descriptive figures are consistent with meaningful short-term returns to TCAT enrollment, albeit questionable medium-term returns. But it is not clear what might be driving the post-TCAT pattern of earnings, or if students would have recovered and fared just as well (or better) without enrolling in a TCAT program. The empirical strategies described in the following section are designed to test for a causal impact of TCAT awards and enrollment, controlling for student heterogeneity and parsing the industrial mechanisms connecting adult higher education to higher earnings.

4 Empirical Strategy

4.1 Linear specification

Consider a simple model of the returns to education that allows for contemporaneous as well as dynamic impacts of human capital and other inputs.

$$Y_{it} = \alpha_0 + E_{it}\beta + Z_{it}\theta + \tau_t + \gamma_i + \delta_i f(t) + \varepsilon_{it}, \tag{2}$$

[24]Non-completers enroll for 3.8 quarters, on average, versus 4.6 for certificate completers and 5.8 for diploma completers.

where Y_{it} is quarter t employment or earnings for individual i, and E_{it} describes educational attainment. In most of the analyses to follow, E_{it} contains binary indicators for attaining a TCAT certificate or diploma at or before quarter t, and these need not be mutually exclusive. The coefficients of interest are in the vector β, interpreted as the average returns to each credential, relative to students who enroll but do not complete a certificate or diploma. This specification, motivated by Jacobson et al. (2005a), is designed to control for individual heterogeneity in earnings as well as the tendency for earnings to be depressed during the search phase immediately after college.

The vector Z_{it} encompasses time-varying student, family, and labor market inputs, including indicators for current enrollment, local unemployment rates,[25] and a third-degree polynomial function of age. Interactions between the age-earnings polynomial and time-invariant student characteristics allow the former to vary by gender, Caucasian race designation, and indicators for missing data.

Z_{it} also includes a set of thirteen indicators denoting i's proximity to enrollment. This vector controls for non-monotonic patterns of earnings (i.e., the Ashenfelter (1978) dip illustrated in Figure 1) that are commonly observed among nontraditional students. Failing to account for the pre-program earnings dip can overstate the effectiveness of college programs in raising earnings (Heckman & Smith, 1999). Six variables in Z_{it} denote working terms where enrollment is one to six quarters in the future. We also control for a binary indicator of active enrollment to account for the expected drop in earnings that represents the opportunity cost of enrollment. Another six variables denote working terms one to six periods after a student leaves college.[26] Quarter fixed

[25]County-level monthly unemployment rates are averaged over the relevant quarter. We do not observe student addresses, but we do observe the institution they ultimately attended and the county where this institution resides. Z_{it} controls for term t average unemployment rates in the county where i attends, will attend, or has attended a TCAT.

[26]Results are not sensitive to controls for the window of time around enrollment. An alternative way to control for

effects (τ_t) control for time-specific shocks to employment outcomes.

Lastly, the function $\gamma_i + \delta_i f(t)$ represents an individual's inherent productivity level and trajectory. Equation 2 is a generalization of two-way fixed effects models used in much of the literature on community college credentials, which implicitly assumes that $f(t) = 1$, i.e., that heterogeneous earnings potential given by $\delta_i f(t)$ has the same impact each quarter and is absorbed into the individual fixed effect, γ_i. Though student fixed effects control for time-invariant dimensions of heterogeneity, the internal validity of a levels specification with $f(t) = 1$ rests on the assumption that underlying, heterogeneous trends in productivity are uncorrelated with the propensity to complete a certificate or diploma. For instance, if future TCAT diploma holders would have had steeper earnings growth with or without a degree, relative to noncompleters, Equation 2 will overstate the returns to diploma attainment. Alternatively, differentially shallower earning paths prior to enrolling could ambiguously bias returns to TCAT credentials depending on the degree of reversion to the mean that completers later experience.[27] With this in mind, we join Dynarski et al. (2017) and Stevens et al. (forthcoming) in specifying Equation 2 to control for linear individual-specific time trends in addition to individual fixed effects, i.e., $\gamma_i + \delta_i t$, where t is zero in the first quarter of the panel and rises by one unit each quarter thereafter.[28] In order to identify β as a causal effect of TCAT completion, we need to

these short-term labor deviations is to replace lagged and leading indicators with $1/k_{it}$, where k_{it} is the number of quarters until ($k_{it} < 0$) or since ($k_{it} > 0$) TCAT entry. We find that doing so yields very similar results. Likewise, inferences are unchanged when we exclude controls for proximity to enrollment. See appendix Tables A5-A7 and related discussion. Also in the appendix, we briefly review Equation 2 results for several subgroups defined by gender, race, or age. Leading conclusions from that analysis are that women, white students, and students who are under age 36 at TCAT entry tend to accrue greater returns to TCAT credentials.

[27] See Dynarski et al. (2017) for a richer discussion of the importance of allowing for student-specific slopes when estimating labor market returns to college credentials. Jepsen et al. (2014) and Bettinger & Soliz (2016) address time-varying individual heterogeneity in part with controls for self-reported student aspirations, which we do not observe for Tennessee students. Bahr et al. (2015) allow secular time trends to vary by fixed student characteristics. Alternatively, Jaggars & Xu (2016) first fit flexible growth curves to individual earnings and then assess how community college education shapes those growth curves.

[28] See Correia (2015) for computational details. As we show in the appendix, preferred results from specifications

assume that completion was orthogonal to unobserved, non-linear trends in human capital or earnings.[29] That is, if an unobserved intervention affecting the trajectory of one's earnings (major life changes such as marriage or the birth of a child, for example) and coincided with TCAT completion, we would incorrectly attribute any change in that trajectory to the TCAT credential.

