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The Opportunity Costs of Career and Technical Education: Coursetaking Tradeoffs for High School CTE Students

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Career and Technical Education (CTE) has long played a substantial, though controversial, role within America's public schools. While supporters argue that CTE may increase student engagement and prepare students for success in the workforce, detractors caution that CTE may inhibit students' access to the rigorous academic coursework needed for college and high-status careers. As students' time in high school is a relatively fixed resource, this paper seeks to better understand the extent to which CTE is associated with trade-offs within students' high school curricula. Using a robust statewide longitudinal data system, this study explores the extent to which CTE may limit course taking in a wide range of subjects (including core academic subjects, electives, and Advanced Placement courses). Special attention is paid to how curricular trade-offs may occur differently among different student populations, keeping in mind the legacy of tracking as a long-employed mechanism for reducing opportunity. On average, results indicate that CTE courses do crowd out students' enrollment in non-CTE elective areas, but that CTE does not lead to large declines in college preparatory coursetaking, though there are nuances for certain student populations. Overall, these findings counter longstanding narratives that CTE participation limits student access to college preparatory coursework.

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Abstract: Career and Technical Education (CTE) has long played a substantial, though controversial, role within America's public schools. While supporters argue that CTE may increase student engagement and prepare students for success in the workforce, detractors caution that CTE may inhibit students' access to the rigorous academic coursework needed for college and high-status careers. As students' time in high school is a relatively fixed resource, this paper seeks to better understand the extent to which CTE is associated with trade-offs within students' high school curricula. Using a robust statewide longitudinal data system, this study explores the extent to which CTE may limit course taking in a wide range of subjects (including core academic subjects, electives, and Advanced Placement courses). Special attention is paid to how curricular trade-offs may occur differently among different student populations, keeping in mind the legacy of tracking as a long-employed mechanism for reducing opportunity. On average, results indicate that CTE courses do crowd out students' enrollment in non-CTE elective areas, but that CTE does not lead to large declines in college preparatory coursetaking, though there are nuances for certain student populations. Overall, these findings counter longstanding narratives that CTE participation limits student access to college preparatory coursework.

Keywords: Career and technical education, Vocational education, High school, Coursetaking, Curriculum, College Preparation, Tracking

Career and Technical Education (CTE) has long played a substantial, though at times controversial, role within America's system of public education. Historically referred to as vocational education, debates over CTE are rooted in foundational questions about the goals of public education, touching on such key topics as workforce preparation, academic rigor, and equity of opportunity across diverse student populations. In today's high schools, CTE plays a prominent role. The US Department of Education estimates that approximately 77% of students take at least one CTE course during high school (2019), but CTE coursetaking remains an understudied area of research at the secondary school level.

In much of the academic literature about CTE and vocational education, CTE has long been closely connected with research on tracking. Vocational "tracks" were historically used as a way to maintain a degree of separation between racially minoritized students and their white peers in the wake of government-mandated racial school integration (Oakes, 1983; Anderson, 1982). Scholars in the 1970s and 1980s found compelling evidence that CTE was often low-quality, and limited students of color, low-income students, and students with disabilities from pursuing postsecondary education and socially-mobile career paths (Bowles & Gintis, 1976; Tyack, 1974; Grubb & Lazerson, 1982, among others).

However, unlike in many European countries and in previous eras in the US, where students were *explicitly* separated into distinct vocational and college preparatory tracks (Dougherty & Ecton, 2021), this is far less common in America's public schools today (Stone & Aliaga, 2005; Yettick et al, 2012). Many policymakers now have come to view the skills necessary for college-readiness and career-readiness to be closely aligned (Lucas, 1999; ACT, 2006; Obama, 2011), rather than as separate "college-preparatory" versus "vocational" tracks. Moreover, states now align college readiness requirements with high school graduation requirements (Mishkind, 2014), making it especially important to revisit assumptions about the extent to which CTE complements or restricts postsecondary preparation. In an era of CTE heavily focused on "College and Career Readiness,"

there is a striking absence of research on the extent to which CTE still may inhibit students' college preparatory curriculum.

Furthermore, students' time in high school is a relatively fixed resource, but little is understood about which courses students do *not* take in order to engage with CTE. In a best-case scenario, students may simply use CTE as a focused way to spend their elective time while meeting graduation requirements. On the other hand, some might worry if CTE coursetaking leads students to take fewer college preparatory classes. Moreover, while intensive marginal curricular choices (in which students substitute CTE classes for other classes) are important, it is also possible that for some students, change may occur at the *extensive* margin, with students taking CTE courses in place of non-credit bearing classes like study hall or test preparation courses. It may be that, rather than reducing non-CTE coursetakeing, CTE could simply induce more coursetaking overall. Given the longstanding debates about CTE and its role in equity and workforce preparation, it is important to better understand these trade-offs that students and schools make at both intensive and extensive margins in order to engage with CTE.

While there has been an increase in research on the effects of CTE in today's context, these studies generally focus directly on the actual treatment (CTE classes or concentration), with little attention to the *opportunity costs* that may be associated with CTE coursetaking. However, given long-running debates about the importance of developing general versus specific skills (for example, Hanushek, et al., 2017), it is important to understand whether CTE still places limitations on student's ability to develop general skills, particularly those skills that prepare students for postsecondary education. One potential mechanism through which CTE may matter, but that has remained unstudied, is that students who take CTE courses are, almost by definition, making curricular trade-offs. If high school seat time is relatively fixed, one potential way CTE may impact students is through the courses they do *not* take in order to make room for CTE in their schedules.

This paper uses a robust state longitudinal data system (SLDS), including coursetaking data, along with student and school characteristics, to isolate the relationship between CTE and other components of high school students' curricular experience. I employ multiple quantitative approaches to answer the following questions:

Research Question 1. To what extent does CTE engagement explain different rates of coursetaking in core academic college-preparatory courses (Math, Science, Social Studies, English/Language Arts)?

Research Question 2. To what extent does CTE engagement explain different rates of coursetaking in other elective areas (including Advanced Placement/International Baccalaureate, Fine Arts, Physical Education/Health, World Languages, and Study Hall/Test Prep Courses)?

Research Question 3. Does the relationship between CTE coursetaking and coursetaking in other areas differ by student population? Specifically, to the extent that substitution patterns exist (RQ1 and RQ2), how does substitution differ for students by gender, racial/ethnic identity, disability, English learner status, socioeconomic status, prior academic achievement, and school type (CTE-dedicated high schools versus comprehensive high schools)? This close attention to heterogeneous relationships is especially policy relevant given that students from particular demographics have historically been overrepresented in CTE and have been the subject of negative tracking in CTE.

Research Question 4. Do the impacts of CTE differ at different levels of CTE engagement? In other words, does the change in non-CTE coursetaking induced by a student taking their first or second CTE course differ from any curricular changes induced by taking larger numbers of CTE courses?

This paper proceeds as follows. I first discuss relevant historical context about CTE, followed by a brief overview of research on outcomes from newer CTE programs. I then describe the administrative data from Massachusetts that is used in this work and the analytic strategy. I conclude with results, limitations of this work, and a discussion of implications for policy and practice.

Literature Review

Historical Context for Vocational Education

Since the expansion of universal schooling, American public education has grappled with several tensions over the desired goals and purpose of education (Kantor & Tyack, 1982; Goldin & Katz, 2008). One of the most distinctive characteristics of American schooling has been a long-stated goal of equity – indeed, the American universal public high school movement was a revolutionary push for egalitarianism.

Parallel to the growth of universal high school, however, was an argument that public schools' primary goal should be to prepare students for the workforce, or to "act as a transmitter between human supply and industrial demand" (Meyer, 1915). Many scholars pointed to the "sorting function" of schools, in which schools sort students in different "tracks" based on skill into the most appropriate training for the jobs they are best-suited to pursue (Bowles & Gintis, 1976; Tyack, 1974; Grubb & Lazerson, 1982).

In the 1970s and 1980s, the national perception of CTE was especially influenced by this idea that CTE was used as a tool for sorting students. Given the historical context of racial integration of public schools, vocational 'tracks' were used to keep racially minoritized students separated from their white peers (Anderson, 1982; Oakes, 1983), leading to movement away from CTE in the 1990s and early 2000s, as high schools emphasized standards and moved towards a

"College for All" framework (Rosenbaum, 2001; Grubb & Lazerson, 2005; Hudson, 2014; Dougherty & Lombardi, 2016).

Recent years have seen a resurgence of interest in CTE from policymakers and school leaders. Some advocates and scholars have pointed to low rates of college completion and high levels of debt among college dropouts (Rosenbaum, 2001; Stone and Aliaga, 2005). Others have called for greater alignment between the skills needed for school and workforce, and highlighted a need to promote training for skills in-demand by employers that do not necessarily require a four-year degree, often referred to as "middle skills jobs" (Schwartz, 2016; Holzer and Baum, 2017; Caplan, 2018). Alongside this, CTE has increasingly emphasized enrollment in applied STEM courses in recent years (Plasman et al., 2020), including among students with disabilities (Theobald et al., 2020). The most recent reauthorization of the Perkins Act (the federal government's primary program supporting CTE) makes this shift particularly explicit, with new language that encourages funding for CTE programs that prepare students for college *and* career, rather than programs that lead students directly into the workforce.

Recent Research on Returns to CTE

While a growing body of evidence supports the contention that CTE may improve some student outcomes, many of these studies generally face challenges stemming from selection bias, since students selecting into CTE are likely to be meaningfully different than non-CTE students. However, these studies consistently show benefits to employment and earnings in the short and medium term (Meer, 2007; Bishop & Mane, 2004, 2005; Mane, 1999), as well as high school graduation (Gottfried & Plasman, 2018; Plank et al., 2008; Stone & Aliaga, 2005).

In a relatively small number of studies supporting causal inference, research generally shows similar findings. Kemple & Willner (2008), for example, use random assignment for admission to oversubscribed career academies, finding a positive impact on earnings (driven by male students).

Similarly, Hemelt et al (2019) also find evidence of improvements in attendance, high school graduation and college-going (with benefits accruing to male students) in a North Carolina career academy with lottery-based admission. Dougherty (2018) and Brunner et al. (2021) both leverage application processes at oversubscribed vocational schools in Massachusetts and Connecticut, respectively, employing regression discontinuity designs to find increased on-time graduation rates and higher post high-school earnings after high school for barely-admitted students, compared to those who just missed the admission threshold.

There is also increasing evidence that the type and nature of CTE participation matters for student outcomes. Ecton & Dougherty (2023), also using data from Massachusetts, find a large degree of variation in outcomes across the different CTE clusters, with some clusters associated with stronger labor market outcomes, and others associated with stronger postsecondary education outcomes. Kreisman & Stange (2018), find that the stronger wage advantages for CTE earnings are largely driven by students who take upper-level CTE coursework, indicating that depth of CTE concentration may be especially meaningful for students. Bonilla (2020), using a regression discontinuity in a California funding formula, finds that high schools saw decreased drop-out rates when they received additional funding, suggesting that CTE programs may have stronger impacts when better funded.

All told, there is increasing evidence that CTE can benefit students, at least in some contexts. Still, far too little is understood about the mechanisms through which these benefits may accrue, and the extent to which different student populations may respond in heterogenous ways to CTE.

