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At What Cost?: Is Technical Education Worth the Investment?

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Abstract

Career and technical education (CTE) has existed in the United States for over a century, and only in recent years have there been opportunities to assess the causal impact of participating in these programs while in high school. To date, no work has assessed whether the relative costs of these programs meet or exceed the benefits as described in recent evaluations. In this paper, we use available cost data to compare average costs per pupil in standalone high school CTE programs in Connecticut and Massachusetts to the most likely counterfactual schools. Under a variety of conservative assumptions about the monetary value of known educational and social benefits, we find that programs in Massachusetts offer clear positive returns on investment, whereas programs in Connecticut offer smaller, though mostly non-negative expected returns. We also consider the potential cost effectiveness of CTE programs offered in other contexts to address questions of generalizability.

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At What Cost?: Is Technical Education Worth the Investment?

1. Introduction

Interest in secondary-level career and technical education (CTE) programs has increased in recent years as policy has shifted to emphasize readiness for both college and career (Hackmann et al., 2019; Jacob, 2017). Causal evidence about the efficacy and impact of stand-alone technical high schools where all students enrolled in the school participate in some form of CTE has also grown in ways that better establish the potential benefits of CTE participation in high school (Bonilla, 2020; Brunner et al., 2021; Dougherty, 2018; Hemelt et al., 2019). Advocates for CTE programs often reason that they confer positive impacts on student engagement and employment outcomes, and recent evidence bolsters such claims. Despite evidence of the benefits of CTE participation, much less research directly addresses what drives the costs of operating CTE programs, relative to traditional comprehensive high schools, and how these cost differences compare to the overall economic benefits they have been shown to produce.

This study adds to the literature in two ways. First, it estimates whether the impacts of CTE-specific schools are a cost-effective means to improve student outcomes. Second, it explores the cost determinants of this type of technical education to understand the source of any differences in expenditures, which may shed light on the source of differential program impacts. In particular we examine how much of the difference in costs between CTE-specific schools and traditional public high schools can be explained by differences in the student-teacher ratio and observable student characteristics (e.g., free or reduced-price lunch eligibility or disability status), which may be attributable to differences in revenues and expenditures based on weighted school funding formulas. In estimating the lifetime social benefits of comprehensive CTE programs, we rely on existing estimates (both causal and from highly-controlled fixed effects models) to attach dollar values to known benefits. For both cost and benefit analyses, we rely primarily on recent work in Massachusetts and Connecticut. We also begin to explore how federally-collected school finance data could be used to estimate cost differences in states that do not use whole-school models of CTE in order to establish bounds for the conditions under which we think that CTE would provide an even or positive return on investment.

We find that under reasonably conservative assumptions, the lifetime public benefits of CTE-dedicated high schools likely exceed the associated marginal educational costs, and suggest that these estimates probably represent lower bounds on the actual net benefit. Using Massachusetts and Connecticut as case studies where internally valid estimates of impacts exist, we show that the reduced social costs and anticipated increases in tax revenue associated with increases in high school graduates, offset the future value of the additional per pupil costs in most cases. Importantly, despite evidence in these contexts that learning outcomes may also improve as a result of CTE participation, we do not monetize the known returns to improved learning outcomes, suggesting our estimates likely understate the true net benefit. Although an ingredients approach (Levin & Belfield, 2015; Levin & McEwan, 2000) to documenting costs may be more comprehensive, our estimates based on retrospective analyses rely on per pupil expenditures which are the policy-relevant figures when considering the public investments made in these CTE programs. Further, we show that our findings and conclusions are robust to a host of different choices made in our assumptions about interest rates, as well as differences in the potential pattern of lifetime returns to benefits of CTE.

The rest of this paper is laid out as follows. In the next section we briefly review the literature related to the known impacts of CTE on educational and workforce outcomes. We then provide more context on the CTE settings in Massachusetts and Connecticut, including causal impact estimates from each state. We then discuss the data sources and methods for this analysis, present results, and discuss them in light of the known literature. We conclude by making recommendations for research and policy.

2. Background & Context

Across the United States, about 77% of students take a CTE course in high school, and 37% take a related series of two or more courses that are counted as fulfilling a concentration (*Bridging the Skills Gap: Career and Technical Education in High School*, 2019). These latter students are investing a non-trivial share of their total elective coursework in receiving training and exposure to a set of skills that may be valuable when transitioning to the workforce. Prior research has found that students who fulfill the requirements to be considered a CTE concentrator tend to have higher earnings after leaving high school (Bishop & Mane, 2004; Brunner et al., 2021). All else equal, higher earnings should tend to realize both private (to the earner) and public (by way of higher tax revenue) benefits. Other research has demonstrated that CTE participation can increase the probability of graduating from high school (Bonilla, 2020; Brunner et al., 2021; Dougherty, 2018; Hemelt et al., 2019). Improving high school graduation rates tends to be quite valuable, with cost/benefit analyses suggesting large positive public lifetime benefits from increasing graduation rates due to increased tax revenue from higher earnings, reduced reliance on public assistance programs, improved health outcomes, and lower crime rates (Belfield & Levin, 2007; Carroll & Erkut, 2009).

CTE Program Delivery

CTE coursework and programs of study are offered in a number of settings. According to the National Center for Education Statistics (NCES) (Gray & Lewis, 2018), the most common setting available to students for participating in CTE is through elective coursework at a traditional, comprehensive high school. In some high school settings, students receive CTE programming by participating in a career academy; a program of study characterized by small learning communities surrounding a common career theme (e.g., health services, engineering, graphic design) where all students within the academy take aligned academic and technical courses. Schools that offer a career academy model can have multiple academies across a number of career themes within a single school building. Other settings for CTE delivery include area technical centers (ATCs), postsecondary institutions, and full-time CTE-dedicated schools. At ATCs, students participating in CTE attend the center part-time to receive technical training that complements the core graduation requirements they otherwise complete in their comprehensive high school. In postsecondary institutions, students often participate in CTE through dual enrollment programs which grant students both secondary and postsecondary credit for their coursework. Finally, at full-time CTE-dedicated schools, all students enrolled in the school study CTE typically by taking the bulk of their elective coursework in one or more CTE programs of study.

CTE program delivery differs not only according to setting, but also in the structures that are implemented to support learning as well as in program quality and intensity. For example, most students completing CTE coursework in comprehensive high schools do so through taking one-off elective courses where not all students enrolled in that elective course follow the same academic schedule. In most comprehensive high schools, only a few introductory-level CTE courses are generally offered alongside traditional arts, music, and world language electives. However, in the growing number of schools that offer career academies or other career pathways programs, students can participate in more intensive and structured CTE programming around a particular career theme. Similarly, in ATCs, students dedicate a longer portion of their day to CTE instruction and receive deeper exposure to CTE coursework. In comparison to comprehensive high schools, ATCs typically offer more program area choices and courses for students. Finally, CTE-dedicated schools are environments where technical and academic skills may be integrated, where all students study CTE, and where there is more flexibility in the structure of the school day to support all aspects of learning.

Considering the range of differences in how CTE is delivered, there are likely differences in the relative costs and funding sources associated with program implementation in each CTE setting. In most comprehensive high schools, space and budgets are limited which may preclude having expensive or expansive applied learning spaces (e.g., an auto shop), but may be able to offer business, applied arts, or other less equipment-intensive CTE programs. ATCs and CTE-dedicated schools on the other hand often serve multiple school districts. Some states treat each ATC or CTE-dedicated school as an independent local education agency (LEA) for the purposes of reporting enrollment, financial, and other data. Other states treat ATCs and CTE-dedicated schools as individual institutions within regional or regular LEAs. In those states, these institutions can be a part of a district that includes regional special education schools, early colleges, alternative schools, or regular elementary and high schools. These regional ATC and CTE-dedicated schools receive funds from each of the districts they serve as well as from the state and federal government in order to support students and provide a variety of programs. This makes it possible to then spread the costs of equipment and instruction across more budgets, while also creating a devoted space for the necessary equipment to support programs like welding, culinary arts, or construction trades.

Study Context

In this study, we focus on programming at secondary-level CTE-dedicated schools in Connecticut and Massachusetts. The state of Connecticut provides much of its intensive CTE programming to public high school students through the Connecticut Technical Education and Career System (CTECS; formerly, the Connecticut Technical High School System). This system acts as a quasi-independent school district comprised of 17 regional high schools where all students participate in CTE. Along with meeting their regular academic coursework requirements for graduation, all students attending a CTECS school must complete CTE coursework in fields such as health science or manufacturing. About half of Massachusetts' public high school students participating in CTE do so at a regional vocational and technical high school (RVTS). Each individual RVTS functions as an independent regional school district. Similar to CTECS students in Connecticut, students attending an RVTS participate in some form of CTE while also completing their regular academic requirements. Other states like New Jersey, Pennsylvania, and Delaware offer similar models of regional or county-based technical school districts. Similar to the CTECS and RVTS systems, students enrolled in technical high schools in New Jersey and Delaware attend these schools full-time and participate in CTE and regular academic coursework. Within the ATC system in Pennsylvania, enrolled secondary students receive career-focused programming at technical centers but receive other specialized academic programming (e.g., Advanced Placement and International Baccalaureate coursework) and complete other graduation requirements in their home school district. While we provide estimates of the costs of these other programs using federal education finance data, we do not have causal estimates of the benefits of these programs in order to conduct a full cost-benefit analysis.

In both Connecticut and Massachusetts, state funding for traditional public schools is determined via a progressive funding formula that assigns greater weight to students with additional needs such as English Language Learners and students requiring special education services. CTECS schools though are funded entirely by the State of Connecticut's General Fund, and students who attend a CTECS school are excluded from their resident district's student count. While the resident districts of CTECS students are responsible for providing transportation to these students (for which they are provided funding by the state as part of the ruling in *Sheff v. O'Neill,* 1996), they are not responsible for providing any funds to CTECS schools. This is in contrast to the RVTS system in Massachusetts where a student's resident district must pay tuition and provide transportation to the RVTS the student attends. The tuition amount is fixed for each school in the RVTS system and is determined by the Commissioner of Education.