Our preferred characterization of individual heterogeneity is supported by a pre-enrollment balancing test. Figure 2 depicts four kernel densities that summarize a series of falsifications tests for estimated earnings premia after receipt of a placebo TCAT certificate (Panel I) or diploma (Panel II). Each density is comprised of 1,000 estimated returns from Equation 2, limited to quarters prior to TCAT entry, where we change the analytical sample in two ways for each iteration. First, we draw a one percent random sample of students, and then we reassign dates of student i's certificate or diploma receipt to randomly selected pre-enrollment quarters. We repeat this procedure for specifications of Equation 2 with and without student-specific linear time trends. The figures illustrate distributions of β estimates for the false effect of reassigned certificates and diplomas on earnings (the appendix includes analogous figures for log earnings and employment). The distribution of placebo estimates for the fixed effects specification (with solid density outlines) is centered at a negative value for both certificate and diploma returns, suggesting that future TCAT credential holders were on a conditionally weaker earnings trajectory relative to non-completers. If that pre-existing trend continued after TCAT entry, fixed effects models would understate the effect of certificates and diplomas on subsequent earnings. Or, completers may revert to the mean in such a way that Equation 2 overstates the returns to

with $\delta_i t$ suggest larger premia than specifications with student fixed effects alone, but are conservative with respect to an even more flexible specification with $\gamma_i + \delta_{1i}t + \delta_{2i}t^2$. See appendix Tables A5-A7 and related discussion.

[29] In the appendix we formally estimate the direction and magnitude of completers' differential quadratic trends in labor outcome prior to enrollment. We find small but significantly negative second-order trends among future completers.

TCAT credentials. Distributions of placebo estimates controlling for student fixed effects and time trends (dashed density outlines) are centered above but close to zero.[30] As we show in Section 5, linear returns to TCAT certificates fall within a standard deviation of the placebo mean, but estimated returns to diplomas are more exceptional.

In some specifications, we append the student panel to a panel of non-students from across the state. Specifically, we select a random sample of 250,000 unique Tennessee workers with non-missing earnings recorded in the unemployment insurance system between 2004 and 2008. We track their earnings histories back to 2001 and forward through 2012. Very little is known about the random non-student sample. We observe longitudinal earnings and industry by quarter, but no data describing demographics, socioeconomic status, or location. We omit any who enroll in a Tennessee TCAT, community college, or public four-year institution between 2004 and 2008 (14.6%), leaving 214,138 individuals who represent the counterfactual to not enrolling in public higher education. As in the student panel, we assume that earnings are zero where they are missing and ignore terms prior to each individuals' first observed record of non-zero earnings. When we apply Equation 2 to the combined panel of students and non-students, we expand the E_{it} attainment vector to include a binary indicator for having left a TCAT without a credential. This allows us to estimate the return to enrolling without completing a program of study. By necessity, specifications with non-students exclude local unemployment rates and interactions between age and demographics. As we show in the appendix, however, these fields have much less bearing on results than controls for time-varying individual heterogeneity, which we include for both the student and combined samples.

[30]Placebo returns to certificates, controlling for student fixed effects and time trends, are \$42 on average with a standard deviation of \$511. Placebo returns to diplomas under the same specification are \$64 on average with a standard deviation of \$320.

In order to test whether industrial mobility is a mechanism explaining higher earnings, we adapt Equation 2 to see if the returns to TCAT credentials are higher for students who migrate to new industries after college. Specifically, we estimate the following:

$$Y_{it} = \alpha_0 + E_{it}\beta_0 + NewInd_i * E_{it}\beta_1 + Z_{it}\theta + \gamma_i + \delta_i f(t) + \tau_t + \varepsilon_{it}, \tag{3}$$

where $NewInd_i$ is an indicator for students whose modal pre-college industry is different from their modal post-college industry. The β_1 coefficients on the $NewInd_i * E_{it}$ interaction are interpreted as the additional returns to particular credentials that accrue to students who migrate to new industries, and β_0 represents the baseline return to E_{it} components for students who complete college but do not change industries.

4.2 Matching extensions

Figure 1 suggests that many TCAT students enroll after a protracted period of reduced employment and earnings, that is, that involuntary separation from the labor force oftentimes precedes their enrollment. It could be the case, then, that TCATs serve as way stations for unemployed workers and that employment outcomes would have rebounded with or without new postsecondary credentials. This regression to the mean would overstate Equation 2 returns to technology center credentials if completers were inherently more apt to bounce back from unemployment. Even with very flexible controls for unobserved heterogeneity, non-experimental linear estimates are vulnerable if students turn to TCATs around the time they would have reached their employment trough regardless of college opportunities, and if thereafter, unobserved productivity drives both credential and workforce outcomes. In order to investigate this possibility, as well as returns to enrollment *per se*, we estimate counterfactual earnings patterns for each TCAT student using workforce outcomes from students or non-students who followed a

similar earnings trajectory prior to his enrollment.

We pre-process the student and non-student pools by limiting the analytical sample to the common support of propensity to enter a TCAT in a given quarter. The enrollment propensity is estimated by logit:

$$Enroll_{it} = \Lambda(W_{it}\zeta), \tag{4}$$

where Λ is the logistic distribution, and $Enroll_{it}$ is the likelihood of student i entering college in quarter t. The vector W_{it} controls for eighteen components that describe the intersection of what we know about both students and non-students: earnings lagged by six quarters, seven quarter-to-quarter lagged changes in earnings, full-time employment and six lagged full-time employment indicators, tenure in the earnings data (a rough proxy for age and experience, equal to the total number of working quarters observed), an industrial score, and a six-quarter-lagged industrial score. The industrial score is equal to predicted earnings from a regression of quarterly earnings on a full-time indicator and indicators for each of thirteen broad NAICS categories. This is intended to characterize i's potential earnings in a given industry. The regression is limited to the year 2001, and parameter estimates are mapped to later years to avoid contaminating the score with industrial changes just before, during, and after TCAT enrollment.