Data

Massachusetts provides a robust landscape in which to conduct this study, with variation across urban, suburban, and rural populations, as well as sufficient racial and socioeconomic variation to allow for consideration of heterogeneous relationships. Moreover, CTE is offered in

two distinct contexts in Massachusetts – with approximately half of CTE concentrators engaging with CTE courses within comprehensive high schools, and the other half enrolling in public schools of choice that are explicitly CTE-dedicated. At these CTE-dedicated high schools, students can apply to attend if they reside within a defined region; some CTE-dedicated high schools are highly competitive and oversubscribed, while others are not competitive and undersubscribed. Students at CTE-dedicated high schools universally concentrate in CTE; students explore multiple CTE clusters in their 9th grade year before choosing a focus area starting in 10th grade. While the main focus of the study considers students across both school settings, subgroup analyses across the different contexts provide a particularly useful opportunity to generalize to different states and localities in which CTE operates either within a comprehensive school *or* at a CTE-dedicated school setting.

This study leverages a robust statewide longitudinal data system (SLDS) available through a partnership with the Massachusetts Department of Elementary and Secondary Education. Student-level data include a broad range of student records, including demographic information, attendance, state standardized test scores meant to assess student learning prior to high school, graduation, and coursetaking records, including CTE coursetaking. Coursetaking and administrative records include all students attending public schools in Massachusetts from the 2011-2012 to 2017-2018 school years, which allows me to capture the full period of expected enrollment (assuming a four-year high school timeline) for four graduating cohorts of students (those with on-time graduation from spring of 2015 through 2018, for a total of 310,524 individual students).

Given the robustness of the available data, the study allows for multiple ways of measuring CTE engagement. As a primary measure, I focus on the Massachusetts designation of CTE concentrators, which are those students identified by their school as being enrolled in a CTE program for two or more academic years ("CTE concentrators"), compared to those students not identified as CTE concentrators ("Non-concentrators"). Massachusetts uses this definition of CTE concentrators for federal reporting purposes, making it a designation with financial implications

through the Perkins Act, and helping with generalization to other states that report CTE concentrators to receive federal block grants. By comparing CTE concentrators to non-concentrators, I can assess the impacts for students who make a concerted, focused investment in CTE.

In addition to the school-generated CTE concentrator label, and because many students engage with CTE without concentrating, I also use coursetaking data to estimate expected differences associated with taking each additional CTE course on coursetaking in other areas. This measure allows me to capture CTE participation for those who students who are not formally labelled as concentrators, while also leveraging the fact that some CTE concentrators take substantially more CTE courses than required by the formal concentrator threshold. Some students (especially those attending CTE-dedicated schools) likely make a clear decision about whether or not to concentrate, but for other students, the marginal choice may more likely be "Should I enroll in an additional CTE course next term?" By using both binary and continuous approaches to measures of CTE participation, I consider how these choices to take additional CTE courses matter for student coursetaking outcomes, among both concentrators and non-concentrators. Moreover, these coursetaking trade-offs may manifest differently for students taking a first or second CTE course, compared to students taking especially large numbers of CTE courses. Since these relationships may be non-linear, the continuous measure allows for an important examination of trade-offs at different rates of CTE coursetaking.

My primary outcomes of interest are the number of courses students take in areas outside of CTE. Specifically, I use 10 non-CTE course categories based on state definitions (ELA, Math, Science, Social Studies, Fine Arts, World Language, PE/Health, Military/JROTC, AP/IB, and Study Hall/Test Prep; see Figure 1 for the distribution of courses taken by students in each subject area). These course types are especially meaningful because they either A) represent courses shown by previous research to support postsecondary enrollment and success, B) represent the primary non-

CTE elective subject areas in Massachusetts high schools, or C.) represent a broad category of generally non-credit bearing or non-academic subject area courses (which I call "Study Hall/Misc"), the vast majority of which are study hall, study skills, test preparation, or support classes for students with disabilities. In order to fulfill the state-recommended MassCore program of study, students must take four courses in ELA and math, three courses in science and social studies, two world language courses, and one fine arts course (Massachusetts Department of Elementary and Secondary Education, 2018).[1] Students who enroll in CTE are also able to opt out of world language course and fine arts course while still completing MassCore, suggesting that these may be categories where trade-offs could be especially likely to occur. Because of the state's recommendations for the number of courses in ELA, math, and to a lesser extent, science and social studies, we might expect that there is less opportunity for coursetaking trade-offs in these core academic categories, though many students do take more than the MassCore-recommended number of courses in those subjects.

I incorporate into my analyses include standard demographic variables shown to predict both participation in CTE and post-high school outcomes of interest. The data include indicators for gender, race, ethnicity, English language status, disability, an indicator of family economic disadvantage, students' town of residence and school attended in 8th and 9th grades. I also include three variables from middle school that capture substantial unobserved heterogeneity in students before they attend high school and are exposed to treatment (CTE classes). These include students' test scores on the required 8th grade Math and English Language Arts exams, and their 8th grade attendance rate. Because these 8th grade characteristics are collected before students attend high school, this provides valuable information about student performance and engagement prior to any exposure to CTE in high school.

[1] Most high school graduation requirements in Massachusetts are set at the local level. The MassCore program of study is recommended by the state, and aims to align the high school program of study with college and workforce expectations.

Analytic Approach

There are clear descriptive differences in academic and elective coursetaking between CTE concentrators and non-concentrators. However, it is unclear whether these descriptive differences are simply due to selection based on unobserved factors or different levels of access to CTE (see Table 1 for descriptive differences among CTE concentrators). For example, I present evidence in Table 2 that CTE concentrators, on average, take fewer AP/IB courses while in high school. This may not be a surprise, given anticipated differential selection into CTE based on preferences and unobserved postsecondary intentions. CTE students also take substantially fewer fine arts and world language courses. There are minor differences in core academic courses, though these differences are largely driven by students who fail to graduate. While these descriptive differences in coursetaking patterns are notable, I attempt to account for differential selection to provide a nuanced look at the trade-offs students make when choosing their courses.

My analytic approach takes full advantage of the scope of the population of public school students in Massachusetts over the nine-year period, allowing for the broadest generalizability across the diverse contexts in which CTE is offered. I use a regression-based framework to consider the predicted change in non-CTE coursetaking for students who were CTE concentrators compared to non-concentrators who are otherwise similar on a wide range of observable characteristics. I fit the following Ordinary Least Squares (OLS) model to answer research questions 1 & 2:

$$(1)\quad Y_{ist} = \beta_1 CTE_i + +\beta_2 Total_i + \boldsymbol{X_i'\gamma} + \pi_s + \tau_t + \epsilon_{ist}$$

Where Y_{ist} is the number of courses student *i* in school *s* and graduating cohort *t* took in a given subject area (e.g., ELA, social studies, world languages, etc.), with individual models fit for each course category. CTE_i is the number of CTE courses student *i* took, and $Total_i$ is the total number of courses a student took. Controlling for the total number of courses students took is essential,

because without this, any increase in CTE_i would largely be a mechanical function of students staying in school longer and taking more classes overall.

Accounting for other factors that might predict coursetaking in Model 1, $\boldsymbol{X_i'}$ represents student demographic characteristics and measures of academic performance and attendance prior to high school to help isolate the impact of CTE. τ_t represents fixed effects for graduating cohort, to account for any factors specific to a given cohort (for example, economic factors). To account for differential access to courses (both CTE and non-CTE), local norms and workforce expectations across different schools and communities, π_s represents fixed effects for high school attended in 9th grade. By incorporating high school fixed effects, I consider the coursetaking behavior of students within the context of students' access to courses and to other students operating within a comparable school environment. These models represent the choices students make, after accounting for their choice of high school.

Since we might *also* be interested in capturing the mediating role of different high school course offerings and school cultures and because I cannot fully account for the extent to which unobserved factors could explain sorting into particular high schools, I also fit identical models that substitute high school fixed effects with town of residence fixed effects. These town of residence fixed effects take account of local economic & other factors that may influence coursetaking. Also, as students in towns throughout the state have the opportunity to opt into CTE-dedicated schools, considering students within the context of their town of residence allows for estimates that incorporate the range of high school choice options students have available to them, given where they live. Throughout the results, I also compare differences in estimates from these two models, which can provide an approximation of how much high school choice explains any observed differences in coursetaking. For example, if I observe strong relationships between CTE and differences in other coursetaking in other subjects in the town of residence fixed effects models, but

these disappear in the high school fixed effects, that would suggest that differences in high school choice and curriculum is the key force behind these differences.

Since this study uses two measures of CTE participation, I also fit a model that incorporates the state's binary definition of a CTE Concentrator:

$$(2)\ Y_{ist} = \beta_1 Concentrator_i + +\beta_2 Total_i + \boldsymbol{X_i'\gamma} + \pi_s + \tau_t + \epsilon_{ist}$$

This model is identical to Model 1, except that the key predictor is now $Concentrator_i$, which is a 1 if student *i* is identified by their school to be a CTE concentrator, and 0 for all other students. As with to Model 1, I also fit models in which I substitute the high school fixed effects for town of residence and middle school fixed effects.

To answer research question 3, I adopt the specifications in models 1 & 2, but only fit them to specific subsets of students. By comparing the magnitudes of $\boldsymbol{\beta_1}$ across different populations, I can observe any heterogeneity in the ways that CTE engagement may relate to coursetaking in the various non-CTE areas.

For research question 4, I consider not only whether a student participated in any or no CTE, but also among those who do participate, how in-depth that participation was. In doing so, I examine how the expected difference in coursetaking in other subjects might differ for students taking larger or smaller numbers of CTE courses. I employ Cerulli's (2015) dose-response framework, which allows for nonlinear relationships between a continuous variable (# of CTE courses) and dependent variable (# of courses in other subjects) in cases where some students take no CTE classes at all. Employing a dose-response model allows that the marginal trade-offs may look quite different when a student is deciding whether to take their first CTE course or their 5th. For example, schools may offer students flexibility to take a small number of electives, so a student taking a small number of CTE courses may not involve a substantial reduction in their ability to take other courses; on the other hand, when students are choosing to take their 5th, 6th, or 7th CTE course, that may involve different types of trade-offs. Consider two groups of students, one that is

"untreated" (i.e., takes no CTE classes, $c = 0$) and one that takes different "doses" of CTE courses, where # of courses is represented by d:

$$(3a)\ c = 1:\ Y_1 = \alpha_1 + \boldsymbol{X_i'\gamma_1} + h(d) + e_1$$

$$(3b)\ c = 0:\ Y_0 = \alpha_0 + \boldsymbol{X_i'\gamma_0} + e_0$$

Here α is the intercept, $\boldsymbol{X_i'}$ is defined as in Equations 1 and 2, h(d) is a response function of the number of CTE courses taken, and e is the error term. Next, the following estimates parameters in Equations 3a and 3b:

$$(4)\ Y_i = \alpha_0 + \boldsymbol{c_i ATE} + \boldsymbol{X'_i\gamma_0} + c_i * (\boldsymbol{X_i'} - \bar{\boldsymbol{X}})\gamma + c_i * \{h(d_i) - \bar{h}\} + \epsilon_i$$

where ATE is the average treatment effect of taking CTE classes. Here, $\epsilon_i = c_i * (e_{1_i} - e_{0_i})$, and $\gamma = \gamma_1 - \gamma_0$. Finally, I specify a quadratic response to the dosage of CTE classes, $h(d) = \lambda_1 d + \lambda_2 d^2$, and use parameter estimates from Equation 4 to compute the following dose-response function:

$$(5)\ ATE(d) = \begin{cases} \alpha + \bar{X}_{d>0}\,\gamma + h(d) & if\ d > 0 \\ \alpha + \bar{X}_{d=0}\,\gamma & if\ d = 0 \end{cases}$$

I use results from Equation 6 to visually display how CTE engagement may differently impact non-CTE coursetaking at different doses of CTE, allowing for a more nuanced understanding of the trade-offs students make.