Credible Causal Estimates of CTE Impact

Recent work finds positive impacts of participation in the CTECS and RVTS system. Using a regression discontinuity design (RDD) that exploits the score-based admissions system utilized by CTECS, Brunner et al. (2021) find that male students admitted to CTECS schools were more likely to graduate on-time, have higher 10th grade standardized test scores, and have higher quarterly earnings, but in the short-term, they had spent less time enrolled in college. No statistically significant effects were found for female students in this study. Similarly, Dougherty (2018) also uses a RD design to examine the impact of attending an RVTS school and Massachusetts. His results suggest that attending a RVTS school increases the probability of on-time graduation, enrollment in high school through grade 11, occupational certificate receipt, and likelihood of passing both of Massachusetts' high school graduation exams.

These results are in line with previous work on the impacts of other types of CTE programs. Studies exploiting a lottery admissions procedure in oversubscribed career academies identify a positive effect of admission on later earnings, but no impacts on graduation rates (Kemple, 2004; Kemple & Willner, 2008; Page, 2012). More recently, Hemelt, Lenard, and Paeplow (2019) identify positive impacts of lottery-based admission to a technology-focused career academy on graduation rates. Using a regression discontinuity design, Bonilla (2020) finds that districts at the threshold for receiving a grant for CTE programs both increased their

CTE spending and experienced lower high school dropout rates. In the context of this study, grantees largely used funds to support or expand CTE pathways programs within regular high schools.

3. Methodology

We use existing impact estimates, and related literature on the economic value of those impacts, to estimate the monetary value of the expected benefits of participating in a stand-alone CTE program. By varying assumptions about the persistence and trajectory of these impacts we estimate a total lifetime public financial benefit of these CTE programs. Then, using publicly available data on school budgets, spending, and student enrollment, we estimate the future value of average per pupil costs of being educated in these CTE programs, relative to their respective counterfactual settings in comprehensive high schools. We then compare the future value of the difference in educational expenditures on CTE schools with the range of projected lifetime public benefits, to assess under what conditions CTE schools may generate a net financial benefit to the public sector. As an extension, we use available data on expenditures for CTE schools that can be identified in the federal F-33 school finance data in three other states, New Jersey, Pennsylvania, and Delaware, to offer additional insight into the relative difference in expenditures on CTE in other similar settings where comparable expenditure data exist.[1]

Data

Connecticut Financial and Demographic Data

Of the 17 schools in the CTECS district, 16 were operating at the time of the evaluation by Brunner et al. (2021) which establishes the impact estimates for these schools. We use estimates of program impacts from Brunner et al. (2021) along with data on school expenditures,

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[1] Note that while it would be beneficial to generalize to other states and regions, New Jersey, Pennsylvania, and Delaware were the only states with data in the F-33 survey that allowed for a clean distinction between CTE dedicated schools or regional centers and their comprehensive high school counterparts.

student enrollment, CTE courses, and number of full-time equivalent (FTE) employees at high schools in Connecticut, all of which is made available through NCES, the Connecticut State Department of Education, or public school district websites. School-level budget data were collected for the counterfactual high schools that CTECS students would have attended, as well as the CTECS schools themselves. Of the original 71 high schools with available budget data, 11 were excluded from analyses due to a lack of available data on student enrollments, course offerings, and/or FTE employees.[2] In total, budget and school characteristic data were available for 17 CTECS schools and 31 counterfactual schools. Data on nominal school budget allocations were collected from the most recently available school district budget (see Appendix Table A5).

Data on total student enrollment; counts of students by race/ethnicity, gender, and free and reduced-price lunch (FRPL) status; student-teacher ratio; and number of FTE employees came from the NCES Common Core of Data (CCD) for the year budget information was available. CCD data were not available at the time of analysis for the 2019-2020 school year, so 2018-2019 data were used for the one district that had budget data for 2020. Counts of special education students and Limited English Proficient (LEP)/English Language Learner (ELL) students came from the Connecticut State Department of Education Public School Information System (PSIS).

Massachusetts Financial and Demographic Data

Data on Massachusetts district-level expenditures and revenues from the 2001-02 to 2016-17 school years come from the School District Finance Survey (F-33) administered by the U.S. Census Bureau and NCES. Data on student enrollment, FTE employees, and student-teacher ratios come from the CCD for the same period. Analyses only include districts for which

[2] The excluded schools were either charter schools or other specialized schools from which very few students that applied to CTECS would have been enrolled in if they did not gain admission to a CTECS school.

all schools are non-charter schools and have 12th grade listed as the highest grade in the district. We also restrict our analyses to exclude the top 5% of regular districts each fiscal year in terms of per pupil expenditures. During the years of analysis, some of the school districts have substantially higher than typical per pupil expenditures likely due to one-time increases in expenditures. No school district is consistently in the 95th percentile in every year. Excluding these outlier school districts increases the precision of our estimates, and our point estimates are largely robust to their exclusion.

New Jersey Financial and Demographic Data

Data on New Jersey district-level expenditures and revenues also come from the F-33 data collection. This represents another state, like Massachusetts, that has a whole-school model of CTE where schools operate as independent districts in terms of their governance and funding structure. The dataset only includes districts for which all schools are non-charter and have 12th grade listed as the highest grade in the district. Counts of FTE employees come from the CCD. Data on student enrollment come from publicly available data files collected from the New Jersey State Department of Education website. State-collected data were linked to NCES-reported data using NCES local education agency IDs. We use state-reported enrollment and student demographic information instead of NCES-reported information because the F-33 student enrollment count only includes students for which the district is financially responsible. In the case of New Jersey, this results in a severe undercount of students (and therefore inflated PPE amounts) particularly among technical districts from which students are often excluded. Publicly-available data on the number of LEP students is not available prior to 2005; therefore, analyses are only conducted using data from the 2005-06 to 2016-17 school years. Data from 2016 were excluded for one outlier district (Cumberland County Vocational School District) because capital outlay expenditures were higher than normal in this year due to the construction of a new high school building. As a result of this construction, per pupil capital outlay expenditures exceeded $100,000 in 2016, which was substantially higher than the median per pupil expenditure.

Pennsylvania and Delaware Financial and Demographic Data

The F-33 data collection only includes district or LEA-level data; therefore, we can only use F-33 data from states that report Area Technical Centers (ATC) expenditure data as if each center is an individual LEA. Pennsylvania and Delaware are the only two states that both classify ATCs as independent LEAs and report financial data in the F-33. While Arkansas, California, and New York also classify ATCs as independent LEAs, these states do not report financial data for ATCs in the F-33 data collection.

Data for Delaware on student enrollment, FTE employees, and student-teacher ratios come from the CCD. As with New Jersey, the CCD student enrollment totals for Pennsylvania only include students enrolled in ATCs within the enrollment counts for each student's home district. Therefore, data on Pennsylvania student enrollment were collected from publicly-available data files provided on the Pennsylvania State Department of Education website. The analytic dataset only includes districts for which all schools are non-charter schools and have 12th grade listed as the highest grade offered in the district. Because the publicly-available data on number of LEP students is not available prior to 2006-07, analyses are only conducted using data from the 2006-07 to 2016-17 school years.

For all states, per-pupil expenditures (PPE) were calculated using current expenditures and total enrollment data. Counts of students by race/ethnicity category, special education status, LEP/ELL status, and gender were converted to percentages of total student enrollment. The student-teacher ratio variable from NCES was calculated as the total student enrollment divided by the number of FTE teachers in the school or district.

Analytic Approach

Our general approach is to estimate the monetary value of observed improvements in outcomes among students who participated in CTE, relative to otherwise similar students who did not. Using credible causal estimates from prior studies in Connecticut and Massachusetts allows us to capture impacts on test scores, high school graduation, and earnings, and translate them into economic value. To make this translation, we rely on existing studies that monetize the lifetime benefits of an additional high school graduate (relative to not graduating) and then place them in the context of the evidence. Further, we also apply a set of assumptions and projections with regard to employment and earnings benefits to estimate the public benefit of additional tax receipts realized from these higher earnings. There may be additional economic returns to an increase in skills net of a student's educational credentials (Araki, 2020; Chetty et al., 2014; Hanushek et al., 2015; Hanushek & Woessmann, 2012; Kerckhoff et al., 2001), but we do not capture specific estimates of these benefits in our results. As we are unaware of any estimates of the monetary benefits of an increase in skills as measured through standardized test scores, we do not incorporate this premium into our benefit calculations. While analyses of CTE participation in an RVTS find no clear impacts on student achievement (Dougherty, 2018), analyses of CTECS participation find a positive impact on students' math and reading skills (Brunner et al., 2021). As such, the expected lifetime benefits we estimate in this study are likely lower bounds on the actual range of total economic benefits to CTE participation.

Estimating Expected Lifetime Benefits for Induced High School Graduates

We draw on Levin and colleagues' (2007) estimates of the lifetime social benefits to producing an additional high school graduate to estimate the anticipated returns to enrollment in a technical school/district, where students just admitted had much higher probabilities of graduating from high school. These benefits are calculated as the additional lifetime tax revenue, savings from reduced enrollment in Medicare/Medicaid, savings from reductions in crime, and savings from lowered welfare receipt that are associated with being a high school completer in comparison to not finishing high school. Of these categories, additional lifetime tax revenue comprises the largest share (roughly 67% of the total expected social benefit). We convert Levin et al.'s (2007) original estimate of overall benefits to 2020 dollars using the U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers (CPI) inflation adjustment calculation, which translates to $291,401 per additional graduate in 2020 dollars. We then use these estimates to calculate the anticipated benefit induced by additional high school graduates shown in Brunner et al. (2021) and Dougherty (2018).

Lifetime Benefits of Higher Earnings

To estimate how higher earnings at the individual level translates into public financial benefits, we obtained data from the U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements (CPS ASEC) on mean earnings and state tax liability after credits by age, educational attainment level, and sex for 2019 (U.S. Census Bureau, 2020). We then calculated the future value of lifetime earnings, state tax liability, and additional lifetime state tax revenue based on interest rates ranging from 2-5% (from here out, "lifetime" includes expected working life, ages 18-65) and a range of values for the CTE earnings premium (see appendix, Table A1).