Parameter estimates are used to predict $\hat{E}nroll_{it}$, the likelihood of enrolling in a TCAT, for each individual in the combined panel of students and non-students. We omit individuals (both students and non-students) whose propensity estimate is in the top or bottom one percent of students' $\hat{E}nroll_{it}$ distribution. Limiting the sample to individuals with non-missing and un-trimmed propensity brings the analytical sample of students to 33,758 and the reservoir of non-student controls to 121,610 workers. Propensity estimates are subjectively low, averaging 21

percentage points just before an individual actually enrolls in a TCAT and 18 percentage points overall. This means that earnings, industry, and employment fluctuations are limited signals of individual demand for a TCAT program, and that unobserved factors largely dictate why some in our sample enroll in a TCAT while others do not. The direction in which these unobservables could bias matching-based returns is unclear, although as we show in the next section, the estimated effect of TCAT credentials on earnings (interpreted as across individuals with and without credentials) is considerably smaller than within-student inferences discussed in Section 4.1.

For the benefit of comparing matching results with the fullest version of Equation 2, we begin by estimating the returns to TCAT credentials as the post-enrollment earnings gap between non-completing students and matched certificate or diploma completers. We then turn our attention to TCAT enrollment *per se*, taking the post-enrollment earnings gap between students and matched non-students as our estimated treatment effect of attending a TCAT. Rather than pair each student with a donor who has a similar (but small) propensity to enter a TCAT, our goal is to match each TCAT student to a donor who experienced a very similar pattern of employment and earnings up to the point that she enrolled in a TCAT. We do so by grouping individuals with quantitatively similar W_{it} vectors.

Specifically, enrollees are matched to donors according to Mahalanobis distance metrics, which measure the standardized distance between a vector of controls, W_j and W_k, for each $j-k$ pair of treated and control individuals. W_{it} contains some of the same set of elements that we use to compute the propensity score. To best mimic Equation 2 in estimates of the returns to completion over non-completion, W_{it} also includes local unemployment and a third-degree polynomial function of age intersected with time-invariant demographics (race, gender, and

indicators for missing data). The distance metric M_{jk} is given by

$M_{jk} = (W_j - W_k)'V^{-1}(W_j - W_k)$, where V is the covariance matrix for W. Matched counterfactual outcomes for treated students are identified by finding the nearest neighbor in terms of M_{jk}.[31]

Mahalanobis matching requires tremendous computing power in this application, with over 155,000 individuals in the analytical sample and earnings outcomes spanning several quarters. We reduce the magnitude of the task by selecting one matching quarter for each non-student. By nature, each student typically has one focal quarter coinciding with his entry into college.[32] We match students to non-students based on M_{jk} distance metrics associated with *that* quarter. But non-students lack such a focal term. Rather than allow a non-student to serve as a match at any point (or multiple points) in his time series, we randomly select one quarter in the 2004-2008 window to serve as his focal point. This adequately reduces the dimensionality of the problem.

Matching results are the average treatment-control difference in inflation-adjusted earnings for each term $t \in [\bar{t} - 6, S_T]$, where $\bar{t}$ is the term a student enters college and S_T is the latest term (up to 16 quarters after enrollment) that student i outcomes are matched to donor outcomes. Pre-enrollment trends are less of a concern in this exercise than they are in the fixed effects strategy, because we are explicitly matching treated students to non-students based on pre-enrollment earnings and employment. Indeed, we find that the matching procedure yields pretreatment differences that hew very close to zero for earnings outcomes in the six quarters prior to enrollment, $t \in [\bar{t} - 6, \bar{t} - 1]$. We take the gap between student and non-student outcomes in the window $t \in [\bar{t}, S_T]$ to be an estimate of the treatment effect from enrolling in a TCAT or

[31] We execute the procedure in Stata, version 14.1, using the user-written command "psmatch2" (Leuven & Sianesi, 2010). Standard errors are derived following Abadie & Imbens (2006).

[32] There are rare exceptions where students left and re-entered the TCAT system.

community college. Results complement those from Section 4.1 linear models, although we emphasize that inferences here reflect gaps across matched individuals rather than within-student deviations from underlying trends.

5 Results

5.1 Returns to technology center attendance and credentials: Linear estimates

Table 2 lists β parameter estimates from Equation 2 for earnings (Column 1), log earnings for those with non-missing, non-zero earnings (Column 2), and the likelihood of having any earnings (Column 3). The top panel of Table 2 reports results when we limit the analytical sample to TCAT students, identifying the returns to completion relative to the counterfactual of enrolling without earning a certificate or diploma. Recall that Equation 2 controls for a series of indicators denoting time until or since TCAT enrollment; as such, β is best thought of as a steady state return net of short-term deviations from long-term trends. TCAT certificates precede a significant conditional rise in earnings, by $292 per quarter, which is largely driven by gains in employment *per se*. The likelihood of recording any earnings rises 5.5 percentage points in the wake of TCAT certificate attainment, but among workers, log earnings rise by a statistically insignificant one percent.

TCAT diplomas appear to raise both employment and earnings relative to noncompleters, and by a substantial degree. We estimate that real earnings rise by $1,034 each quarter after attaining a TCAT diploma, or 18.5% relative to the pre-enrollment mean from Table 1, and employment rises 11.3 percentage points. These premia are at the lower end of comparable estimates from WIA training (Heinrich et al., 2013) and well within the range of estimated returns from comparable community college credentials (Belfield & Bailey, 2017). If noncompleters represent

the best counterfactual, earnings gains such as these would have moved a median earner to the 59^{th} percentile of the earnings distribution.[33] At an annualized rate, estimated returns to TCAT diplomas could have lifted a single-earner family of four from the poverty line to 119% of the poverty line.

Looking back to Figure 1, it may be the case that returns to completion manifest as a more prolonged rise in post-enrollment earnings and a later taper. It is also helpful to refer back to Figure 2 when interpreting the magnitude of returns to TCAT diplomas and certificates. Quarterly premia of $292 following a TCAT certificate are well within the $511 standard deviation of false certificate returns with respect to pre-enrollment earnings. TCAT diplomas, however, yield $1,034 in quarterly gains, more than three standard deviations above the pre-enrollment placebo mean. This foreshadows results to come, which generally show diploma returns to be more robust than certificate returns.