Results

Overall, evidence suggests that the most substantial trade-offs associated with CTE are in reduced levels of elective coursetaking, particularly in the fine arts and world languages. CTE is also associated with lower levels of AP & IB courses, along with lower rates of study hall and test prep courses. In contrast, there are only minor associations between CTE and core academic coursetaking, which might be expected given the state's recommended program of study leaves less flexibility in terms of ELA, math, science, and social studies. However, analysis of specific math

courses suggests that there may be stronger evidence of trade-offs between CTE and more advanced coursework that often prepares students for admissions at many selective colleges. Additionally, I find evidence that any coursetaking differences associated with CTE is largely driven by students who take moderate or large numbers of CTE courses, while students who take only a CTE course or two see no or only minor expected differences in their coursetaking levels in other subjects. While some differences in the types of course trade-offs experienced by different student populations (particularly students with disabilities and students with high and low levels of pre-HS academic achievement), the results are generally consistent across a wide range of student populations. Moreover, while students' choice of high school (and any constraints related to curricular options within their high school) is responsible for some of observed trade-offs, high school context does not account for all of the differences observed here.

Turning first to research questions 1 & 2, I present in Figures 2 & 3 the marginal difference in courses taken in each of 10 course categories that is predicted by each additional CTE course taken, on average. Figure 2 includes fixed effects for students' town of residence to account for differences within the context of a student's options for high school and other local factors, and Figure 3 includes high school fixed effects to highlight differences within the context of a student's curricular options after choosing a high school to attend. In both models, CTE coursetaking predicts lower levels of coursetaking in all four core academic content areas, but these magnitudes are small (all estimates for core academic class are between 0.015 and 0.044 SDs). For example, Figure 2 indicates that, holding other student characteristics constant, each additional CTE course is associated with a .031 course decrease in ELA courses. In other words, for CTE to predict a full ELA course decrease, students would need to take roughly 32 additional CTE courses, an implausible difference that highlights the relatively insubstantial relevance of this estimate. Given that the Massachusetts Department of Elementary and Secondary Education recommends that students to take four ELA courses, it is likely sensible that the elasticity of ELA (and to a lesser

extent, the other core academic subjects) would be more constrained than in elective areas. While still small, the magnitudes are somewhat larger for social studies and science than ELA and math, suggesting there may be slightly more coursetaking substitution happening with social studies and sciences (which might be expected given that only three courses are recommended in these areas rather than four for math and science), though these differences are only significant before accounting for high school choice.

Figures 2 and 3 also demonstrate that the largest predicted differences are seen when considering electives (where students should have more latitude in their curricular choices), particularly the fine arts and world languages. For example, an additional CTE course predicts a .305-.311 course decrease in the Fine Arts, meaning that for every 3 CTE courses taken, we would expect an approximate 1 course decrease in fine arts courses. CTE coursetaking is also related to a decrease in AP/IB courses, and to study hall/test prep courses. Notably, the magnitudes of the coefficients are only modestly different when accounting for students' high school choice through high school fixed effects, indicating that these relationships remain relatively similar even after accounting for students' curricular options at their high school. One difference that does stand out here is with world languages, for which high school fixed effects reduce the expected difference by roughly half, suggesting that schools with higher rates of CTE participation may also have lower rates of world language coursetaking (echoing findings from Brunner et al, 2019, which found limited world language offerings at similar CTE-dedicated schools in Connecticut).

Figure 4-5 display results that are analogous to Figure 2-3 in specification, but instead of using the continuous coursetaking variable to measure CTE engagement, these figures use the state CTE concentrator definition of CTE concentrator (i.e., those students reported by their school to be engaged in a CTE program for 2 or more years). While many CTE courses count towards the concentrator status, the CTE concentrator measure allows greater discretion at the school level for schools to identify who they consider to be engaged in a dedicated CTE program. As such, by

comparing CTE concentrators to students *not* labeled by their school as concentrators (non-concentrators), we can observe the marginal differences in non-CTE coursetaking for those with especially deep commitment to CTE to those with no or more limited exposure. As shown in Table 2, CTE Concentrators take an average of 5.7 CTE courses, while non-concentrators still take 2.2 courses, on average. As such, CTE Concentrators take an average of 3.5 more CTE courses, meaning they are making a substantially larger commitment within their schedule.

Figures 4 & 5 again show that CTE concentration is associated with essentially no differences in core academic coursetaking. Instead, more substantial relationships are again seen with electives, particularly fine arts and to a lesser extent, world language. CTE concentrators are also, across both models, predicted to take substantially fewer AP/IB and study hall/test prep courses, all else equal. The predicted differences in elective coursetaking are less dramatic in the model including high school fixed effects, suggesting the schools with greater CTE offerings also have more limited offerings and/or student interest in the other elective areas. While the larger magnitudes in Figure 4 suggest that at least some of the change of elective coursetaking is attributable to which high school students choose to attend, Figure 4 highlights that even within the context of courses offered within a given school, there are still substantial curricular trade-offs associated with CTE (again, especially with the fine arts), with CTE concentrators taking about 1 fewer fine arts class than similar non-concentrators at the same high school.

Turning next to research question 3, Figures 6-9 display outcomes for different student groups to examine how coursetaking trade-offs may differ by student population. In both figures, I present the concentrator vs. non-concentrator comparison for ease of interpretation. Additional analyses confirm similar results when using the total CTE courses measure of CTE exposure.

First, Figure 6 presents evidence related to the coursetaking trade-offs by 8th grade test scores to understand how these relationships might differ by prior academic achievement. In particular, I focus on the highest-scoring students (top 20%), lowest-scoring students (bottom 20%)

and the middle 20%; the students in these three groups likely face different curricular choices (including outside of CTE) and face the likelihood of different post-high school plans, meaning that consideration of these groups separately allows some insight into how coursetaking trade-offs might present differently. While the results are mostly similar for the core academic courses, there are some differences across the testing distribution in how students experience different elective trade-offs from CTE, especially in the study hall/miscellaneous category and AP/IB classes. As Figure 6 shows, higher-scoring students see a substantial predicted decrease in AP/IB coursetaking, with high-scoring CTE concentrators taking 1.2 fewer AP/IB courses than otherwise predicted. Meanwhile, lower-scoring CTE concentrators see a larger predicted decrease in Study Hall and Miscellaneous courses. Figure 7 suggests that high schools explain approximately half of these differences. While these finding might not be surprising given that, for example, higher-scoring students are more likely to take AP/IB courses and therefore are more able to see a shift in that area, it is still important and worthwhile to consider some of these marginal trade-offs may be different for different students.

Figure 8 presents the results of an approach similar to that in Figure 7, but instead considers how the relationship between CTE and other subject areas may differ across six student populations. Figure 8 explores heterogeneity by gender, given that many studies have found gendered differences in the returns to CTE (Brunner et al, 2019; Hemelt et al, 2019; Kemple & Willner, 2008), and for racially/ethnically minoritized students, English learners, students with disabilities, and students from lower-income families (those who were ever eligible for free and reduced lunch throughout their time in high school), given that these student populations have previously been shown to be targeted by CTE programs. Again, across all student populations, there is only minor variation in predicted differences across the core academic courses. While most of the relationships are relatively steady across student populations, the most striking difference is for students with disabilities, among whom CTE concentrators are predicted to take 1.517 fewer study

hall classes, a much larger difference than for any other student population examined. Similar to the finding for lower-scoring students, this indicates that CTE may be a replacement for study hall, test prep, or other miscellaneous courses, particularly for certain students who may be disproportionately placed in those courses in the absence of CTE as an alternative option.

Figure 9 illustrates similar estimates by the type of high schools students attend, to consider whether relationships differ between students who engage with CTE within the context of a comprehensive high school and those who attend CTE-dedicated schools. Because the overwhelming majority of students at CTE-dedicated high schools are CTE concentrators, I use the number of CTE courses taken for these analyses. Figure 9 illustrates that there are slightly larger predicted differences in core academic coursetaking at CTE-dedicated schools from additional courses taken. However, in the fine arts and AP/IB, the predicted difference is far larger at comprehensive high schools (where only minor relationships exist). Given the intensive CTE-focused nature of the CTE-dedicated schools, this may indicate that there may be less flexibility and potentially less offerings in the fine arts and AP/IB than at comprehensive high schools.

While the evidence presented here suggests only modest curricular trade-offs occur between CTE and coursetaking in the core academic subjects, we might wonder whether CTE is associated with students taking different courses *within* those subject areas. To consider this possibility, Figure 10 takes the most common math course types, and considers the extent to which CTE concentrators are expected to take courses in those areas than otherwise similar non-concentrator peers. Figure 10 highlights that CTE concentrators are actually nearly 10% more likely to have taken courses in the three "traditional pathway" areas as defined by the state – Algebra I, Algebra II, and Geometry (MDESE, 2017). Conversely, CTE Concentrators are less likely to take courses in advanced fields like statistics, pre-calculus, calculus, and AP/IB math. Figure 11 demonstrates that these differences are smaller when considering coursetaking within the context of a student's school.

Turning next to research question 4, Figure 12 shows the predicted average treatment effect among the treated (ATE(t)) at each level of CTE coursetaking from 1 course to 12 courses (representing approximately 99% of CTE students) using a dose-response model that estimates the ATE(t) at each dosage level of CTE coursetaking (as measured by the number of CTE courses a student takes). In other words, given that a student takes at least 1 CTE course, Figure 12 shows the predicted ATE(t) of CTE coursetaking by the number of CTE courses a student takes. Figure 12 highlights that, for most course types, the negative ATE(t) of CTE coursetaking on non-CTE coursetaking is especially driven by students who take larger numbers of CTE courses. For example, looking at Science courses as an outcome, we see that for students taking 1 or 2 CTE courses, there is essentially no expected difference in Science coursetaking. This ATE(t) begins to increase at 3 CTE courses, and for students taking 10 CTE courses, students take nearly a full science course less than we might otherwise expect. Notably, for ELA, math, social studies, science, and world language, there is no clear difference associated with a small number of CTE courses; instead, the difference presents among students taking large numbers of CTE courses (with the ATE(t) becoming especially large for World Languages). However, with the fine arts, AP/IB, and study hall courses, an expected difference is seen even at small doses of CTE coursetaking, though the estimates become substantially larger at higher dosages. This analysis highlights that the marginal trade-offs likely varies considerably for students engaging across different levels of CTE courses.