CTE earnings premium estimates come from previous literature on CTE outcomes (Bertrand et al., 2020; Brunner et al., 2021; Hanushek et al., 2017; Kreisman & Stange, 2018; Silliman & Virtanen, 2019). This body of literature establishes a range of possible CTE earnings premium estimates for high school graduates: an earnings premium that starts at 5% and ranges up to 50% for workers aged 18-25. After age 25, these annual premiums are linearly smoothed to zero over the course of the lifetime. We also converted Levin et al.'s (2007) estimates of savings to public health, crime reduction, and welfare from an additional high school graduate to 2020 dollars using the CPI inflation adjustment (appendix Table A2).

Next, we computed a range of total additional benefits per CTE student (appendix Table A3). To do this, we made another set of assumptions about the benefits of CTE for students who participated but would have otherwise graduated (i.e., those not induced to graduate, but who would have been expected to graduate under counterfactual conditions, about 75% of students). Specifically, we assumed that at a minimum, all graduates received an earnings premium from their CTE participation and their status as a high school graduate (i.e., the range of values presented in Panel A. of Table A1). Based on Brunner et al. (2021) and Dougherty (2018), we then assumed that an additional 10% of students attending a technical school are induced to graduate. Induced graduates were assumed to generate public financial benefits through two channels: 1) additional tax revenue due to increased earnings from being a CTE high school graduate and, 2) additional public benefits from improved health, reduced crime rates, and lowered reliance on welfare (*a la* Belfield and colleagues 2007).

Finally, using the observed overall average graduation rate of 85%, we assumed that the remaining 15% of students in technical schools do not graduate from high school and do not receive any additional benefits from being a CTE student.[3] Based on Brunner et al. (2021), we assume that CTECS benefits only accrue to the proportion of the student body that is male (i.e., about 60% of students). We assume that benefits accrue to all students in the RVTS setting based on Dougherty (2018). See the Technical Appendix for further details on the process for calculating estimates of benefits.

Estimating Sources of Cost Differences

[3] This is a conservative assumption since students could have skills that lead to higher earnings that lead them to drop out to increase the period of time over which they can benefit from those higher earnings. However, because earnings benefits for non-graduates might decay to zero sooner than age 65, we favor a more conservative than assumption of zero premium.

Rather than compare simple differences in the average per pupil expenditures in CTE and non-CTE settings, we adjusted for differences in observable student characteristics between the two settings in each state. This was done to isolate the additional costs directly associated with providing CTE from other expenditure differences driven by differences in the student body that impact budget allocations (e.g., the percentage of FRPL-eligible students that influences funding allocations in the weighted student funding formulas in each state).

To establish average differences in expenditures between technical schools and comparison schools, we fit a series of OLS models for each state, where the primary predictor of interest was an indicator of whether a school/district was a CTE school/district. In these models we included year fixed effects (except in Connecticut where we had only one year of budget data available). The primary outcomes of interest are overall per pupil expenditures and spending by category (e.g., instruction, support services, and capital outlays). To these baseline models we added controls for up to a quadratic term in student enrollment, and then sequentially added other predictors to see what factors explained more of the average difference in outcomes across school types. Focal predictors included student-teacher ratio, share of FRPL-eligible students, share of special education students, and share of students who are LEP/ELL. The last three of these predictors were used as proxies for groups that receive different weights in school funding formulas, and those are places where revenue and spending might systematically differ based on student characteristics, and not the specific type of educational program.

We calculated total additional per pupil costs for technical schools by summing the annual difference (both regression-adjusted and unadjusted) in cost over four years for each state (appendix Table A4). We assume that this additional per pupil cost applies to every student regardless of whether the student graduates from high school on time. Because students who do not graduate on-time are still treated as if they attended high school for a full four years, our estimate of the total cost difference likely represents an upper bound for the expected additional cost.[4] The future value of this total cost was then adjusted to account for the future forgone value of that money over the student's career (ages 18-65). In these calculations, we allowed the interest rate to range from 2 to 5%. Our calculations of the future value of per pupil CTE expenditures in Connecticut range from $40,185-$161,565 controlling for school characteristics and $38,062-$153,028 without controls for interest rates of 2 to5% (Table A4).

4. Results

Overall, we find that even after adjusting for school size and student demographic composition, technical schools spent more, on average, than their counterfactual comprehensive schools across both states. Models that condition on student demographics explained some of the difference, especially in Massachusetts where differences in student composition were larger between school settings, but meaningful differences in expenditures remained. Net of demographics, student-teacher ratio explained another roughly 20% of the average difference in spending, suggesting that at least 1/5th of the cost differences may be accounted for by smaller class sizes. In both states we find that total additional public benefits of CTE on student high school completion exceed the future value of the increased expenditures, though this conclusion does depend on assumptions related to discount rate and initial earnings premiums which we detail below.

Differences between Technical and Non-Technical Schools

In Tables 1 and 2 we provide summary statistics for characteristics of school districts in Massachusetts and high schools in Connecticut (see Appendix Tables A6-A8 for similar tables for New Jersey, Pennsylvania, and Delaware). In comparison to regular school districts, RVTS

[4] In Massachusetts, only an additional 1% of students graduate in five years (https://profiles.doe.mass.edu/grad/grad_report.aspx). Our calculation of a net benefit holds even assuming one more year of funding for 1 of every 100 students since the lifetime benefits of inducing an additional graduate exceed the future value of an additional year of current expenditures.

districts in Massachusetts have larger shares of FRPL-eligible students and students with an IEP but a smaller share of ELL students. In Connecticut, CTECS schools have a lower share of students with an IEP and ELL students than regular high schools. In both states, the pupil-teacher ratio is larger in comprehensive schools, implying smaller class sizes, on average, in the technical schools.

We extend our descriptive analyses by controlling for sets of observable characteristics to determine how much of the average differences in spending per pupil in technical schools can be accounted for by differences in enrollment. In tables 3 and 4 we present estimates of the differences in spending conditional on a variety of characteristics. In columns 1 of both tables, we present unconditional mean differences, and in columns 2 and 3 we sequentially add linear and both linear and quadratic terms in enrollment. In both states we find that accounting for differences in overall enrollment account for little of the mean differences in spending. In columns 4 of each table, we add in measures of student eligibility for subsidized meals, disability identifications, and measures of student race or ethnicity. In Table 3 for Connecticut, we see that there is no real change in the cost difference even after accounting for student demographics or educational service eligibility. This is unsurprising since the descriptive statistics showed little average differences in student characteristics across setting. In contrast, in table 4 for Massachusetts we see that accounting for these same factors reduces the average cost difference by 40%. Finally, in columns 5 of both tables, we add in student-teacher ratio to capture how much of the remaining average difference in spending is related to small classes or more instructional staff. In both states, we see roughly a 20% reduction in the spending difference once we condition on these differences in staffing.

In table 5 we present estimates of differences between technical high schools and counterfactual comprehensive high schools in Massachusetts on expenditure categories. This more detailed analysis cannot be done in Connecticut because CTECS schools are all part of one school district that does not report their financial data to the F-33 system. Instead, we rely on local budget data that does not include detailed breakdowns by spending category for CTECS schools.. Across all five columns of Table 5 we present the regression-adjusted differences in spending between RVTS schools and their counterparts, controlling for student characteristics and student-teacher ratio. Estimates make clear that the overall difference in per pupil expenditures shows up across each of the four subcategories as well, with instructional and support services being the largest share, followed by capital outlays, and then a very small difference in non-elementary or secondary expenditures which include community services, adult education, and other non-elementary/secondary programs that may be more prevalent in technical schools than comprehensive high schools. Differences across each of these categories suggests that differences in spending are broad-based and not driven only by differences in the extent to which expenditures on equipment, capital, or staffing are larger in technical education.

In the appendices we report analogous estimates of expenditure differences for New Jersey, Pennsylvania, and Delaware. New Jersey is the only of the states that had a school structure similar to Massachusetts and Connecticut, and in this instance, we see a similar pattern across estimates reported in Table A8. In Pennsylvania and Delaware that both of area technical centers, the patterns differ, with nominally lower average expenditures per pupil, but not statistically different in the former, but sustained higher costs for CTE in the latter. We also report breakdowns of differences by spending category for New Jersey, Pennsylvania, and Delaware in appendix tables A12 through A14, respectively. The patterns are similar to Massachusetts in New Jersey, where the school structure is most similar to Massachusetts and Connecticut, however, in Pennsylvania, the noisy, small negative average differences in current expenditures appear to mask potentially higher spending on services and non-elementary and secondary education. In Delaware, we also see noisy, though positive, overall average differences in current expenditures, which mask what appear to be larger spending differences in all areas except capital outlays.

Cost-Benefit Results

We calculate net benefits by taking the difference between the estimated range of total lifetime benefits and our estimates of the total costs. Net benefits in Connecticut (Table 6) are positive when interest rates are low and/or when the earnings premium is high (above 20% when the interest rate is at 4 or 5%). Given that Brunner et al. (2021) identify a roughly 30% earnings premium for CTECS students through age 23, this finding suggests that the public benefits of CTECS likely outweigh the costs, even when only accounting for the benefits realized through improved graduation rates and higher tax receipts for males, and assuming no benefits to females, or via the better test score outcomes also found in Brunner et al. (2021). Under most conditions, benefits exceed costs in Massachusetts when using differences that account for characteristics of the student population (Table 7). For cost estimates from Massachusetts without controls, net benefits are only positive when interest rates are low or when the starting CTE earnings premium is above 25%).

To our knowledge, there exists no causal estimates of the impacts of CTE programs in New Jersey, Pennsylvania, or Delaware. Our estimates of the differences in average program costs therefore serve as possible bounds for understanding how substantial program benefits would need to be for each program to be considered cost-effective. Considering the higher costs of CTE-specific high schools in New Jersey and Delaware relative to that of Connecticut and Massachusetts, the benefits of these programs would likely have to be as great or greater than the benefits identified in Connecticut and Massachusetts. In Pennsylvania though, benefits of participation likely do not need to be large in order for these programs to have a cost-effective positive impact, under the assumption that the cost data we can access represent a comprehensive accounting for differences in the cost of program delivery.