The bottom panel of Table 2 reports results from a more restricted version of Equation 2, where the analytical sample is expanded to include non-students. This exercise is unique in that we abstract away from our previous focus (and much of the related literature) on returns to technical credentials to examine the broader impact of technical enrollment *per se*. It may well be the case that the labor market values participation in formal adult education as well as program completion. And given that a minority of sub-baccalaureate enrollees complete a program of study (true among TCAT students as well as two-year communality college students nationwide), the merits of enrolling without finishing deserve further examination. With the addition of non-student labor outcomes, we can look to enrollment itself as the treatment of interest.

[33]The median TCAT noncompleter earned $5,951 at least two years after leaving. This figure plus $1,034 is at the 59^{th} percentile.

In the Equation 2 specification, non-students help to identify quarterly shocks τ_t, which spanned the nationwide economic expansion of 2001-2007 as well as the trough of the Great Recession. Estimated returns to TCAT attendance are represented in the "Post-TCAT" row, and can be interpreted as within-student gains from attendance, net of student fixed effects, student time trends, short-term deviations in earnings around the time of enrollment, and τ_t shocks experienced by students and non-students alike. We estimate these gains to be $242 per quarter after one leaves a TCAT, or about 10.8 log points conditional on having any earnings. The likelihood of having any earnings falls, however, by a small but precisely estimated 0.7 percentage points. Looking to the last two rows of Table 2, we estimate that attaining a TCAT certificate precedes $166 in quarterly earnings premia *in addition* to gains from attendance, whereas a diploma yields $707 in additional earnings.

5.2 Returns to technology center attendance and credentials: Further evidence from matching

The linear specification of Equation 2 affords us great flexibility in controlling for unobserved heterogeneity in individual productivity – both fixed and time-varying – but relies on extrapolation between counterfactual outcomes, drawn from either non-completers or non-students, and completers who typically followed a deeper dip in earnings and employment prior to enrollment. Next, we use matching-based identification to explore the question of whether students – and completers, in particular – follow the same upward earnings path as others who have reached a similar nadir. If so, this would be more consistent with regression to the mean than with gains from new human capital.

As described in Section 4.2, we first use Mahalanobis matching to identify for each TCAT

completer, at the point of entry into college, the best available counterfactual wage outcomes observed among non-completers. We then extend the donor pool to include non-students and estimate the returns to attendance, with or without a credential. There, the matching vector excludes variables that are not common to students and non-students: specifically, local unemployment and age-by-demographic functions.

In parallel to Section 5.1, we first examine wage gaps between TCAT certificate or diploma completers and their counterparts who enrolled and left without a credential. Figure 3 depicts matching estimates for returns to certificates (Panel I) and diplomas (Panel II). By design, matched treatment effects hew close to zero for quarters prior to enrollment, although we are not able to completely eliminate statistical differences in the pre-TCAT earnings gap between completers and non-completers. Given the deep Ashenfelter's (1978) dip depicted in Figure 1 for earnings, a minimal albeit statistically significant gap in pre-enrollment earnings means that certificate and diploma completers are typically matched to non-completers who have also experienced a deep decline in earnings. Each panel traces two sets of estimated treatment effects. Echoing Equation 2, one controls for all available information about students, including local unemployment and age-by-demographic profiles ("matched on past earnings and other observables"). In order to assess the importance of controls not uniformly available across student and non-student samples, the other series of matching treatment effects relies on prior earnings levels, earnings differences, and industries of occupation ("matched on past earnings"), as articulated in Section 4.2. With respect to certificate and diploma premia, Figure 3 shows that non-wage student observables have very little bearing on treatment effect estimates. Now considering the pattern of matched earnings gaps between completers and non-completers, we detect no significant difference in post-enrollment earnings for certificate completers. Diploma

recipients, however, typically out-earn matched non-completers by $653 per quarter after initial enrollment, and up to $1,372 after two years.

Perhaps more policy relevant is the return to enrolling in a TCAT at all, given low completion rates and the opportunity cost that nontraditional students face. Figure 4 depicts matching results for TCAT enrollment, overall (Panel I) and by attainment (Panel II[34]). For TCAT entrants, estimated wage gaps remain close to zero for three quarters after enrolling and climb for about two years, averaging $428 across all post-enrollment quarters, and levelling at $800 - 1,000 per quarter 2-4 years after enrollment.

Though estimated with a fundamentally different donor pool, key insights from Figure 3 are repeated in Panel II of Figure 4: matched wage gaps for TCAT diploma completers quickly dominate those of certificate completers and noncompleters, and certificate completers fare about as well as non-completers in the years following TCAT entry. Would individuals who left the system without a certificate or diploma have been better off by staying away from this form of postsecondary education? Contrary to that notion, matching results imply that TCAT noncompleters consistently out-earned their non-student counterparts as early as five quarters after initial enrollment, with post-enrollment earnings gaps ranging from an insignificant $80 one quarter after enrollment to a significant $555 four years later.

5.3 Launching pad? The role of industrial mobility

Do postsecondary technical credentials increase access to different industries? To assess this question descriptively, we first identify each student's modal industry prior to and following

[34]Confidence intervals are omitted from Panel II of Figure 4 for clarity. Markers indicate statistical significance at 95% confidence or greater.

enrollment.[35] Two stylized facts stand out: TCAT students flow disproportionately into the health industry after college and flow disproportionately out of manufacturing into a variety of industries, including a large share who flow from manufacturing to health. The volume of individuals working in health occupations rises by 69% after TCAT enrollment, whereas manufacturing falls by 32%. Other net sending industries include retail and food/accommodation services. After health, the largest net receiving industries include education, transportation, and public services.