Limitations

While my analyses in this study have strong generalizability based on the large sample size and diverse set of educational contexts, there are clear limitations to causal interpretation given the potential for unobserved characteristics that may influence students' coursetaking decisions. Though strict causal interpretations may warrant caution, there is still value in a more descriptive understanding on the trade-offs take when students engage with CTE, particularly if an assumption

remains among many educators, education researchers, and policymakers that CTE participation inhibits college preparatory academic coursework.

To address concerns of unobserved bias, I follow the tests proposed by Oster (2016), building upon Altonji, Elder, & Taber (2005), to identify the amount of selection on unobservable factors that would be necessary for the true effect to be zero. Tables 3 & 4 present these findings, using $\boldsymbol{R_{max}}$ values of 1.3*R* and 2*R,* as proposed by Oster. Table 3 presents coefficient bounds for the range of coefficients on β_1 (CTE Concentration) from a model with no unobserved bias to one in which unobservable characteristics explain 30% as much as the observed characteristics (resulting in a R-square 130% the size of the observed R-squared). If 0 is not within the coefficient bound, unobserved bias would need to explain the outcomes by more than 30% as much as observed characteristics. The bias $\boldsymbol{\delta}$ represents how many times larger unobserved characteristics would have to be than observed factors for β_1 to be 0. Table 3 then presents more conservative estimates with a $\boldsymbol{R_{max}}$ of 2, in which unobserved factors would need to be as large as observed factors in order to invalidate results. These results show that the relationships found in this paper between CTE concentration and lower levels of coursetaking in the fine arts, world language, and to a lesser extent, other elective areas could withstand even large levels of unobserved variable bias before estimates would diminish to 0. On the other hand, looking at ELA, coefficient bounds overlapping 0 and bias deltas below 0 suggest that even relatively small amounts of unobserved bias could nullify the results.

Table 4 displays similar bias estimates for models with high school fixed effects. Here, non-zero relationships between CTE and world language, fine arts, military/JROTC, AP/IB and study courses would all still hold even with omitted variables as strong as all the observed variables. Again, Table 4 suggests that the small relationships found for ELA and the other core academic subjects are relatively subject to omitted variable bias, suggesting that the small relationships between CTE and core academic courses should be taken with a grain of salt.

Furthermore, while coursetaking data can provide information on how student spend their time in high school, we know far less about the quality and rigor of the courses students take. It may be possible, for example, that CTE students are in academic courses with lower-performing teachers or in less-demanding academic courses (if, for example, the rigor of academic courses was not as high as the same courses at comprehensive high school). Thus, this analysis speaks less definitively about what learning trade-offs are made when students engage with CTE, but rather, what differences occur in how students spend their time. Moreover, this analysis does not speak to how or by whom course choices are made. It is possible that these choices are made by students and families; however, if choices were made by schools and counselors, any soft tracking of students into CTE and away from electives and more advanced coursework would not be clear from this analysis.

Finally, because my models control for the total number of courses students take in high school to avoid conflated additional CTE courses with simply being in school for longer periods of time, my approach limits one potential avenue through which CTE could impact coursetaking; if CTE induces students to persist in high school longer (due to increased engagement, for example), I do not observe the role CTE plays in keeping students in school and taking more academic classes. Conversely, if CTE induces some students to leave school early (perhaps due to exposure to work), that would not be captured in these results, though a growing body of evidence suggests that CTE likely increases high school persistence and attendance (Dougherty, 2018; Gottfried & Plasman, 2018; Hemelt et al, 2019), making this a relatively small concern. Given this evidence that CTE can improve student retention, this likely means that estimates presented from this model will be somewhat conservative in nature.

Discussion

With renewed interest in CTE from policymakers and politicians, key questions remain about the ways that CTE can either benefit students through greater engagement in school and stronger career preparation, or the ways it could harm students by limiting their preparation for

postsecondary education and the careers that require college degrees. Stronger evidence is emerging that CTE seems to induce positive labor market returns (at least in the short-to-mid-term range), with less clear evidence of changes in postsecondary educational outcomes. As this evidence base grows, this study represents one of the first quantitative attempts to consider a key mechanism through which we might expect CTE to have an impact.

While CTE research generally focuses on the direct effects of CTE experiences, this research asks a novel set of research questions – simply put, whether CTE participation causes students to lose other opportunities that may be important to their future success. It is currently not understood whether CTE coursetaking and concentration causes students to take fewer courses in academic preparatory classes, or whether students use CTE as a more-focused way of filling their elective opportunities. Here, I find evidence suggesting the later. Given that many states (including Massachusetts) have crafted their recommended - and in some states, required - high school graduation programs of study to align with college admissions requirements, this finding makes sense given the shift in high school curricular policy. It seems likely that given the large number of core academic classes needed for high school graduation, there is simply little flexibility left in students' schedules to see major differences in the numbers of core academic courses they take. Rather, elective areas like the fine arts, AP/IB, study hall, and to an extent, world languages, might be areas where students have greater flexibility. These results suggest that CTE may operate more as an elective area for students in many cases.

However, key nuances exist in these findings with important implications. First, the types of trade-offs differ by student population. Among lower-scoring students, for example, and students with disabilities, I observe especially strong evidence of trade-offs between CTE and courses in study hall, test prep, and other support classes. On the one hand, this might suggest that these students are using CTE as a way of engaging in a more enriching, engaging curriculum that could have real-world relevance for them and their future careers. On the other hand, if students with

disabilities or those struggling to pass mandatory exams are taking CTE instead of support classes or courses that include services which could benefit them, this may be a reason for concern.

Higher-scoring students, meanwhile, see especially strong trade-offs in AP/IB classes when they engage with CTE. This may call into question whether the trade-offs higher-scoring students take to engage in CTE are as prudent, given that they may be giving up the opportunity to take classes that may set them up especially well for postsecondary admission and success, especially in more selective colleges. Similarly, while I find essentially no trade-offs between CTE and math courses in aggregate, I do find evidence of substantive trade-offs between CTE and more advanced math courses like statistics and calculus that might position high-achieving students especially well for competitive college admissions. Considering both AP/IB and advanced math courses, these findings suggest that while CTE does not appear to limit baseline college preparatory coursework, trade-offs may be more likely when considering advanced academic electives, or college-preparatory academic courses above and beyond the state-recommended program of study. For students, families, and policymakers making decisions about how to engage with CTE (especially among higher-scoring students), a recognition of these trade-offs may be important to consider. This is especially relevant given findings from Massachusetts from that students of color were less likely than their white peers to have enough information to make well-informed choices about whether and how to participate in CTE (Ansel et al., 2022).

This study also highlights that school choice and school setting is important, but not fully determinative of the types of curricular trade-offs students might make in high school. In particular, there is substantially less variation in world languages (and to a lesser extent, fine arts) after accounting for school fixed effects, suggesting that these elective courses are simply much less common at schools where CTE is more common. Indeed, within CTE-dedicated schools, there is very little variation in these elective areas, with less than a quarter of the anticipated difference for world language courses associated with CTE compared to what was observed across the full sample.

Smaller curricular trade-offs within these CTE-dedicated school contexts may make some intuitive sense; given the additional emphasis on CTE, there may simply be less room in students' schedules for additional electives. For students who choose to enter CTE-dedicated schools, then, there is a strong likelihood that there is some level of limitation on their likelihood of taking certain elective courses outside of CTE. Still, while the extensive margins in which students choose a school that is more or less focused on CTE, the intensive marginal course choices students make within the context of their high school still matter, especially for students at comprehensive high schools.

Though this analysis does not claim causality, it is unclear and worth further examination to determine which direction the causal relationship would flow between increased rates of CTE coursetaking and coursetaking in other elective areas. Perhaps some students may take CTE courses because they are less interested in the fine arts or world languages, for example. Other students may want to take more of fine arts and world languages, but are unable to make room in their schedule after CTE courses fill the limited flexible time in their schedules. Related, this study cannot explain whether these differences coursetaking patterns are driven by student interest or by less robust school offerings in non-CTE courses at CTE-dedicated schools. Constraints on student schedules, limited staff or space capacity may make it more difficult for CTE-dedicated schools to offer as many world language or fine arts classes, for example, even if high levels of student interest *does* exist. On the other hand, some students may explicitly view CTE and world languages as 'competitive' for time in their schedule; they may view these as elective trade-offs, and may make their coursetaking choices using this approach.

As CTE grows in popularity and policy salience, it is essential to fully understand the implications of CTE – not only the experiences students gain, but also the experiences that students lose in order to make room within their schedule. This can (and likely should) color our understanding of what CTE means for students, and how the public and policymakers should consider the trade-offs students make as they engage with CTE. Given the long and controversial

history of vocational education and CTE within the American public schooling system, this work speaks to fundamental implications about access, equity, and opportunity. These results offer a counterargument to the longstanding perception that CTE serves as what many have called as a "dumping ground" for low-achieving students (Kelly & Price, 2009; Summers, 2014), and helps address gaps in the literature that researchers and policymakers need to know about the opportunities students lose through their participation in CTE.

These results suggest that CTE students in the Massachusetts context still complete courses in core college preparatory subject areas at similar rates to non-CTE students, though there are notable differences for students with disabilities, and students with especially low- or high-test scores. Especially for students who take only a small number of CTE courses, the trade-offs in terms of academic courses taken are minimal, although these trade-offs do become more substantial for students who take several CTE courses. Overall, CTE appears to function more as an elective for students, leading to trade-offs with other elective areas, rather than the core academic areas.