5. Discussion

In this study, we examined whether the benefits conferred by CTE-specific schools are worth the public costs of providing such programming. Using previously-established estimates of the lifetime benefits of being a high school graduate and the impact of being a CTE student on lifetime earnings, we establish ranges for the likely public benefits of CTE-specific schools. We draw from a variety of data sources to establish cost differences between CTE-specific schools and regular high schools after accounting for differences in student populations and student-teacher ratios. We focus our study on the technical school systems in Connecticut and Massachusetts for which we have credible causal estimates of their benefits in terms of graduation rates and earnings. We also provide estimates of the costs of similar programs in other states to provide information on how these costs might appear in other contexts.

We find that the estimated benefits of CTE-specific schools in Connecticut and Massachusetts likely outweigh their costs under most conservative plausible estimates of the lifetime public benefits and costs. After accounting for sizes of certain student populations which impact the allocation of funds to these programs and assuming a roughly 30% starting earnings premium, our estimates of the net program benefit range from about $8,100 to nearly $12,100 in Connecticut when interest rates are between 2-3% and from about $56,500 to $113,900 in Massachusetts when interest rates are between 2-5%. These net benefits in both states are large enough that any potentially omitted costs would have to be rather large (relative to the mean difference in program delivery costs) to push these net benefits to zero or below. However, if the initial impacts on earnings were smaller, or if those benefits faded out more quickly than estimated, these programs may not be cost effective. For example, if we smooth the linear decay of the initial earnings premium to age 45, rather than age 65 (as in Figure 2), there are more cases where the net benefit may be zero or negative.

Accounting for net benefits in the aggregate abstracts from the potential for programs to have different average costs and to produce different average benefits. This is particularly true in Connecticut where the earnings premiums only accrue to males, but average differences in program costs are spread across all students. Of course, the programs that males enroll in are disproportionately male (80%) and predominantly fall into the skilled construction trades, manufacturing, and automotive fields (Brunner et al. 2021). If these programs were to drive differences in average costs (because they are more equipment intensive than predominantly female programs), the net benefit may be more less clear. Future work on cost differences in CTE should certainly align program-specific costs with associated outcomes.

Cost-benefit calculations should also not be the sole driver of decisions about what programming to offer. In fact, and for example, there may be non-financial benefits of ensuring a steady supply of students coming from early childhood education programs to help staff childcare needs, even if those programs do not produce a net financial return on investment.

If similar sized benefits exist in states with costlier program delivery systems, such as New Jersey and Delaware, CTE-specific schools may still be cost-effective. In fact, the causal estimates from the studies in Massachusetts and Connecticut are in line with other estimates from North Carolina (Hemelt et al., 2019) and California(Bonilla, 2020), indicating that the benefits calculations may be reasonable to consider generalizing to other settings where the treatment conditions are similar. Federal data do not allow for the parsing of financial data for CTE programs in North Carolina or California, but in the other three states where this was possible, we found that cost differences were roughly in line, or smaller, than what we estimated in Massachusetts and Connecticut (see Tables A6 through A8).

Limitations

While this study presents our best estimates of the costs and benefits of CTE-specific schools, we note some limitations of this work. On the cost side, we are limited in our ability to apply an ingredients method (Levin & Belfield, 2015; Levin & McEwan, 2000) to estimate the total costs of CTE-specific schools. Because we rely on budget data and data on expenditures from government reporting systems, we perhaps underestimate costs that are financed through other means such as donations and we are unable to estimate the opportunity cost of specific school personnel. Considering that we are conducting a retrospective analysis of these programs, we are unable to obtain data on individual cost ingredients. While future studies employing an ingredients approach may provide more detailed estimates of the cost of CTE-specific schools, our study is in conversation with other literature on public finance and economics of education which heavily rely on similar cost measures.

A related limitation of this study is our use of budgeted expenditure data for estimating the costs associated with CTECS schools. Having access to data on actual expenditures would improve the accuracy of our cost estimates for these schools. While there may be some differences between actual and budgeted expenditures, budgeted expenditures are still a policy-relevant figure for understanding cost considerations.

Limitations to the calculation of benefits include the inability to monetize the demonstrated positive impacts on test scores in Connecticut, or to account for potential other social benefits from CTE participants whose graduation outcomes were not impacted. For example, if the 75% of CTE students who would always graduate from high school, see benefits in addition to their higher average starting earnings, we have systematically not accounted for those potential benefits which could be private or public (e.g., lower probability of reliance on public programs, fewer instances of contact with the justice system).

Notwithstanding the data and inferential limitations, this work represents a novel and important step forward in the consideration of technical education and the relative benefits of the delivery systems that exist in the United States. Though we capitalize on natural experiments that exist only in two northeastern states, other recent research that highlights better high school completion (Bonilla, 2020; Hemelt et al., 2019), better test scores (Hemelt et al., 2019) and sustained higher earnings through age 25 (Ecton & Dougherty, 2022) suggest that there may be other settings in which similar analysis could be undertaken. In addition, by providing some evidence of the differences in CTE program costs in New Jersey, Pennsylvania, and Delaware (where federal financial data allow for the easy separation of CTE programs), we set initial bounds on how large the program benefits may have to be to make those delivery methods cost effective.

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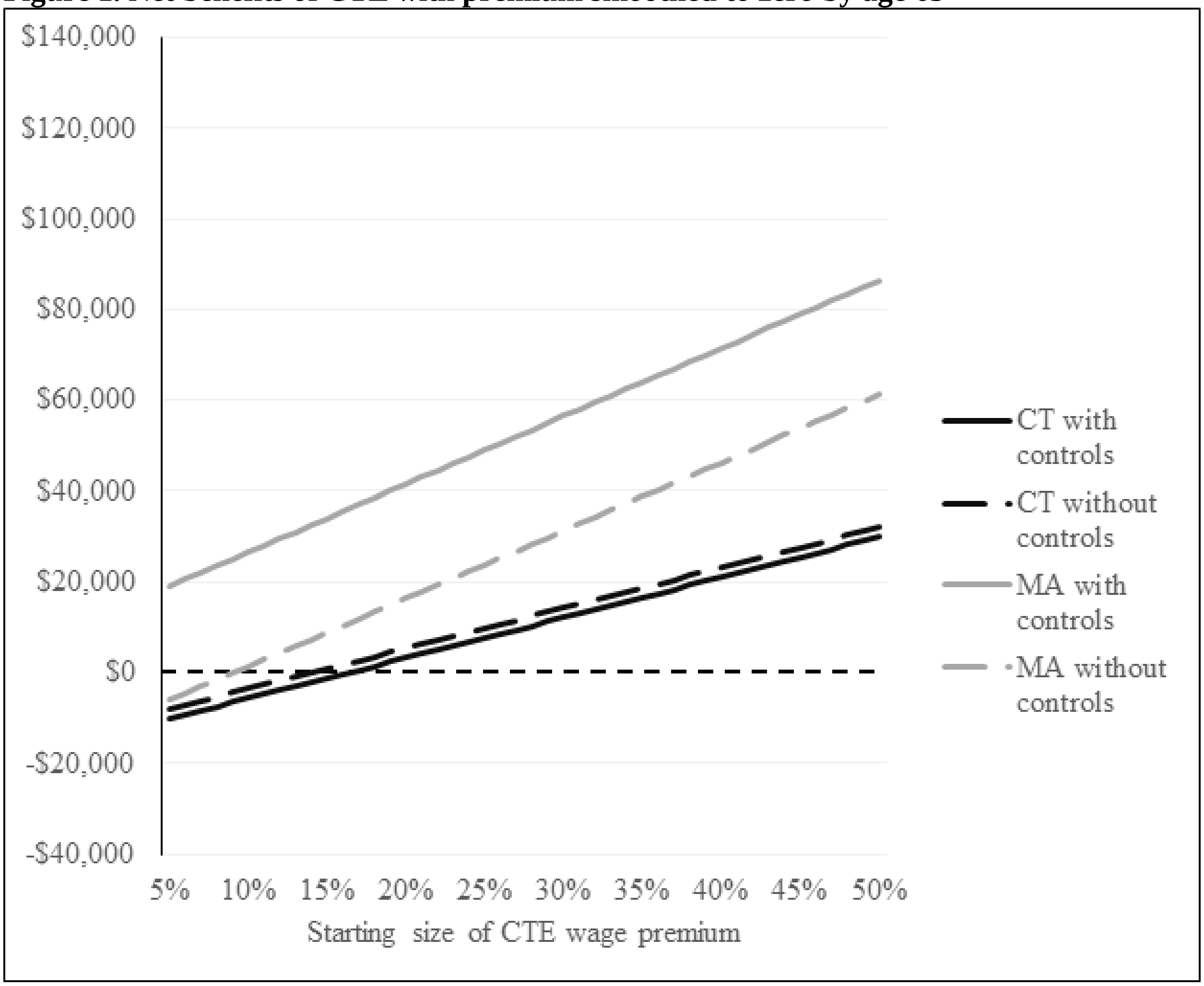
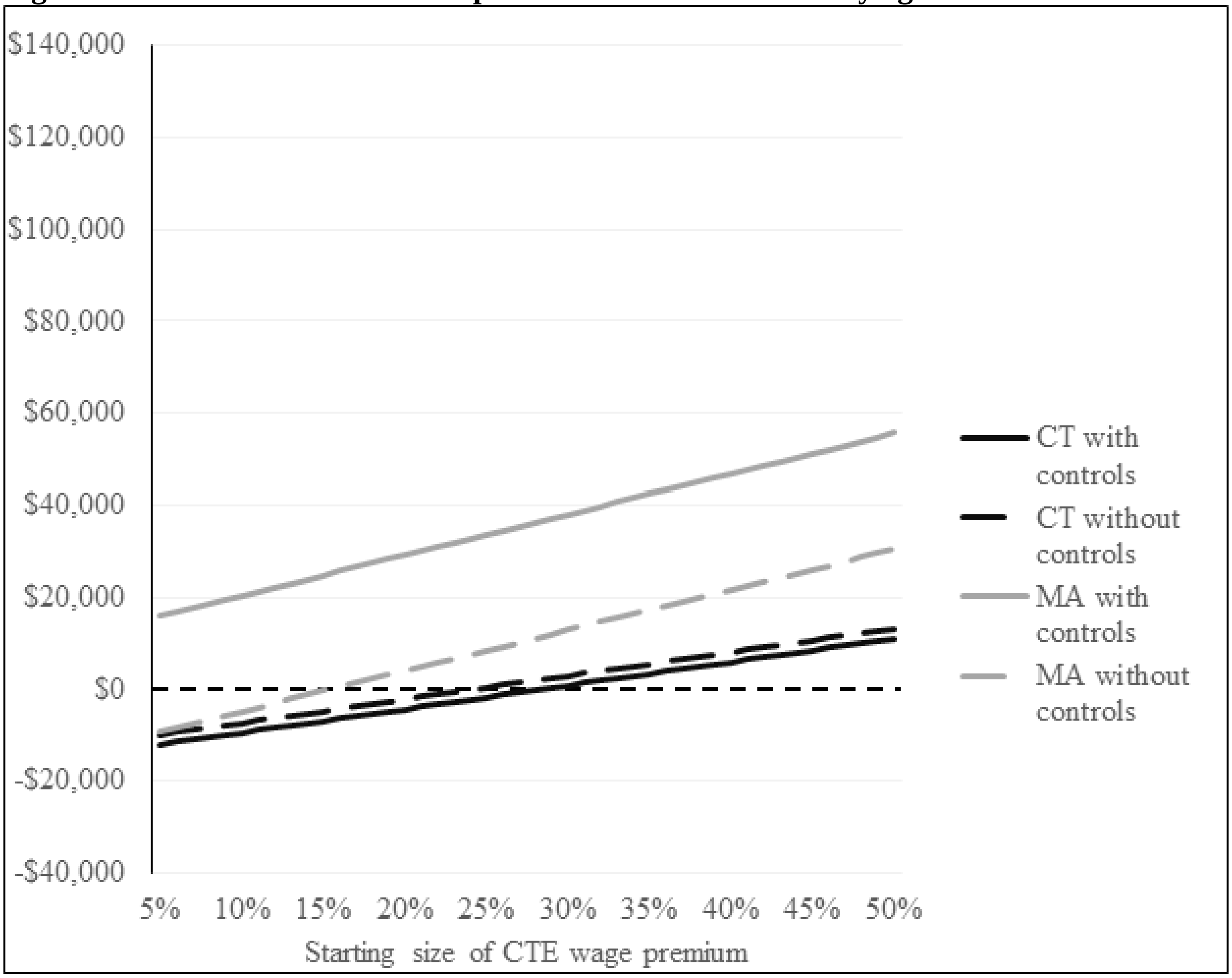
Tables & Figures