To better quantify the impact of technical education on choice of industry, we apply our preferred, fully specified version of Equation 2 to the student panel and the linear probability of working in one of the thirteen broad industry groups, conditioning on student fixed effects, student time trends, and other variables described in Section 4.1. Results are found in Table 3. We show that TCAT credentials meaningfully increase the likelihood of employment in the health industry (Column 9), by 4 percentage points following certificate attainment and nearly 11 percentage points following diploma attainment (28 and 74%, respectively, of pre-TCAT participation in health). Construction employment rise by 1-2 percentage points (18-38%), and employment in the transportation industry rises by up to 71% of its 2-percentage-point pre-TCAT mean. Manufacturing employment (Column 3) falls by on net by 6% after earning a diploma, and employment also falls in food/accommodation service (Column 11) and retail (Column 5). The popularity of manufacturing programs such as Industrial Maintenance and Industrial Technology, combined with a small rate of conditional outmigration from the manufacturing sector, underscores the roles that technical colleges can play in advancing workers within aging sectors (by offering middle-skilled manufacturing programs), or instead, redirecting workers toward

[35] Industrial mobility is comprehensively depicted in appendix Figure A1, a Sankey diagram of students' pre-TCAT and post-TCAT industries.

growing hubs for vocational skills (e.g., from manufacturing to health). In terms of the earnings potential of students' new industries, we find that the industrial score rises by $238 after certificate receipt and $373 after diploma receipt. Subjectively small movements in the industrial score (4-7% of the pre-TCAT mean), pitted against comparatively larger gains in earnings overall (18.5% for diploma completers) emphasize that industrial mobility is likely not the entire reason that TCAT completers outperform their peers.

We turn to Equation 3 to test whether higher earnings and new industries are connected, i.e., whether returns accrue more strongly to completers who migrate to new fields. Table 4 lists coefficients for credentials and their interaction with industrial mobility indicators. Column 1 of Table 4 reports that students who parlay a TCAT certificate into a new industry attain higher earnings on the order of $459 per quarter, on top of an imprecisely estimated $136 premium awarded to certificate holders whose primary industry does not change. Depending on how we view the insignificant baseline effect of a TCAT certificate, this means that 77 - 100 percent of returns to TCAT certificates accrue to students who change industries. Table 4 Column 2 results similarly suggest that any positive gains from certificates go to students who changed industries (recall from Table 2 that overall log-earnings returns to certificates are null). Employment gains favored industrial mobility among certificate holders as well; movers realized a 7.2 percentage point increase in employment relative to non-movers, who themselves gained 3.2 percentage points over noncompleters.

Industrial mobility explains less of the evident returns to TCAT diplomas. There are $1,041 quarterly returns to diplomas in terms of earnings, but the additional premia for changing industries after enrolling and completing a diploma program is just $193. There were, however, substantial changes in employment for industrially mobile TCAT diploma holders. Diploma

recipients who returned to (or never left) their pre-TCAT modal industry were 6.4 percentage points more likely to have earnings in any given quarter than non-students, while those who moved to a new industry were an additional 9.2 percentage points more likely to be working. Together, these insights suggest that diploma programs deepen students' expertise in their field while providing entrée to – but not necessarily higher earnings in – new fields.

6 Conclusions

The emerging importance of sub-baccalaureate institutions in facilitating course corrections for nontraditional adult students comes at a time when the returns to two-year credentials, and in particular, to those earned outside of traditional community colleges, are little understood. A rapidly growing volume of work in this area shows that there are meaningful returns to sub-baccalaureate credentials like diplomas (also known as long-term certificates) or associate's degrees, although results for short-term certificates are mixed. Our analysis extends this literature to consider nondegree granting public institutions typically known as technology centers, or in Tennessee, as Tennessee Colleges of Applied Technology. These settings offer intensive and competency-based technical education, integrated and universal remedial education, a high volume of student-faculty contact hours, part-time accessibility, and reputations for outstanding completion and job placement rates. Yet, to date, the research base on technology centers is largely qualitative or descriptive and does not speak to student selection into technology center enrollment or completion.

We take a three-part approach to evaluating the labor market returns to TCAT enrollment in Tennessee. First, we build on recent work that quantifies the returns to community college awards relative to enrolling without completing by estimating the linear return to TCAT diplomas and

certificates for five cohorts of TCAT students. With regards to earnings and employment, we find substantial returns to Tennessee's technology center diplomas, measuring $707-1,034 in additional quarterly earnings (13-19% of the pre-TCAT average), and accompanied by 11 percentage point gains in employment. This is on par with returns to similar community college credentials in other states (Belfield & Bailey, 2017).

Second, we expand the scope of our analysis to consider the TCAT student investment against the alternative of not enrolling at all. This is particularly relevant for the majority of TCAT students who eventually leave without a certificate or diploma. Both linear and matching-based empirical designs detect significant effects of enrolling without completing a technology center credential, measuring $242 in additional quarterly earnings within a student's individual career trajectory, or $555 across students and matched non-students four years after TCAT entry.

Synthesizing the findings discussed Sections 5.1 and 5.2, we reiterate that Equation 2 and matching results are not directly comparable, since linear estimates are identified primarily from within-student changes in earnings trajectories after enrollment, whereas matching estimates are identified across student pairs who experienced a similar earnings trajectory prior to enrollment. Nevertheless, both methodologies attribute large and significant premia to completing a diploma-granting TCAT program of study. Estimated returns to TCAT certificates are smaller and less consistent across identification strategies, and perhaps no better than the counterfactual of leaving college without a credential. That counterfactual, however, compares favorably to the alternative of not enrolling in a TCAT. Both linear and matching models detect small but significant earnings premia to TCAT attendance without completing a certificate or diploma. In this respect, TCAT certificate programs compare favorably to for-profit certificate programs, whose students see no discernible gain over matched non-students (Cellini & Turner,

forthcoming).

The third prong of our study takes on the question of why these credentials evidently have (at least short-term) impacts on labor outcomes. We highlight and find support for industrial mobility as one mediating factor. Importantly, TCAT credentials increase students' access to the health industry and decrease participation in fields like manufacturing, retail, and accommodation. For earnings, the short-term returns to certificates are stronger for students who move into new industries, and the relative likelihood of employment *per se* is up to twice as large as it is for students who do not parlay a TCAT diploma or certificate into a new industry.