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Table 1. Descriptive Statistics by Concentrator Status

	All Students	CTE Concentrators	Non-CTE Concentrators	Graduates & CTE Concentrators	Graduates & Non-CTE Concentrators	Non-Graduates & CTE Concentrators	Non-Graduates & Non-CTE Concentrators
CTE Concentrator	0.21	1.00	0.00	1.00	0.00	1.00	0.00
	(0.41)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CTE Courses	2.90	5.70	2.15	5.93	2.41	3.20	0.88
	(3.20)	(4.64)	(2.14)	(4.67)	(2.17)	(3.51)	(1.40)
Male	0.51	0.55	0.50	0.54	0.48	0.59	0.57
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.49)	(0.50)
Black	0.10	0.09	0.10	0.09	0.09	0.12	0.14
	(0.30)	(0.29)	(0.30)	(0.29)	(0.29)	(0.32)	(0.35)
Latinx	0.18	0.21	0.17	0.20	0.14	0.33	0.35
	(0.38)	(0.41)	(0.38)	(0.40)	(0.34)	(0.47)	(0.48)
Asian	0.06	0.04	0.07	0.04	0.07	0.04	0.05
	(0.24)	(0.21)	(0.25)	(0.21)	(0.25)	(0.19)	(0.22)
Low-Income	0.47	0.59	0.44	0.57	0.38	0.82	0.70
	(0.50)	(0.49)	(0.50)	(0.50)	(0.49)	(0.38)	(0.46)
English Learner	0.10	0.08	0.10	0.07	0.07	0.17	0.24
	(0.29)	(0.27)	(0.30)	(0.26)	(0.26)	(0.38)	(0.43)
Student w/Disability	0.20	0.25	0.19	0.24	0.16	0.42	0.35
	(0.40)	(0.43)	(0.39)	(0.42)	(0.36)	(0.49)	(0.48)
8th Grade Math (Std)	-0.00	-0.28	0.07	-0.25	0.17	-0.65	-0.39
	(0.92)	(0.85)	(0.92)	(0.86)	(0.92)	(0.76)	(0.78)
8th Grade ELA (Std)	0.01	-0.28	0.08	-0.24	0.19	-0.72	-0.42
	(0.91)	(0.89)	(0.90)	(0.87)	(0.86)	(1.00)	(0.95)
8th Grade Attendance	0.96	0.96	0.96	0.97	0.96	0.94	0.93
	(0.06)	(0.05)	(0.06)	(0.04)	(0.05)	(0.07)	(0.09)
Observations	310524	65307	245217	59959	203282	5348	41935

Graduating Cohorts of 2015-2018

Table 2. Number of Courses in Each Category by Concentrator Status

	All Students	CTE Concentrators	Non-CTE Concentrators	Graduates & CTE Concentrators	Graduates & Non-CTE Concentrators	Non-Graduates & CTE Concentrators	Non-Graduates & Non-CTE Concentrators
English/Language Arts	4.55	4.78	4.49	4.91	4.89	3.26	2.55
	(2.21)	(2.28)	(2.19)	(2.23)	(1.88)	(2.25)	(2.50)
Math	4.06	4.30	3.99	4.44	4.42	2.76	1.93
	(1.78)	(1.44)	(1.85)	(1.33)	(1.55)	(1.68)	(1.79)
Science	3.84	3.78	3.85	3.90	4.31	2.34	1.63
	(1.89)	(1.41)	(1.99)	(1.34)	(1.75)	(1.44)	(1.58)
Social Studies	4.17	4.15	4.18	4.30	4.69	2.49	1.67
	(1.99)	(1.63)	(2.08)	(1.56)	(1.78)	(1.50)	(1.52)
Fine Arts	2.29	1.05	2.63	1.07	2.93	0.79	1.15
	(2.50)	(1.71)	(2.57)	(1.74)	(2.62)	(1.39)	(1.63)
World Language	2.31	1.42	2.55	1.49	2.93	0.59	0.71
	(1.75)	(1.49)	(1.74)	(1.50)	(1.61)	(0.96)	(1.01)
PE/Health	3.99	4.40	3.88	4.51	4.26	3.07	2.03
	(2.39)	(2.20)	(2.42)	(2.17)	(2.32)	(2.07)	(2.02)
Military/JROTC	0.09	0.12	0.08	0.12	0.08	0.12	0.07
	(0.54)	(0.64)	(0.51)	(0.65)	(0.54)	(0.52)	(0.37)
AP/IB	1.33	0.59	1.52	0.64	1.82	0.03	0.06
	(2.31)	(1.47)	(2.45)	(1.52)	(2.58)	(0.25)	(0.40)
Study Hall/Test Prep/Misc	1.80	1.69	1.82	1.66	1.81	2.03	1.88
	(3.00)	(2.55)	(3.11)	(2.39)	(2.86)	(3.96)	(4.08)
CTE	2.90	5.70	2.15	5.93	2.41	3.20	0.88
	(3.20)	(4.64)	(2.14)	(4.67)	(2.17)	(3.51)	(1.40)
Observations	310524	65307	245217	59959	203282	5348	41935

Graduating Cohorts of 2015-2018

Table 3
Estimates of coefficient bounds and bias needed to find null results
Models with Town of Residence Fixed Effects

	ELA	Math	Science	Social Studies	World Language	Fine Arts	PE/Health	Military/ JROTC	AP/IB	Study Hall/ Misc
CTE Concentrator Difference	0.065	0.169	-0.065	-0.208	-1.706	-1.037	0.434	-0.033	-0.577	-0.486
Standard Error	*0.063*	*0.046*	*0.042*	*0.066*	*0.094*	*0.053*	*0.121*	*0.025*	*0.038*	*0.108*
Coefficient Bound (R_{max} =1.3R)	(.065, -.006)	(.169, .095)	(-.065, -.119)	(-.208, -.295)	(-1.706, -1.759)	(-1.037, -1.058)	(.434, .33)	(-.033, -.039)	(-.577, -.495)	(-.486, -.596)
Bias δ (R_{max} =1.3R)	0.913	2.248	-1.244	-2.464	-53.347	-240.652	3.873	-6.338	6.160	-4.488
Coefficient Bound (R_{max} =2R)	(.065, -.179)	(.169, 0)	(-.065, -.231)	(-.208, -.495)	(-1.706, -1.89)	(-1.037, -1.11)	(.434, .075)	(-.033, -.052)	(-.577, -.295)	(-.486, -.864)
Bias δ (R_{max} =2R)	0.274	0.998	-0.419	-0.778	-23.972	-86.608	1.196	-2.018	1.930	-1.389
R-Squared	0.492	0.596	0.528	0.511	0.223	0.489	0.343	0.018	0.422	0.250

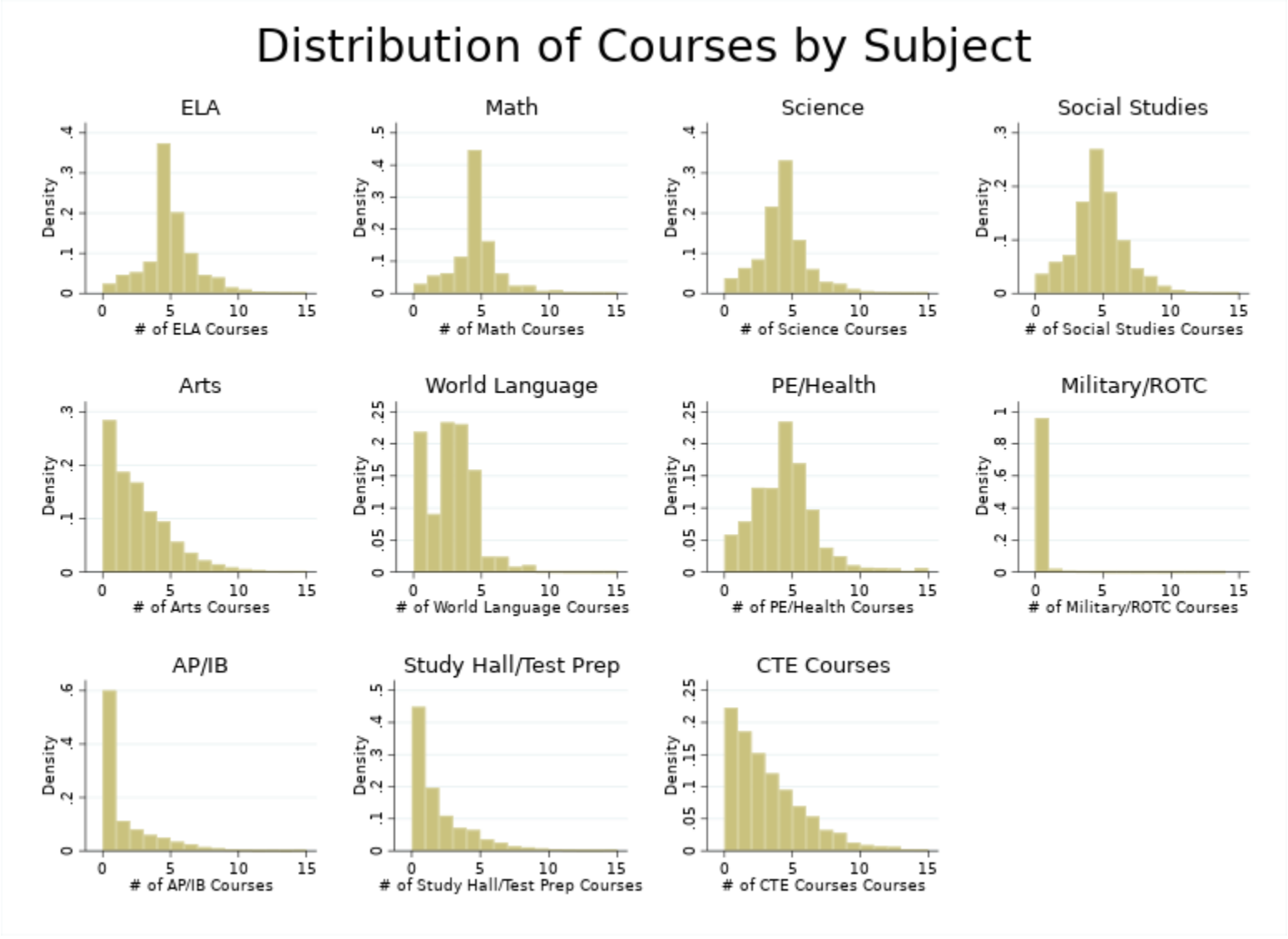
Notes: CTE Concentrator Difference, Standard Errors, and R-Squared are from Model 2 and include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018. Models include fixed effects for students' town of residence. Coefficient bounds refer to the range of estimates associated with CTE Concentration on each course category difference (by column) as the degree of selection on unobservables increases from none to 30% (row 3) or to 100% (row 5) of selection on observables. Bias **δ** represents the amount of selection on unobservables that would be needed to move estimates of the CTE Concentrator Difference to 0. Calculations of coefficient bourns and Bias **δ**s were conducting using the "psacalc" STATA package (Oster, 2019).

Table 4
Estimates of coefficient bounds and bias needed to find null results
Models with High School Fixed Effects

	ELA	Math	Science	Social Studies	World Language	Fine Arts	PE/Health	Military/ JROTC	AP/IB	Study Hall/ Misc
CTE Concentrator Difference	0.134	0.181	0.033	-0.075	-1.168	-0.293	0.123	-0.041	-0.433	-0.291
Standard Error	*0.050*	*0.034*	*0.031*	*0.047*	*0.076*	*0.055*	*0.067*	*0.019*	*0.041*	*0.111*
Coefficient Bound (R_{max} =1.3R)	(.134, .04)	(.181, .085)	(.033, -.051)	(-.075, -.19)	(-1.168, -1.225)	(-.293, -.339)	(.123, .02)	(-.041, -.048)	(-.433, -.422)	(-.291, -.369)
Bias δ (R_{max} =1.3R)	1.428	1.878	0.395	-0.650	-17.839	-6.581	1.198	-4.948	33.068	-3.743
Coefficient Bound (R_{max} 2R)	(.134, -.181)	(.181, -.075)	(.033, -.251)	(-.075, -.463)	(-1.168, -1.361)	(-.293, -.447)	(.123, -.223)	(-.041, -.067)	(-.433, -.396)	(-.291, -.556)
Bias δ (R_{max} =2R)	0.429	0.710	0.119	-0.195	-6.268	-1.993	0.360	-1.545	10.026	-1.128
R-Squared	0.468	0.557	0.480	0.458	0.157	0.411	0.316	0.017	0.438	0.263