Figure 1. Net benefits of CTE with premium smoothed to zero by age 65



Note: Figure shows the difference between estimated lifetime future benefits and total estimated costs from models with and without controls when assuming an interest rate of 2%. CTE wage premium is held constant from ages 18-25 and linearly smoothed to zero by age 65.

Figure 2. Net benefits of CTE with premium smoothed to zero by age 45



Note: Figure shows the difference between estimated lifetime future benefits and total estimated costs from models with and without controls when assuming an interest rate of 2%. CTE wage premium is held constant from ages 18-25 and linearly smoothed to zero by age 45.

Table 1: Summary statistics for Connecticut high schools

	(1) All High Schools	(2) Regular High Schools	(3) CTECS Schools	(4) Difference (2) – (3)
Characteristics of student population				
% FRPL-eligible students	58.47	61.17	53.53	7.65
	(16.8)	(19.7)	(7.4)	
% students with an IEP	14.11	16.00	10.67	5.33***
	(5.2)	(5.2)	(3.1)	
% ELL students	8.19	10.16	4.26	5.90**
	(8.6)	(9.9)	(2.5)	
% female students	45.06	47.78	40.11	7.67**
	(9.0)	(8.5)	(7.7)	
% Hispanic students	37.39	36.85	38.38	-1.53
	(17.8)	(17.7)	(18.6)	
% Black students	21.64	27.17	11.56	15.61***
	(16.3)	(16.5)	(10.1)	
% Non-White/non-Black/non-Hispanic students	5.62	5.72	5.44	0.28
	(3.0)	(3.4)	(2.4)	
Characteristics of schools				
Total students	748.60	815.74	626.18	189.57
	(417.9)	(502.3)	(123.4)	
Pupil/teacher ratio	12.44	13.58	10.35	3.23***
	(2.9)	(2.9)	(1.6)	
Budgeted per pupil expenditures: 2018-2020	11183.18	9880.50	13558.65	-3678.14***
	(2510.3)	(1790.5)	(1793.5)	
Observations	48	31	17	48

Note: CTECS = Connecticut Technical Education and Career System. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. ELL = English Language Learner. Standard deviations in parentheses. Difference column represents the difference between CTECS schools and regular high schools. * p <.05, ** p <.01, *** p <.001

Table 2: Summary statistics for Massachusetts school districts

	(1) All Districts	(2) Regular Districts	(3) Technical Districts	(4) Difference (2) – (3)
Characteristics of student population				
% FRPL-eligible students	21.97	20.89	31.12	-10.23***
	(18.9)	(19.0)	(15.8)	
% students with an IEP	17.08	16.12	25.22	-9.11***
	(5.3)	(3.6)	(9.1)	
% ELL students	2.46	2.63	1.05	1.57***
	(4.5)	(4.7)	(2.0)	
% female students	48.10	49.03	40.25	8.78***
	(4.1)	(2.8)	(4.7)	
% Hispanic students	7.47	7.01	11.39	-4.38***
	(12.7)	(12.2)	(16.2)	
% Black students	3.61	3.60	3.69	-0.09
	(6.0)	(6.0)	(5.4)	
% Non-White/non-Black/non-Hispanic students	5.25	5.49	3.23	2.26***
	(5.2)	(5.3)	(3.2)	
Characteristics of district				
Total students	3431.56	3721.96	980.54	2741.42***
	(4020.2)	(4154.6)	(419.0)	
Pupil/teacher ratio	13.46	13.75	11.02	2.74***
	(2.2)	(1.9)	(2.9)	
Total current expenditures per pupil	14840.37	14262.57	19717.02	-5454.45***
	(3864.3)	(3256.8)	(4990.2)	
Current capital outlay expenditures per pupil	670.86	611.85	1168.86	-557.00***
	(1532.0)	(1283.2)	(2828.7)	
Current instructional expenditures per pupil	8110.29	7809.60	10648.11	-2838.50***
	(1827.2)	(1508.9)	(2260.3)	
Current support services expenditures per pupil	4620.10	4337.22	7007.58	-2670.36***
	(1518.5)	(1213.1)	(1725.5)	
Current expenditures per pupil for other programs	372.70	359.80	481.59	-121.79***
	(136.1)	(129.1)	(144.9)	
Current non-elementary/secondary expenditures per pupil	65.79	52.46	178.36	-125.90***
	(178.5)	(129.5)	(381.4)	
Total revenues per pupil	15221.14	14602.28	20444.44	-5842.16***
	(4088.6)	(3443.9)	(5220.0)	
Observations	3389	3030	359	3389

Note: RVTS = Regional Vocational Technical School. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. ELL = English Language Learner. Standard deviations in parentheses. Difference column represents the difference between RVTS districts and regular districts. * p <.05, ** p <.01, *** p <.001

Table 3: Estimates of difference in school-level per pupil total budgeted expenditures – Connecticut

	(1)	(2)	(3)	(4)	(5)
CTECS school	3678.1***	3522.0***	3582.5***	3883.3***	2957.5***
	(538.8)	(546.6)	(572.3)	(728.8)	(760.2)
Total enrollment		-0.824	-2.096	-0.917	-0.508
		(0.505)	(2.365)	(2.403)	(2.259)
Total enrollment squared			5.99e-4	-9.50 e-5	-1.69e-4
			(9.55e-4)	(0.001)	(0.001)
Percentage of FRPL-eligible students				-7.002	3.100
				(22.77)	(19.75)
Percentage of students with an IEP				162.0**	107.5
				(51.50)	(59.80)
Percentage of students who are Black				-23.37	-21.64
				(21.19)	(19.19)
Percentage of students who are Hispanic/Latino				12.04	15.00
				(21.01)	(18.52)
Student-teacher ratio					-239.9*
					(89.39)
Constant	9880.5***	10552.4***	11044.8***	8742.0***	11831.3***
	(323.2)	(606.2)	(1135.4)	(1487.3)	(2054.5)
R^2	0.502	0.519	0.522	0.621	0.665
Adjusted R^2	0.491	0.498	0.490	0.555	0.596
F	46.61	26.64	22.60	9.49	12.56
DF model	1	2	3	7	8
DF residual	46	45	44	40	39
Number of observations	48	48	48	48	48

Note: CTECS = Connecticut Technical Education and Career System. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. Standard errors clustered by school district in parentheses. Technical schools are located in a single technical school district (i.e., CTECS). Counterfactual schools come from 16 other regular school districts. Data on expenditures come from school budgets published between 2018-20. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Estimates of difference in district-level per pupil total current expenditures – Massachusetts