One policy inference we might draw from these results as well as those from the related literature on returns to community college credentials is that sub-baccalaureate college sectors should emphasize the completion of longer programs of study and discount the value of certificates and enrolling without earning a credential. While our results consistently find support for the added value of diploma completion, we cannot rule out the idea that even noncompleters realize returns to postsecondary education relative to the counterfactual of *not* enrolling at all. Like much of the related literature, our richest parametric results identify the effect of adult education under the notion that completers have more education than noncompleters. But when we shift the identification margin from attainment to enrollment, we find that certificate holders and noncompleters realize wage gains over matched non-students whose earnings and industrial histories are similar. This indicates that adult education serves as more than a way station, and when considered alongside our findings for industrial mobility, implies that technical education can facilitate course corrections in the form of new industries of employment, higher rates of employment, and higher earnings overall.

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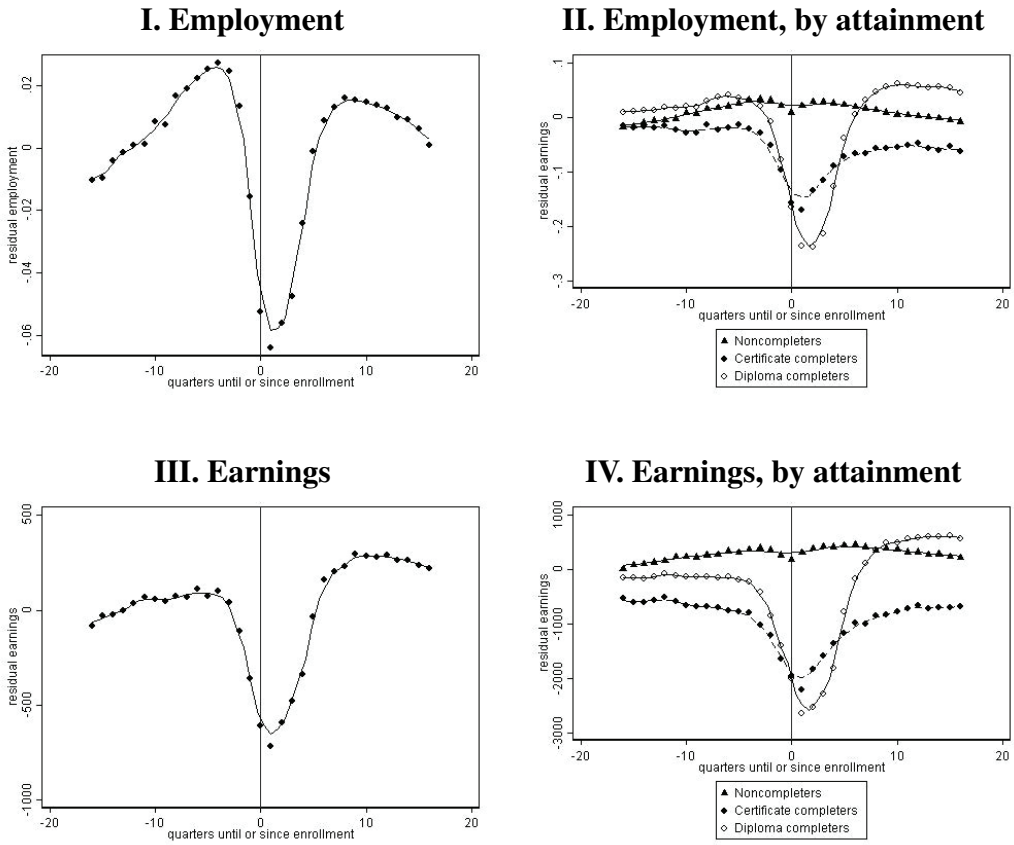
Table 1: Descriptive statistics

Panel summary statistics	(1) Mean
Any earnings (0,1)	0.823
Quarterly earnings	5,577
	(5,513
ln(quarterly earnings)†	8.443
	(1.074)
Age	31.726
	(10.574)
County unemployment rate (0,100)	5.801
	(1.556)
Missing age (0,1)	0.062
N_{it} (pre-enrollment student-quarters)	773,105

Student summary statistics	(1) Mean
Ever attain a TCAT certificate (0,1)	0.106
Ever attain 2+ distinct TCAT certificates (0,1)‡	0.006
Ever attain a TCAT diploma (0,1)	0.264
Ever attain a TCAT diploma and certificate (0,1)‡	0.010
Female (0,1)	0.511
White (0,1)	0.813
Missing gender and race (0,1)	0.003
N_i (students)	39,877

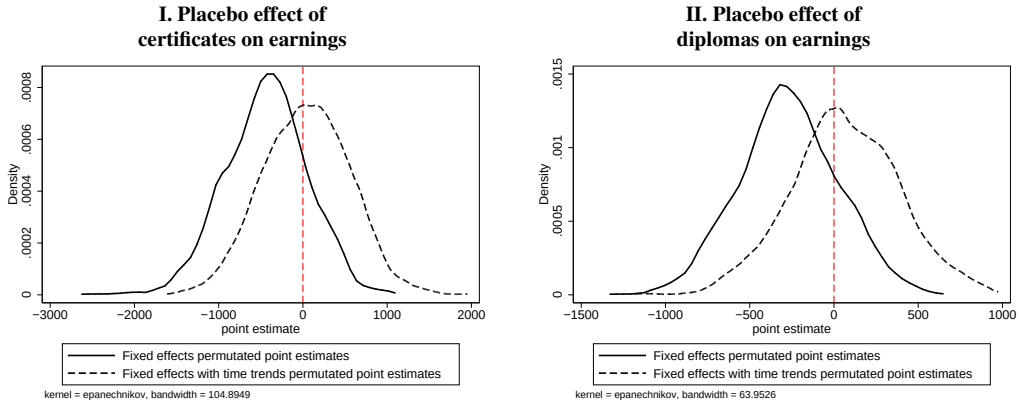
NOTES: †Log-transformed earnings exclude quarters with missing earnings. ‡We observe the last and highest credential attained in each student's program of study. Multiple certificates or diplomas are from enrolling and completing multiple programs. Variable means are in Column 1, and standard deviations for continuous variables are in parentheses below their respective means. All summary statistics are computed from quarters prior to enrollment. Inflation-adjusted quarterly earnings are in 2009 dollars and are assumed to be zero if missing.