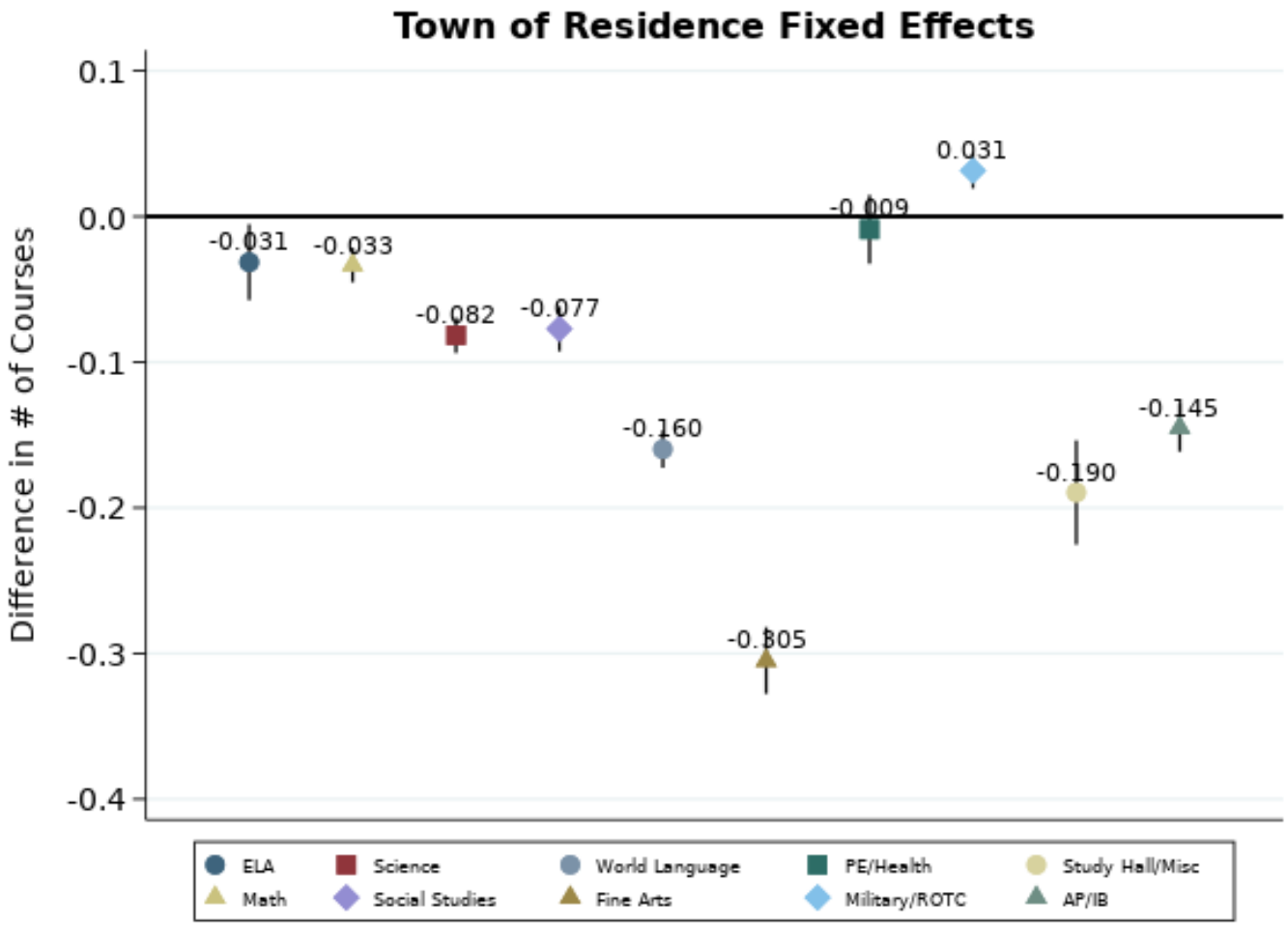
Notes: CTE Concentrator Difference, Standard Errors, and R-Squared are from Model 2 and include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018. Models include fixed effects for the high school a student attended in 9th grade. Coefficient bounds refer to the range of estimates associated with CTE Concentration on each course category difference (by column) as the degree of selection on unobservables increases from none to 30% (row 3) or to 100% (row 5) of selection on observables. Bias **δ** represents the amount of selection on unobservables that would be needed to move estimates of the CTE Concentrator Difference to 0. Calculations of coefficient bourns and Bias **δ**s were conducting using the "psacalc" STATA package (Oster, 2019).

Figure 1. Coursetaking by Subject



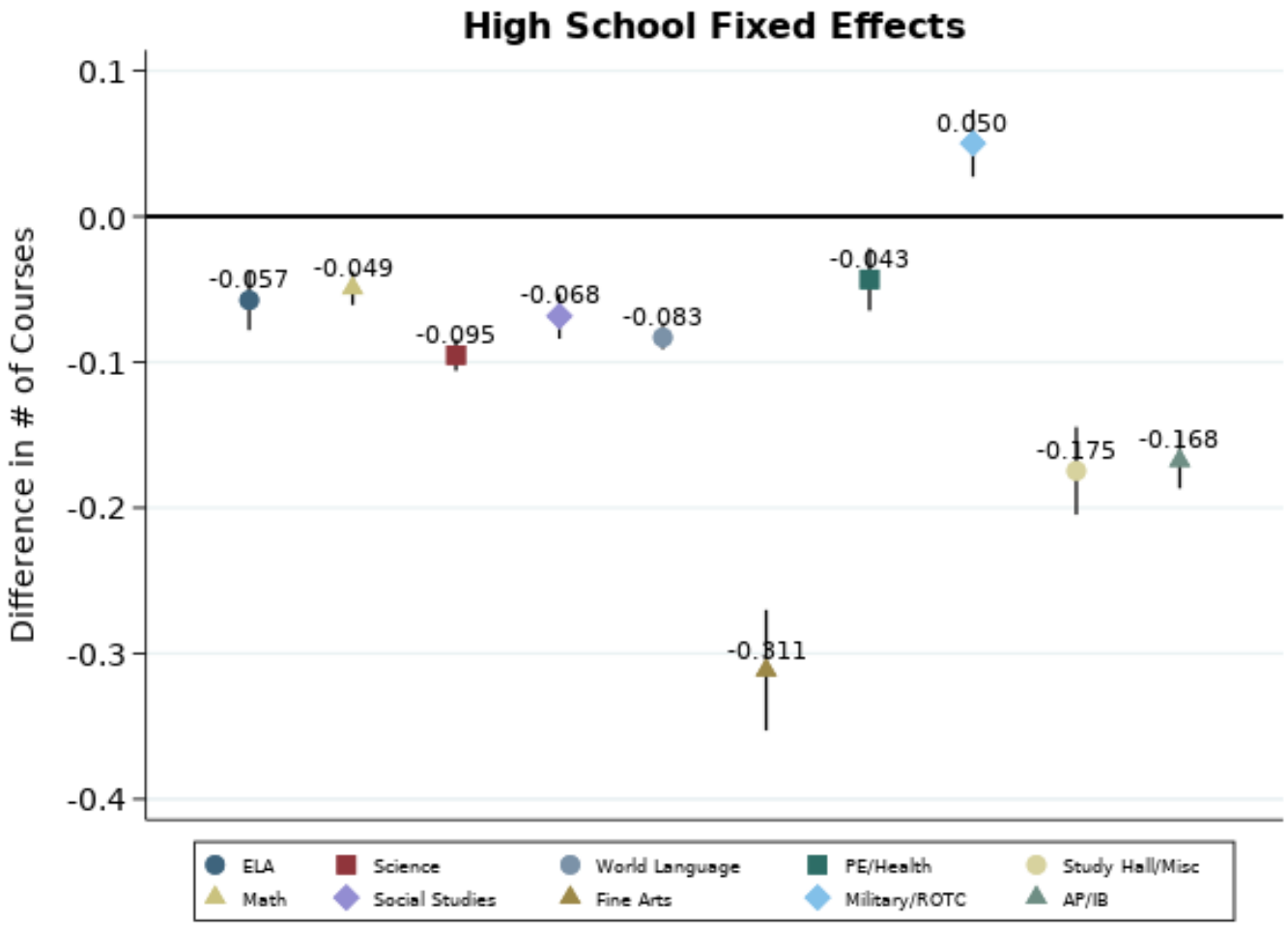
Notes: Counts of the number of students taken in high school per student. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 2. Differences in the # of Courses in Content Areas Predicted by An Additional CTE Course



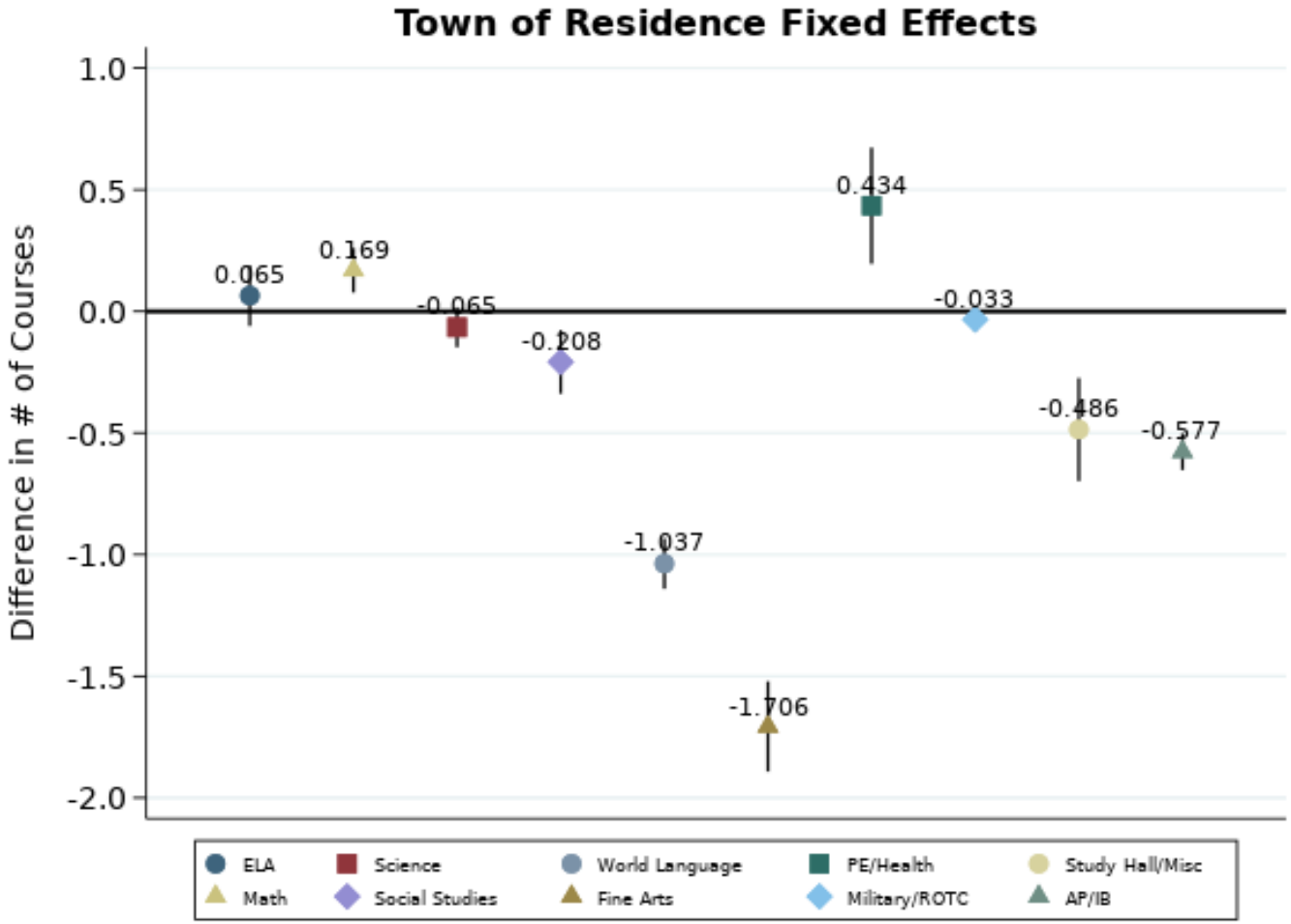
Notes: Estimates are the coefficient associated with an additional CTE course on the expected difference in the number of courses in each subject area. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 3. Differences in the # of Courses in Content Areas Predicted by An Additional CTE Course