	(1)	(2)	(3)	(4)	(5)
RVTS district	5440.7***	5557.1***	5293.8***	3008.3***	2277.5***
	(587.9)	(600.0)	(606.1)	(381.1)	(342.2)
Total enrollment		0.042	-0.097	-0.291***	-0.164**
		(0.036)	(0.064)	(0.078)	(0.062)
Total enrollment squared			3.94e-6**	5.54e-6***	3.49e-6***
			(1.33e-6)	(1.33e-6)	(9.99e-7)
Percentage of students with an IEP				180.3***	130.6***
				(33.59)	(29.13)
Percentage of FRPL-eligible students				-9.86	-21.22*
				(10.44)	(8.76)
Percentage of students who are Black				76.83**	67.55**
				(27.24)	(23.73)
Percentage of students who are Hispanic/Latino				57.97***	51.36***
				(13.16)	(10.95)
Student-teacher ratio					-589.5***
					(51.1)
Constant	11184.4***	11021.1***	11392.5***	8968.3***	16768.1***
	(186.2)	(246.4)	(296.4)	(592.7)	(860.9)
R^2	0.469	0.471	0.478	0.562	0.640
Adjusted R^2	0.467	0.468	0.476	0.559	0.638
F	173.56	163.27	159.37	132.54	158.63
DF model	14	15	16	20	21
DF residual	261	261	261	261	261
Number of observations	3389	3389	3389	3389	3389
Number of districts	262	262	262	262	262

Note: RVTS = Regional Vocational Technical School. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Estimates of difference in district-level per pupil expenditures by expense category – Massachusetts

	(1) Total current expenditures	(2) Current capital outlay expenditures	(3) Current instructional expenditures	(4) Current support services expenditures	(5) Current non-elementary/ secondary expenditures
RVTS district	2277.549***	744.786***	1413.147***	1249.472***	78.109*
	(342.171)	(213.180)	(162.463)	(223.207)	(36.781)
Constant	16768.061***	838.889**	9872.108***	5266.617***	-13.918
	(860.937)	(285.207)	(524.070)	(434.250)	(63.166)
R^2	0.640	0.042	0.688	0.668	0.105
Adjusted R^2	0.638	0.036	0.686	0.666	0.100
F	158.63	8.57	214.18	139.29	3.97
DF model	21	21	21	21	21
DF residual	261	261	261	261	261
Number of observations	3389	3389	3389	3389	3389
Number of districts	262	262	262	262	262

Note: RVTS = Regional Vocational Technical School. All models include controls for a quadratic on total enrollment, percentage of students with an IEP, percentage of FRPL-eligible students, percentage of students who are Black, percentage of students who are Hispanic, and student teacher ratio. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Net benefits of CTE in Connecticut

	Interest rate			
	0.02	0.03	0.04	0.05
Starting size of CTE premium				
With controls				
5%	(10,112)	(21,641)	(41,202)	(73,753)
10%	(5,664)	(15,689)	(33,180)	(62,877)
15%	(1,216)	(9,736)	(25,159)	(52,002)
20%	3,232	(3,783)	(17,138)	(41,126)
25%	7,680	2,170	(9,116)	(30,250)
30%	12,127	8,123	(1,095)	(19,375)
35%	16,575	14,076	6,927	(8,499)
40%	21,023	20,028	14,948	2,376
45%	25,471	25,981	22,970	13,252
50%	29,918	31,934	30,991	24,127
Without controls				
5%	(7,988)	(18,250)	(35,809)	(65,215)
10%	(3,540)	(12,297)	(27,787)	(54,340)
15%	907	(6,344)	(19,766)	(43,464)
20%	5,355	(391)	(11,745)	(32,589)
25%	9,803	5,562	(3,723)	(21,713)
30%	14,251	11,514	4,298	(10,838)
35%	18,699	17,467	12,320	38
40%	23,146	23,420	20,341	10,914
45%	27,594	29,373	28,363	21,789
50%	32,042	35,326	36,384	32,665

Note: Cell values represent the difference between estimated lifetime future benefits (Table A3) and total estimated costs in Connecticut from models with and without controls (Table A4). Controls include a quadratic on total enrollment, percentage of students with an IEP, percentage of FRPL-eligible students, percentage of students who are Black, and percentage of students who are Hispanic. Shading corresponds to the amount of the net benefit; cells with darker shading have relatively higher net benefits. CTE wage premium is held constant at the starting CTE premium level from ages 18-25 and linearly smoothed to zero by age 65.

Table 7: Net benefits of CTE in Massachusetts

	Interest rate			
	0.02	0.03	0.04	0.05
Starting size of CTE premium				
With controls				
5%	19,062	21,314	22,587	21,549
10%	26,545	31,364	36,174	40,029
15%	34,027	41,413	49,761	58,509
20%	41,510	51,462	63,348	76,989
25%	48,992	61,512	76,935	95,469
30%	56,475	71,561	90,522	113,949
35%	63,957	81,611	104,108	132,429
40%	71,440	91,660	117,695	150,909
45%	78,922	101,709	131,282	169,388
50%	86,405	111,759	144,869	187,868
Without controls				
5%	(6,110)	(18,892)	(41,344)	(79,654)
10%	1,373	(8,843)	(27,757)	(61,174)
15%	8,855	1,207	(14,170)	(42,694)
20%	16,338	11,256	(583)	(24,215)
25%	23,820	21,305	13,004	(5,735)
30%	31,303	31,355	26,591	12,745
35%	38,785	41,404	40,178	31,225
40%	46,268	51,454	53,765	49,705
45%	53,750	61,503	67,352	68,185
50%	61,233	71,552	80,939	86,665

Note: Cell values represent the difference between estimated lifetime future benefits (Table 3) and total estimated costs in Massachusetts from models with and without controls (Table 4). Controls include a quadratic on total enrollment, percentage of students with an IEP, percentage of FRPL-eligible students, percentage of students who are Black, and percentage of students who are Hispanic. Shading corresponds to the amount of the net benefit; cells with darker shading have relatively higher net benefits. CTE wage premium is held constant at the starting CTE premium level from ages 18-25 and linearly smoothed to zero by age 65.

Technical Appendix

Calculation of future value of additional state tax revenue from CTE premium

To generate estimates presented in Table A1 of the future value of state tax revenue from additional lifetime earnings, we use data from the 2019 U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements (CPS ASEC). Values are converted to 2020 dollars using the CPI adjustment factor. We rely on earnings data for the overall population and the population of adult males by age group. We separately estimate lifetime future benefits for both the population overall and for the population of individuals whose highest level of educational attainment is a high school diploma.

We generate estimates of the lifetime earnings premium of CTE participation across a range of premia (i.e., 5%-50%) established by previous literature. In our preferred specification, the CTE premium for each level is held constant from ages 18-25 and is linearly smoothed to zero by age 65. In our supplementary analyses, the CTE premium is constant from age 18-25 and linearly smoothed to zero by age 45. State tax revenue is calculated as the future value of lifetime state tax liability divided by the future value of lifetime earnings. In this case, state tax revenue represents about 5.5% of the future value of lifetime earnings.

To calculate the future value of additional state tax revenue from the CTE earnings premium, we first linearly interpolate earnings across age groups and apply the relevant CTE premium to each age group earnings average. Next, we calculate the 5.5% difference in state tax revenue for each age group average, which we then inflate based on the range of interest rates (i.e., 0.02-0.05). Finally, we sum these amounts across all age groups for each subpopulation (i.e., males overall, males with only a high school diploma, the overall population, and the overall population with only a high school diploma).

Calculation of future value of total public benefits per CTE student

In Table A3, we calculate total future benefits of CTE schools as the sum of benefits accrued from increased graduation rates and CTE earnings premia. Based on results from Brunner et al. (2021), we assume that in Connecticut this benefit only accrues to male students. While all students incur the additional cost of providing CTE, we only apply benefits to the proportion of male students in the CTECS (i.e., 60% of students). As Dougherty (2018) did not estimate significant differences in outcomes by student gender, for Massachusetts we assume that benefits and costs accrue to all students. Based on these prior analyses of RVTS students and CTECS students, we assume a 10% increase in the number of high school graduates produced by CTE schools in comparison to regular public schools. For this 10% of students, we would expect an increase in earnings not only due to being a high school graduate but also for having CTE exposure. Thus, estimates of the state tax revenue increase come from the estimates shown in panel A of Table A1. We also expect that these students accrue additional public benefits from reductions in public health spending, crime reduction, and reded welfare reliance (i.e., the values presented in table A2). We further assume a CTE earnings premium boost for the 75% of students who would otherwise be expected to graduate (i.e., the average graduation rate at comparison group public schools). The value of this earnings premium comes from the range of estimates presented in panel B of Table A1, which represent the future value of the average increase in state tax revenue across the lifetime for all levels of education at or above a high school diploma.

To calculate the range of estimates in Table A3 of the future value of total public benefits per CTE student, we specifically use the following formula:

$$0.1\times(\text{Additional state tax revenue from CTE graduates} + \text{Savings on public health expenditures} + \text{Savings from crime reduction} + \text{Savings on welfare expenditures}) + 0.75\times(\text{Additional state tax revenue from CTE students overall})$$

Table A1: Future value of additional state tax revenue from CTE premium

		Interest rate			
		0.02	0.03	0.04	0.05
Panel A. – High school diploma only					
Starting size of CTE premium – Males					
	5%	5,547	7,516	10,253	14,071
	10%	11,094	15,032	20,506	28,143
	15%	16,641	22,548	30,759	42,214
	20%	22,188	30,064	41,012	56,286
	25%	27,735	37,580	51,266	70,357
	30%	33,282	45,096	61,519	84,428
	35%	38,829	52,612	71,772	98,500
	40%	44,376	60,128	82,025	112,571
	45%	49,923	67,644	92,278	126,643
	50%	55,470	75,160	102,531	140,714
Starting size of CTE premium – Overall					
	5%	7,325	9,925	13,540	18,582
	10%	14,651	19,851	27,080	37,165
	15%	21,976	29,776	40,620	55,747
	20%	29,301	39,702	54,160	74,330
	25%	36,626	49,627	67,700	92,912
	30%	43,952	59,553	81,240	111,494
	35%	51,277	69,478	94,780	130,077
	40%	58,602	79,403	108,320	148,659
	45%	65,927	89,329	121,860	167,241
	50%	73,253	99,254	135,400	185,824
Panel B. – All levels of education					
Starting size of CTE premium – Males					
	5%	9,144	12,226	16,458	22,292
	10%	18,289	24,453	32,917	44,583
	15%	27,433	36,679	49,375	66,875
	20%	36,578	48,905	65,833	89,167
	25%	45,722	61,132	82,292	111,459
	30%	54,866	73,358	98,750	133,750
	35%	64,011	85,584	115,208	156,042
	40%	73,155	97,811	131,667	178,334
	45%	82,299	110,037	148,125	200,626
	50%	91,444	122,263	164,584	222,917
Starting size of CTE premium – Overall					
	5%	9,000	12,076	16,311	22,162
	10%	18,000	24,152	32,621	44,324
	15%	27,000	36,227	48,932	66,487
	20%	36,000	48,303	65,242	88,649
	25%	45,000	60,379	81,553	110,811
	30%	54,000	72,455	97,863	132,973
	35%	63,000	84,531	114,174	155,135

40%	72,000	96,606	130,484	177,298
45%	81,000	108,682	146,795	199,460
50%	90,000	120,758	163,106	221,622

Note: Values are based on 2019 earnings data from the 2019 U.S. Census Bureau, Current Population Survey, Annual Social and Economic Supplements (CPS ASEC). Values have been converted to 2020 dollars using the CPI adjustment factor. See Technical Appendix for details on the calculation of estimates.