Figure 1: Regression-adjusted employment and earnings relative to TCAT entry



NOTES: $N_i = 39{,}877$ students up to four years before or after enrollment. The figure plots mean-smoothing polynomials (lines) and quarterly averages (markers) for residuals from Equation 1 regressions for the binary likelihood of employment (panels I-II) and inflation-adjusted earnings (panels III-IV), controlling for quarter fixed effects, county unemployment, and cubic functions of age, gender, and race.

Figure 2: Permutated point estimates of false returns to pre-enrollment TCAT certificates and diplomas



NOTES: Figures plot the distribution of point estimates from 1,000 iterations of Equation 2 for random one percent samples of students, limited to pre-enrollment quarters, with placebo attainment assigned to random quarters for those who later attained TCAT diplomas or certificates. Solid-line densities represent permutation results for specifications of Equation 2 without individual time trends, and dashed-line densities represent permutation results for specifications of Equation 2 with individual time trends. See the appendix for pre-enrollment tests of employment and log earnings.

Table 2: Linear estimates of returns to TCAT enrollment and awards

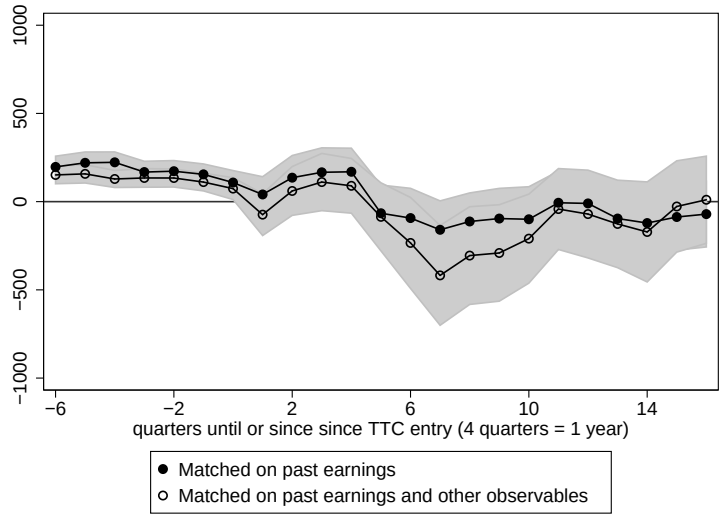
Returns to completion (student sample)	(1) Earnings	(2) ln(Earnings)	(3) Any earnings (0,1)
TCAT certificate	291.5***	0.0117	0.0547***
	(59.23)	(0.0165)	(0.00680)
TCAT diploma	1034.3***	0.173***	0.113***
	(36.88)	(0.0105)	(0.00434)
N_{it} (student-quarters)	1,447,619	1,110,763	1,447,619
N_i (students)	39,877	39,877	39,877
Adjusted R^2	0.720	0.594	0.430
Returns to enrollment and completion (combined sample)	**(4) Earnings**	**(5) ln(Earnings)**	**(6) Any earnings (0,1)**
Post-TCAT	241.6***	0.108***	-0.00693**
	(27.06)	(0.00690)	(0.00282)
Post-TCAT, with certificate	165.6***	0.0335*	0.0383***
	(49.80)	(0.0546)	(0.0173)
Post-TCAT, with diploma	707.4***	0.138***	0.0899***
	(31.89)	(0.0112)	(0.00414)
N_{it} (person-quarters)	10,714,383	7,826,889	10,714,383
N_i (persons)	258,258	251,106	258,258
Adjusted R^2	0.501	0.708	0.579

NOTES: The table lists results of Equation 2. For Columns 1-3, the sample is limited to individuals who enrolled in a TCAT between 2004 and 2008, and Equation 2 controls include time-varying local unemployment, student fixed effects and time trends, enrollment proximity indicators, and a third-degree polynomial function of age interacted with gender and race. Specifications reported in Columns 4-6 include students and non-students, but without time-varying unemployment and demographic controls. Robust standard errors clustered at the student level are in parentheses below each coefficient.

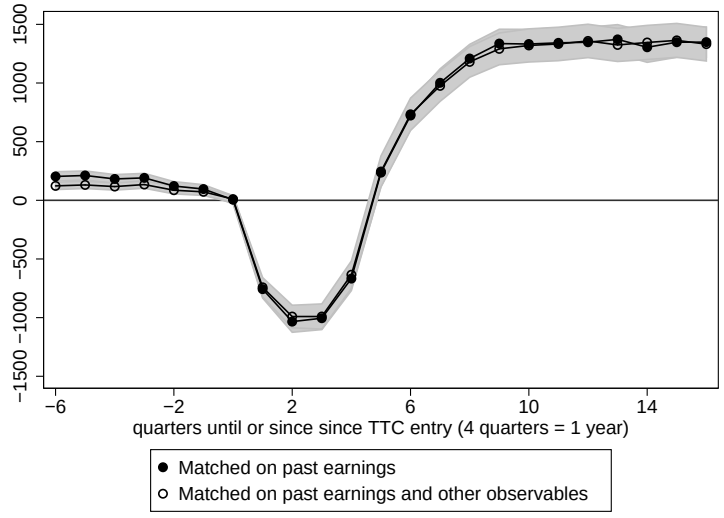
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 3: Matching estimates of returns to TCAT awards among students