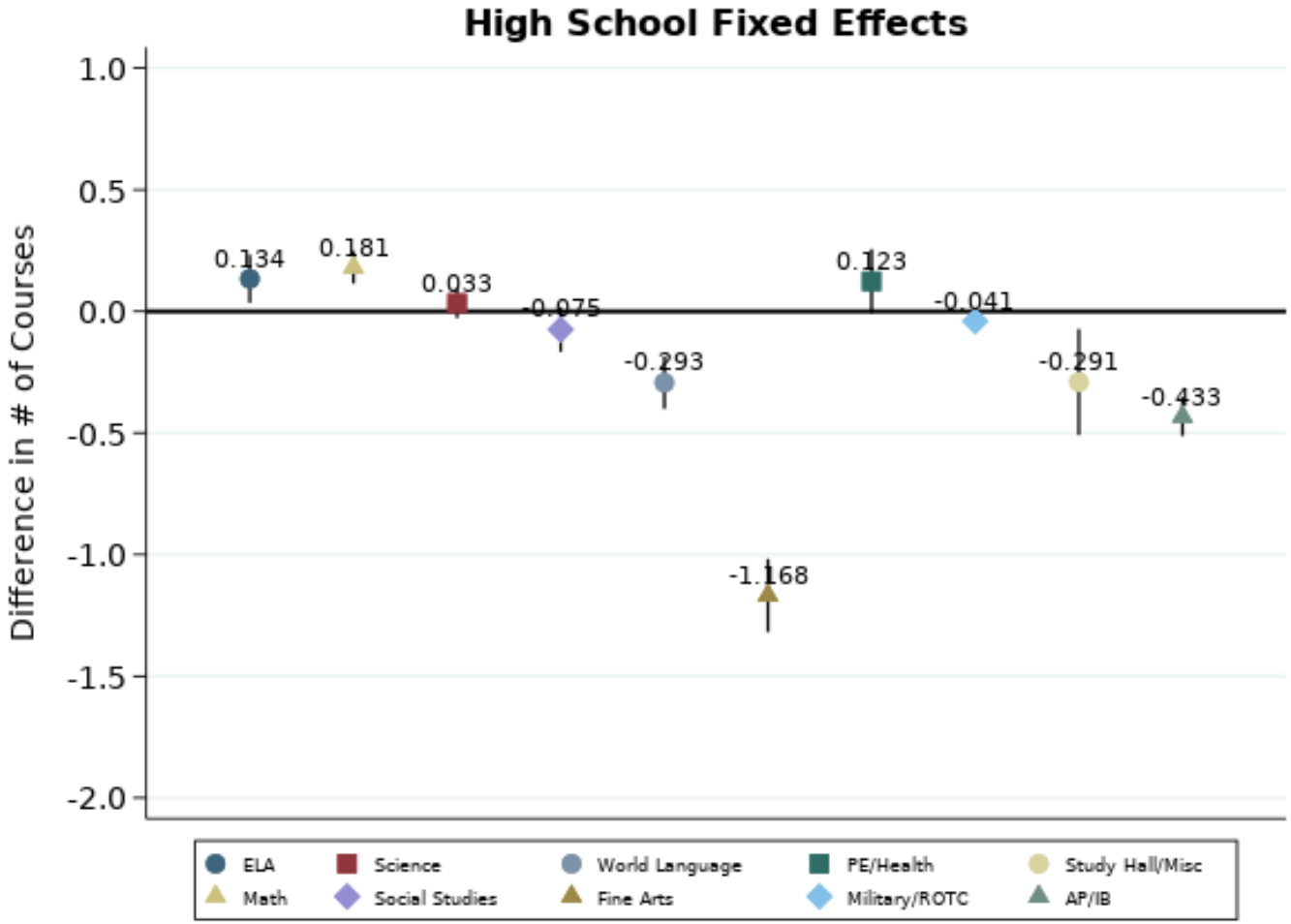
Notes: Estimates are the coefficient associated with an additional CTE course on the expected difference in the number of courses in each subject area. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort fixed effects as well as fixed effects for the high school a student attended in 9th grade, with errors clustered by high school. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 4. Differences in the # of Courses in Content Areas Predicted by Being a CTE Concentrator



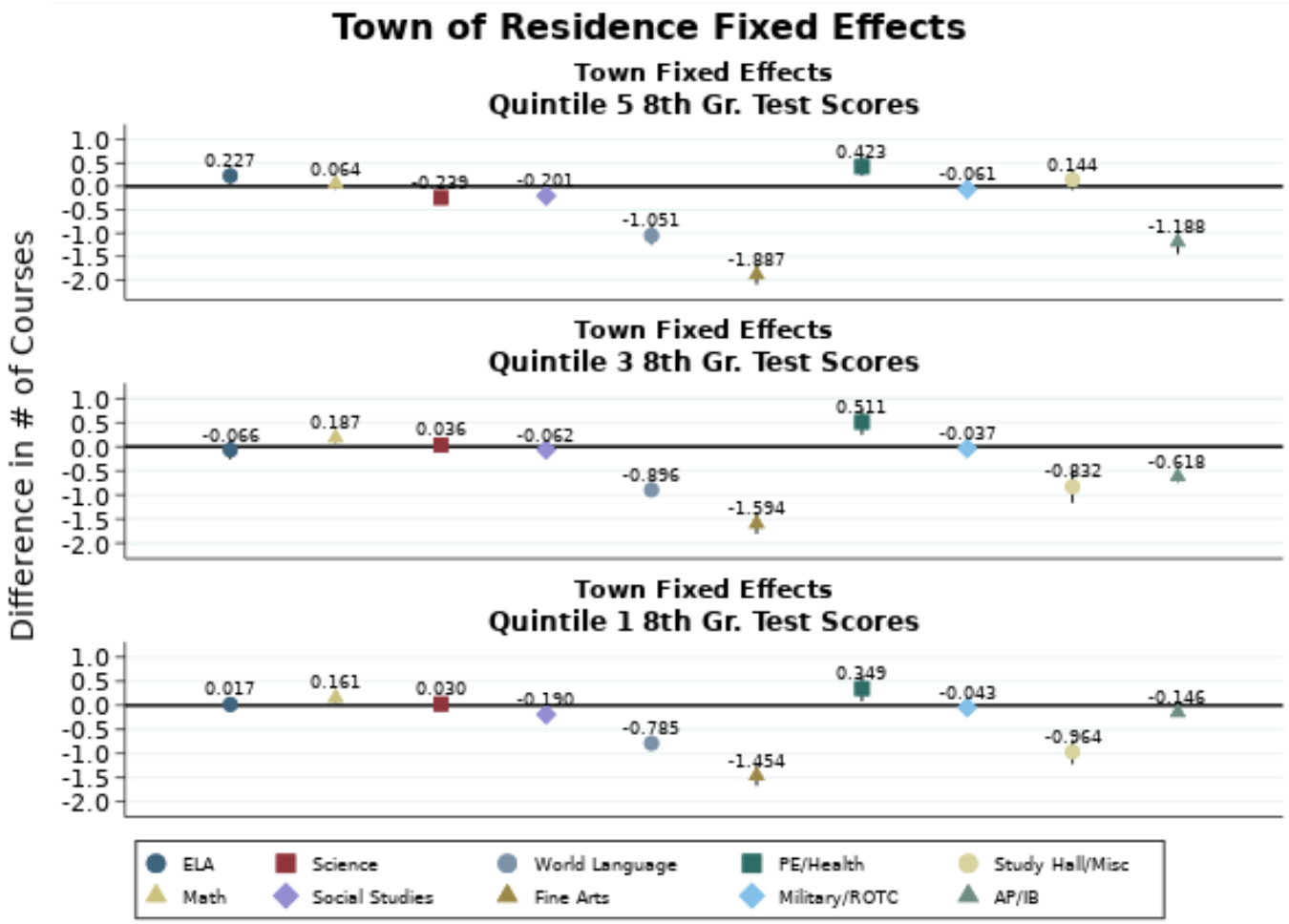
Notes: Estimates are the coefficient associated with a being a CTE Concentrator on the expected difference in the number of courses in each subject area, compared to non-CTE Concentrators who were otherwise similar on observable characteristics. CTE Concentrators are those students indicated by their school to be enrolled in CTE for two or more years. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 5. Differences in the # of Courses in Content Areas Predicted by Being a CTE Concentrator