Table A2: Future value of benefits from public health, crime reduction, and welfare savings per additional high school graduate

	Interest rate			
	0.02	0.03	0.04	0.05
Public health savings	137,528	213,334	329,523	506,878
Criminal justice system savings	90,327	140,116	216,427	332,912
Welfare savings	10,187	15,803	24,409	37,547

Note: Values are based on Levin et al. (2007) estimates of the overall average lifetime public savings per new expected high school graduate. Values have been converted to 2020 dollars using the CPI adjustment factor.

Table A3: Total future value of benefits from CTE

	Interest rate			
	0.02	0.03	0.04	0.05
Panel A. – Massachusetts				
Starting size of CTE premium				
5%	50,193	71,038	101,650	146,708
10%	57,675	81,087	115,237	165,188
15%	65,158	91,136	128,824	183,668
20%	72,640	101,186	142,411	202,147
25%	80,123	111,235	155,998	220,627
30%	87,605	121,285	169,585	239,107
35%	95,088	131,334	183,172	257,587
40%	102,570	141,383	196,759	276,067
45%	110,053	151,433	210,345	294,547
50%	117,535	161,482	223,932	313,027
Panel B. – Connecticut				
Starting size of CTE premium				
5%	30,074	42,546	60,859	87,812
10%	34,522	48,499	68,881	98,688
15%	38,969	54,451	76,902	109,563
20%	43,417	60,404	84,924	120,439
25%	47,865	66,357	92,945	131,315
30%	52,313	72,310	100,967	142,190
35%	56,761	78,263	108,988	153,066
40%	61,208	84,215	117,010	163,941
45%	65,656	90,168	125,031	174,817
50%	70,104	96,121	133,052	185,692

Note: Based on benefits accruing from a 10% increase in CTE high school graduates, and a CTE earnings premium boost for the 75% of students who are already expected to graduate. See Technical Appendix for details on the calculation of estimates.

Table A4: Future value of additional per pupil expenditure for CTE

	Interest rate			
	0.02	0.03	0.04	0.05
With controls				
Connecticut	40,185	64,187	102,061	161,565
New Jersey	54,614	87,233	138,705	219,573
Massachusetts	31,130	49,723	79,063	125,158
Pennsylvania	(7,505)	(11,987)	(19,060)	(30,172)
Delaware	77,615	123,973	197,124	312,051
Without controls				
Connecticut	38,062	60,795	96,668	153,028
New Jersey	71,239	113,788	180,930	286,416
Massachusetts	56,302	89,930	142,994	226,362
Pennsylvania	(8,271)	(13,212)	(21,007)	(33,255)
Delaware	53,711	85,791	136,412	215,943

Note: CTE = career and technical education. Future value calculated as the total per student cost of 4 years of obtaining a CTE-specific high school education over student career (ages 20-65). The regression-adjusted estimates of additional per pupil expenditures at CTE schools are $3,883.30 per year in Connecticut, $3,008.25 per year in Massachusetts, $5,277.56 in New Jersey, -$725.20 in Pennsylvania, and $7,500.26 in Delaware. The non-adjusted estimates of additional per pupil expenditures at CTE schools are $3,678.10 per year in Connecticut, $5,440.73 per year in Massachusetts, $6,884.15 in New Jersey, -$799.30 in Pennsylvania, and $5,190.26 in Delaware. Regression-adjusted estimates come from Column 4 of tables 3 and 4 and appendix tables A5, A6, and A7.

Table A5: Number of schools in analytic sample by school type and fiscal year of expenditure data

District type	Expenditure data fiscal year		
	2017-18	2018-19	2019-20
Regular public school high schools	5	25	1
Connecticut Technical Education and Career System (CTECS) schools	0	17	0

Note: Data on school expenditures come from published district budgets retrieved from school district websites.

Table A6: Summary statistics for New Jersey school districts

	(1) All Districts	(2) Regular Districts	(3) Technical Districts	(4) Difference (2) – (3)
Characteristics of student population				
% FRPL-eligible students	27.74	27.35	34.83	-7.48***
	(24.0)	(23.9)	(24.3)	
% students with an IEP	17.92	17.97	16.52	1.46
	(6.2)	(5.4)	(18.1)	
% ELL students	3.00	3.08	0.88	2.20***
	(4.2)	(4.3)	(1.4)	
% female students	48.42	48.40	48.79	-0.39
	(2.3)	(1.8)	(6.8)	
% Hispanic students	17.64	17.41	21.87	-4.46***
	(18.7)	(18.8)	(17.0)	
% Black students	12.26	12.03	16.50	-4.47***
	(16.7)	(16.8)	(14.5)	
% Non-White/non-Black/non-Hispanic students	8.59	8.58	8.73	-0.15
	(9.3)	(9.4)	(9.0)	
Characteristics of district				
Total students	3413.70	3534.75	1246.41	2288.34***
	(3966.7)	(4037.3)	(819.7)	
Pupil/teacher ratio	12.61	12.74	9.85	2.89***
	(2.8)	(2.7)	(2.8)	
Total current expenditures per pupil	20522.60	20159.37	26923.94	-6764.58***
	(6889.2)	(6570.1)	(8955.3)	
Current capital outlay expenditures per pupil	1188.90	1077.88	3145.40	-2067.52***
	(2406.3)	(2110.4)	(5039.7)	
Current instructional expenditures per pupil	10055.17	9935.40	12166.00	-2230.61***
	(2424.3)	(2327.9)	(3045.8)	
Current support services expenditures per pupil	6521.49	6385.97	8909.80	-2523.83***
	(2019.3)	(1866.7)	(2921.3)	
Current expenditures per pupil for other programs	578.94	566.28	802.01	-235.73***
	(1220.3)	(1238.8)	(797.8)	
Current non-elementary/secondary expenditures per pupil	188.43	105.60	1648.24	-1542.64***
	(650.3)	(309.7)	(1987.3)	
Total revenues per pupil	20749.17	20404.81	26818.04	-6413.23***
	(6865.5)	(6581.9)	(8702.4)	
Observations	4302	4071	231	4302

Note: FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. ELL = English Language Learner. Standard deviations in parentheses. Difference column represents the difference between technical school districts and regular districts. * p <.05, ** p <.01, *** p <.001

Table A7: Summary statistics for Pennsylvania school districts and ATCs

	(1) All Districts	(2) Regular Districts	(3) ATCs	(4) Difference (2) – (3)
Characteristics of student population				
% FRPL-eligible students	38.26	38.16	42.77	-4.61**
	(18.8)	(18.8)	(17.2)	
% students with an IEP	17.35	17.53	0.00	17.53***
	(4.0)	(3.6)	(0.0)	
% ELL students	1.24	1.25	0.72	0.53***
	(2.4)	(2.4)	(1.2)	
% female students	48.35	48.48	42.62	5.85***
	(1.7)	(1.4)	(3.9)	
% Hispanic students	4.39	4.37	5.06	-0.69
	(8.2)	(8.2)	(6.6)	
% Black students	6.66	6.68	5.84	0.84
	(13.3)	(13.4)	(6.8)	
% Non-White/non-Black/non-Hispanic students	3.83	3.86	2.52	1.34***
	(3.9)	(3.9)	(2.6)	
Characteristics of district				
Total enrollment	3225.02	3277.97	836.54	2441.43***
	(7063.4)	(7131.8)	(551.9)	
Pupil/teacher ratio	14.18	14.18	14.04	0.14
	(1.8)	(1.7)	(4.1)	
Total current expenditures per pupil	15660.54	15679.45	14807.52	871.92
	(3729.1)	(3711.5)	(4387.4)	
Current capital outlay expenditures per pupil	1088.48	1095.43	774.84	320.59*
	(1841.2)	(1848.9)	(1425.3)	
Current instructional expenditures per pupil	7840.46	7852.42	7300.98	551.44*
	(1542.7)	(1519.5)	(2308.2)	
Current support services expenditures per pupil	4371.87	4360.55	4882.64	-522.09**
	(971.9)	(951.5)	(1573.5)	
Current expenditures per pupil for other programs	510.81	503.70	831.53	-327.83**
	(221.2)	(137.1)	(1147.4)	
Current non-elementary/secondary expenditures per pupil	90.22	78.32	627.06	-548.74***
	(193.0)	(122.5)	(868.2)	
Total revenues per pupil	15783.76	15825.06	13920.65	1904.41***
	(3235.0)	(3159.6)	(5380.1)	
Observations	4565	4466	99	4565

Note: ATCs = Area Technical Centers. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. ELL = English Language Learner. Standard deviations in parentheses. Difference column represents the difference between technical school districts and regular districts. * p <.05, ** p <.01, *** p <.001