I. TCAT certificate returns relative to matched non-completing students



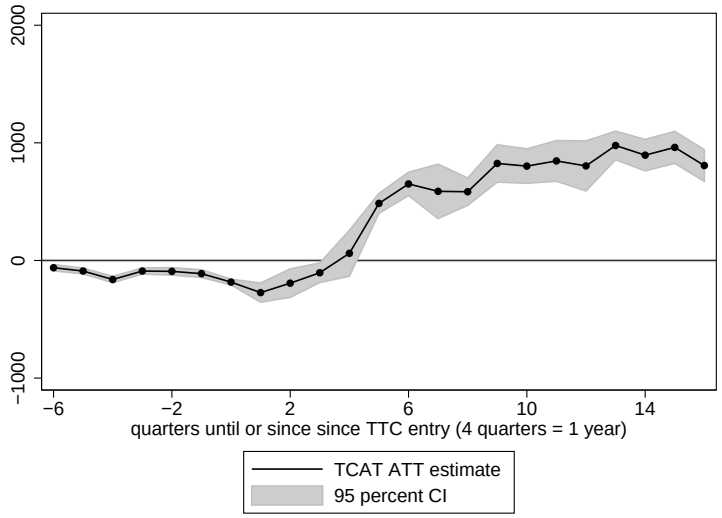
II. TCAT diploma returns relative to matched non-completing students



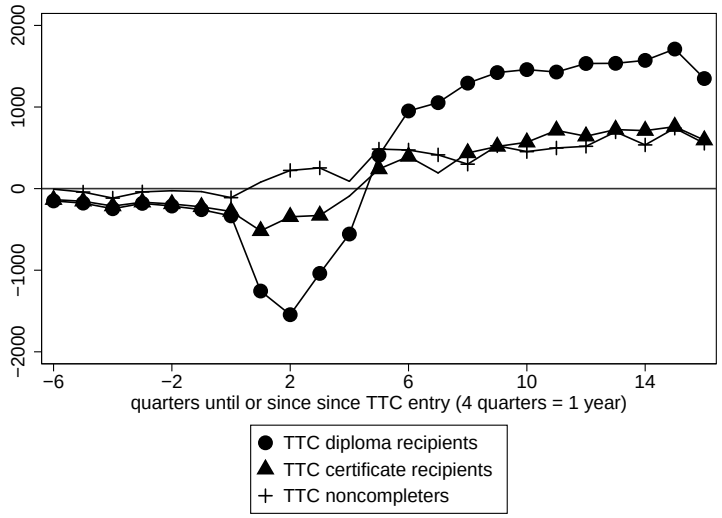
NOTES: $N_i = 33{,}758$ individuals with TCAT entry propensity estimates. Quarterly earnings differences between completers and non-completers (ATT) are estimated by Mahalanobis matching. "Other observables" include third-degree polynomial functions of age interacted with gender, race, and indicators for missing demographic data.

Figure 4: Matching estimates of returns to TCAT enrollment and awards

I. TCAT earnings gains over matched non-students



II. TCAT student earnings gains over matched non-students, by attainment



NOTES: $N_i = 155{,}368$ individuals with TCAT entry propensity estimates. Quarterly earnings differences between students and non-students (ATT) are estimated by Mahalanobis matching.

Table 3: TCAT awards and industrial choice

	(1) Utilities	(2) Construction	(3) Manuf.	(4) Wholesale	(5) Retail	(6) Transport	(7) Bus. Services
pre-TCAT mean	[0.042]	[0.0458]	[0.2678]	[0.0260]	[0.0953]	[0.0217]	[0.1091]
TCAT certificate	-0.0000416	0.00847***	0.00394	-0.00191	-0.00284	0.0153***	0.00495
	(0.000977)	(0.00248)	(0.00520)	(0.00264)	(0.00461)	(0.00268)	(0.00460)
TCAT diploma	0.00311***	0.0176***	-0.0160***	0.000106	-0.00521*	0.00960***	0.0248***
	(0.000552)	(0.00155)	(0.00330)	(0.00162)	(0.00277)	(0.00156)	(0.00279)
	(8) Education	(9) Health	(10) Proff. Services	(11) Food + Accom.	(12) Publ. Services	(13) Other	(14) Ind. Score
pre-TCAT mean	[0.0260]	[0.1444]	[0.0114]	[0.1156]	[0.0478]	[0.0447]	[5,705]
TCAT certificate	0.00250	0.0411***	0.00686***	-0.00635*	0.00539	-0.000831	237.8***
	(0.00194)	(0.00461)	(0.00161)	(0.00372)	(0.00329)	(0.00207)	(30.74)
TCAT diploma	0.00321**	0.107***	0.00299**	-0.0123***	-0.000646	0.00226*	373.1***
	(0.00144)	(0.00363)	(0.00118)	(0.00226)	(0.00193)	(0.00137)	(19.47)

NOTES: N_{it} = 1,447,619 student-quarters. N_i = 39,877 students. The dependent variable for each column is an indicator for employment in a particular industry, estimated by Equation 2. Controls include time-varying local unemployment, student fixed effects and time trends, enrollment proximity indicators, and a third-degree polynomial function of age interacted with gender, race, and indicators for missing demographic data. Pre-TCAT industrial shares are in brackets below industry names. Robust standard errors clustered at the student level are in parentheses below each coefficient.

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Equation 3 results - interactive earnings returns to technology center credentials

	(1)	(2)	(3)
Outcome (quarterly)	Earnings	ln(Earnings)	Any earnings (0,1)
TCAT certificate	135.9	-0.0379	0.0319***
	(103.8)	(0.0240)	(0.0107)
TCAT diploma	1041.2***	0.142***	0.0644***
	(62.77)	(0.0155)	(0.00731)
Industrial mobility × TCAT certificate	459.2***	0.105***	0.0716***
	(128.0)	(0.0324)	(0.0141)
Industrial mobility × TCAT diploma	192.7**	0.0640***	0.0923***
	(75.36)	(0.0202)	(0.00904)
N_{it} (student-quarters)	1,220,031	970,555	1,220,031
N_i (students)	33,522	33,522	33,522
Adjusted R^2	0.704	0.573	0.355

NOTES: Column 1-3 results are estimated from Equation 3. Robust standard errors clustered at the student level are in parentheses below each coefficient.
* significant at 10%; ** significant at 5%; *** significant at 1%