Table A8: Summary statistics for Delaware school districts and ATCs

	(1) All Districts	(2) Regular Districts	(3) ATCs	(4) Difference (2) – (3)
Characteristics of student population				
% FRPL-eligible students	39.62	42.36	25.00	17.36***
	(14.0)	(13.3)	(7.1)	
% students with an IEP	14.83	15.66	10.43	5.23***
	(3.0)	(2.4)	(2.1)	
% ELL students	4.44	5.14	0.59	4.55***
	(3.8)	(3.7)	(0.8)	
% female students	48.87	48.54	50.63	-2.09***
	(1.4)	(1.0)	(2.0)	
% Hispanic students	9.73	10.17	7.37	2.81***
	(6.6)	(6.8)	(4.8)	
% Black students	28.54	29.15	25.28	3.87*
	(10.2)	(10.2)	(9.8)	
% Non-White/non-Black/non-Hispanic students	3.96	4.14	3.01	1.13**
	(2.3)	(2.3)	(2.1)	
Characteristics of district				
Total enrollment	6123.43	6858.99	2200.42	4658.58***
	(4631.6)	(4655.9)	(1421.0)	
Pupil/teacher ratio	14.79	15.13	12.94	2.19***
	(1.4)	(1.2)	(1.3)	
Total current expenditures per pupil	15008.70	14189.19	19379.45	-5190.26***
	(3747.2)	(3149.2)	(3680.6)	
Current capital outlay expenditures per pupil	1716.00	1624.36	2204.77	-580.41
	(2067.2)	(1955.6)	(2551.8)	
Current instructional expenditures per pupil	7574.88	7359.12	8725.58	-1366.45***
	(1437.7)	(1399.0)	(1048.9)	
Current support services expenditures per pupil	4185.69	3919.53	5605.18	-1685.65***
	(1035.8)	(848.6)	(751.6)	
Current expenditures per pupil for other programs	524.02	521.26	538.76	-17.50
	(157.2)	(148.8)	(197.3)	
Current non-elementary/secondary expenditures per pupil	474.55	167.71	2111.00	-1943.29***
	(1006.0)	(715.5)	(706.2)	
Total revenues per pupil	14999.06	14121.55	19679.10	-5557.55***
	(3946.8)	(3413.7)	(3261.6)	
Observations	304	256	48	304

Note: ATCs = Area Technical Centers. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. ELL = English Language Learner. Standard deviations in parentheses. Difference column represents the difference between technical school districts and regular districts. * p <.05, ** p <.01, *** p <.001

Table A9: Estimates of difference in district-level per pupil total current expenditures – New Jersey

	(1)	(2)	(3)	(4)	(6)
Technical school district	6884.2***	6598.4***	5871.3***	5277.6**	4211.8**
	(1592.9)	(1603.9)	(1595.5)	(1629.2)	(1360.7)
Total enrollment		-0.13	-0.80***	-0.93***	-0.66***
		(0.109)	(0.137)	(0.135)	(0.108)
Total enrollment squared			2.98e-5***	3.15e-5***	2.37e-5***
			(5.66e-6)	(6.19e-6)	(3.97e-6)
Percentage of FRPL-eligible students				-3.12	-29.89
				(18.14)	(15.81)
Percentage of students with an IEP				5.23	5.53
				(103.89)	(86.56)
Percentage of students who are Black				59.77**	58.54***
				(20.11)	(16.43)
Percentage of students who are Hispanic/Latino				23.34	46.31**
				(19.88)	(17.28)
Student-teacher ratio					-1425.4***
					(300.3)
Constant	16257.2***	16775. 6***	18464.2***	17789.1***	34985.7***
	(253.7)	(473.7)	(461.0)	(1435.3)	(3862.4)
R^2	0.123	0.128	0.175	0.198	0.344
Adjusted R^2	0.120	0.125	0.172	0.194	0.341
F	41.22	38.91	39.90	34.59	41.43
DF model	13	14	15	19	20
DF residual	512	512	512	512	512
Number of observations	4302	4302	4302	4302	4302
Number of districts	513	513	513	513	513

Note: FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A10: Estimates of difference in district-level per pupil total current expenditures – Pennsylvania

	(1)	(2)	(3)	(4)	(6)
ATC	-799.3	-702.6	-610.8	-725.2	-632.9
	(1122.1)	(1125.1)	(1133.1)	(1168.3)	(1067.0)
Total enrollment		0.040***	0.086	-0.104	-0.030
		(0.011)	(0.058)	(0.062)	(0.056)
Total enrollment squared			-3.47e-7	6.36e-7	2.53e-7
			(3.70e-7)	(3.91e-7)	(3.40e-7)
Percentage of FRPL-eligible students				-38.47***	-50.29***
				(7.921)	(6.743)
Percentage of students who are Hispanic/Latino				13.07	35.47**
				(14.40)	(12.57)
Percentage of students who are Black				141.0***	137.9***
				(17.84)	(18.85)
Student-teacher ratio					-690.3***
					(78.41)
Constant	13946.4***	13811.6***	13679.7***	14471.8***	24360.4***
	(157.6)	(159.4)	(220.3)	(345.4)	(1167.4)
R^2	0.120	0.126	0.127	0.301	0.403
Adjusted R^2	0.118	0.124	0.125	0.299	0.401
F	79.81	74.28	143.98	120.94	228.18
DF model	9	10	11	14	15
DF residual	513	513	513	513	513
Number of observations	4565	4565	4565	4565	4565
Number of districts	514	514	514	514	514

Note: ATC = Area Technical Center. FRPL = free or reduced-price lunch program. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A11: Estimates of difference in district-level per pupil total current expenditures – Delaware

	(1)	(2)	(3)	(4)	(6)
ATC	5190.3***	5855.8***	5840.1***	7500.3***	4533.4
	(619.0)	(750.5)	(818.4)	(1201.2)	(2165.7)
Total enrollment		0.143*	0.130	0.147	-0.005
		(0.066)	(0.263)	(0.273)	(0.228)
Total enrollment squared			7.14e-7	1.25e-6	5.99e-6
			(1.26e-5)	(1.13e-5)	(9.22e-6)
Percentage students with an IEP				174.5	82.60
				(182.6)	(128.3)
Percentage FRPL-eligible students				44.19	2.250
				(35.26)	(47.01)
Percentage students who are Black				-12.48	7.081
				(54.35)	(41.52)
Percentage of students who are Hispanic/Latino				-29.50	18.18
				(78.18)	(76.66)
Student-teacher ratio					-709.8
					(483.0)
Constant	10714.5***	9772.7***	9808.4***	6035.7*	19469.5
	(284.6)	(633.7)	(1034.7)	(2152.2)	(9292.9)
R^2	0.527	0.554	0.554	0.581	0.619
Adjusted R^2	0.501	0.528	0.526	0.548	0.588
F	331.95	345.55	326.61	780.28	82.25
DF model	16	17	17	17	17
DF residual	18	18	18	18	18
Number of observations	304	304	304	304	304
Number of districts	19	19	19	19	19

Note: ATC = Area Technical Center. FRPL = free or reduced-price lunch program. IEP = Individualized Education Program. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A12: Estimates of difference in district-level per pupil expenditures by expense category – New Jersey

	(1) Total current expenditures	(2) Current capital outlay expenditures	(3) Current instructional expenditures	(4) Current support services expenditures	(5) Current non-elementary/ secondary expenditures
Technical school district	4211.801**	1830.249***	1457.218**	2023.783***	1499.266***
	(1360.729)	(407.355)	(525.468)	(508.117)	(306.710)
Constant	34985.742***	2403.235***	15902.235***	10393.662***	519.771**
	(3862.372)	(457.036)	(1612.417)	(1194.468)	(172.792)
R^2	0.344	0.063	0.455	0.404	0.321
Adjusted R^2	0.341	0.059	0.453	0.401	0.318
F	41.43	6.27	160.98	77.84	5.34
DF model	20	20	20	20	20
DF residual	512	512	512	512	512
Number of observations	4302	4302	4302	4302	4302
Number of districts	513	513	513	513	513

Note: All models include controls for a quadratic on total enrollment, percentage of students with an IEP, percentage of FRPL-eligible students, percentage of students who are Black, percentage of student who are Hispanic, and student teacher ratio. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A13: Estimates of difference in district-level per pupil expenditures by expense category – Pennsylvania

	(1) Total current expenditures	(2) Current capital outlay expenditures	(3) Current instructional expenditures	(4) Current support services expenditures	(5) Current non-elementary/ secondary expenditures
ATC	-725.194	-286.759	-416.992	520.918	555.866*
	(1168.313)	(151.064)	(635.502)	(425.796)	(224.998)
Constant	14471.800***	1589.217***	7111.187***	4185.724***	37.212*
	(345.422)	(131.438)	(136.243)	(116.686)	(15.467)
R^2	0.301	0.016	0.339	0.253	0.272
Adjusted R^2	0.299	0.013	0.337	0.251	0.270
F	120.94	4.88	226.93	153.30	38.49
DF model	14	14	14	14	13
DF residual	513	513	513	513	513
Number of observations	4565	4565	4565	4565	4565
Number of districts	514	514	514	514	514

Note: ATC = Area Technical Center. All models include controls for a quadratic on total enrollment, percentage of FRPL-eligible students, percentage of students who are Black, percentage of student who are Hispanic, and student teacher ratio. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A14: Estimates of difference in district-level per pupil expenditures by expense category – Delaware

	(1) Total current expenditures	(2) Current capital outlay expenditures	(3) Current instructional expenditures	(4) Current support services expenditures	(5) Current non-elementary/ secondary expenditures
ATC	4533.352	427.123	1301.290*	1872.528***	1386.965**
	(2165.745)	(1786.829)	(539.939)	(341.611)	(472.395)
Constant	19469.462	75.993	9119.267***	4951.110**	3627.229
	(9292.869)	(7393.936)	(2148.158)	(1374.283)	(2113.099)
R^2	0.619	0.079	0.852	0.772	0.615
Adjusted R^2	0.588	0.003	0.840	0.753	0.583
F	82.25	11.69	2823.21	355.18	140.42
DF model	17	17	17	17	17
DF residual	18	18	18	18	18
Number of observations	304	304	304	304	304
Number of districts	19	19	19	19	19

Note: ATC = Area Technical Center. All models include controls for a quadratic on total enrollment, percentage of students with an IEP, percentage of FRPL-eligible students, percentage of students who are Black, percentage of student who are Hispanic, and student teacher ratio. Standard errors clustered by school district in parentheses. Models include year fixed effects. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$