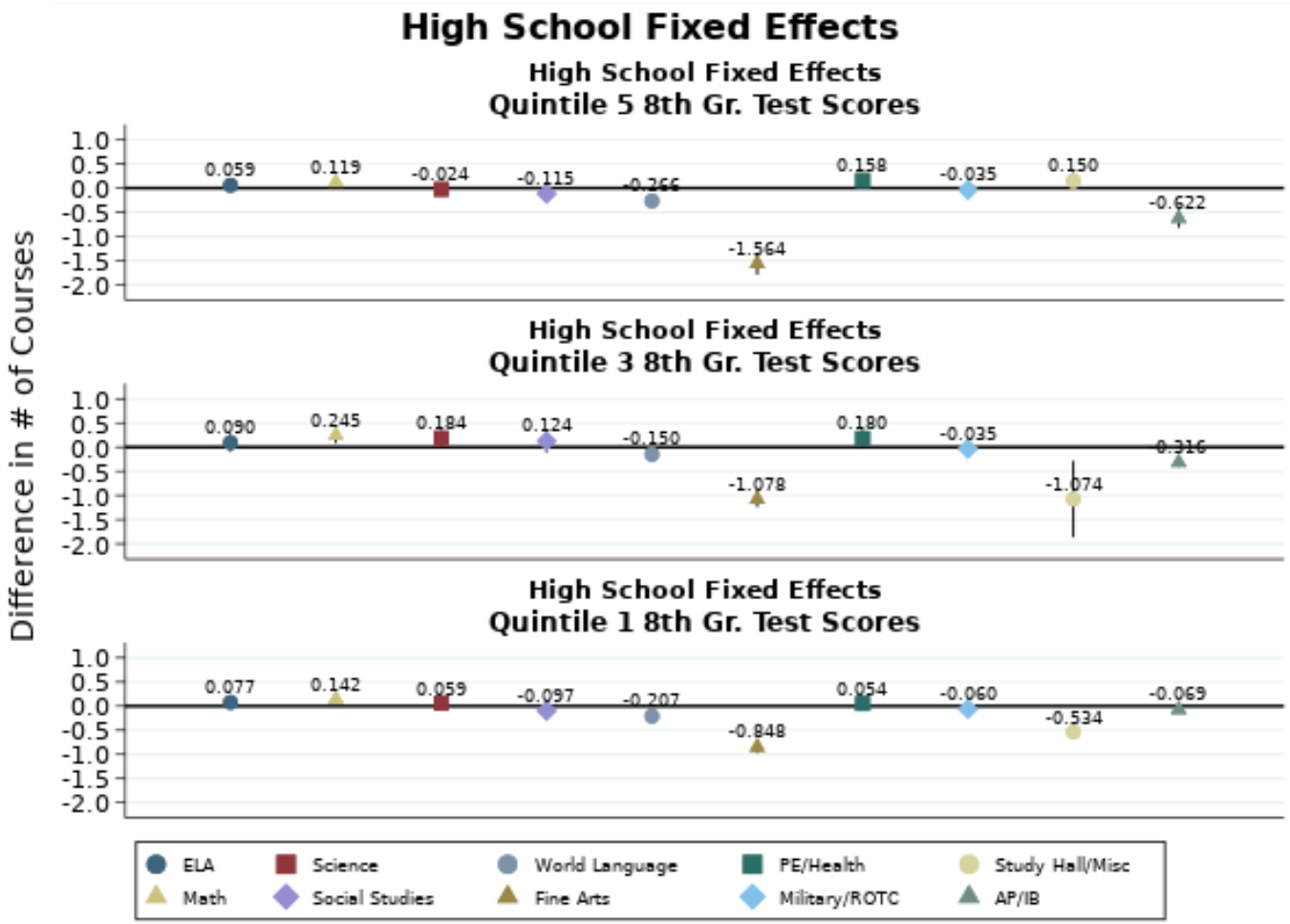
Notes: Estimates are the coefficient associated with a being a CTE Concentrator on the expected difference in the number of courses in each subject area, compared to non-CTE Concentrators who were otherwise similar on observable characteristics. CTE Concentrators are those students indicated by their school to be enrolled in CTE for two or more years. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort fixed effects as well as fixed effects for the high school a student attended in 9th grade, with errors clustered by high school. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 6. Differences in the # of Courses in Content Areas Predicted by Being a CTE Concentrator, by Test Scores



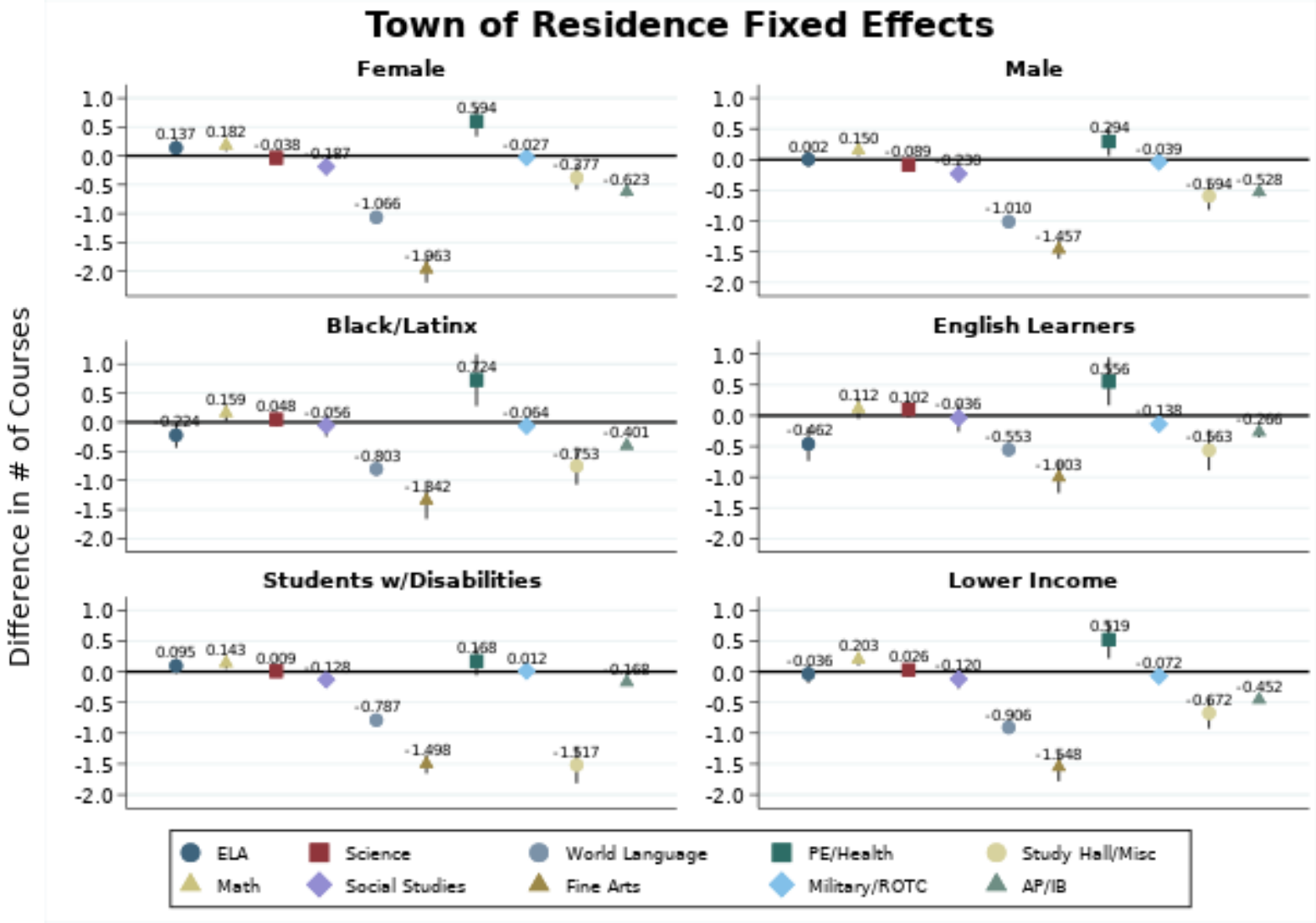
Notes: Estimates are the coefficient associated with a being a CTE Concentrator on the expected difference in the number of courses in each subject area, compared to non-CTE Concentrators who were otherwise similar on observable characteristics. CTE Concentrators are those students indicated by their school to be enrolled in CTE for two or more years. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 7. Differences in the # of Courses in Content Areas Predicted by Being a CTE Concentrator, by Test Scores



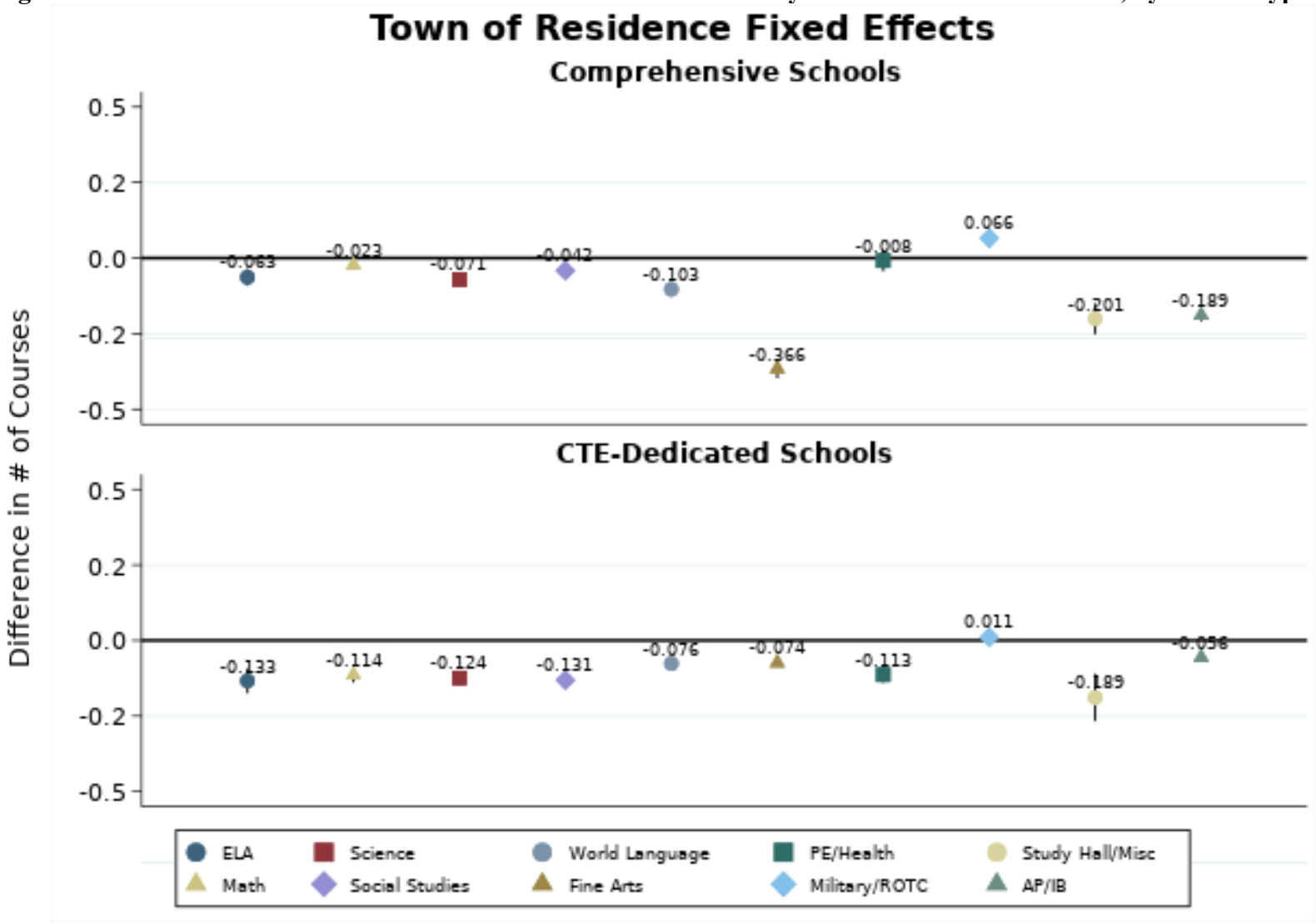
Notes: Estimates are the coefficient associated with a being a CTE Concentrator on the expected difference in the number of courses in each subject area, compared to non-CTE Concentrators who were otherwise similar on observable characteristics. CTE Concentrators are those students indicated by their school to be enrolled in CTE for two or more years. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort fixed effects as well as fixed effects for the high school a student attended in 9th grade, with errors clustered by high school. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 8. Differences in the # of Courses in Content Areas Predicted by Being a CTE Concentrator, by Student Population



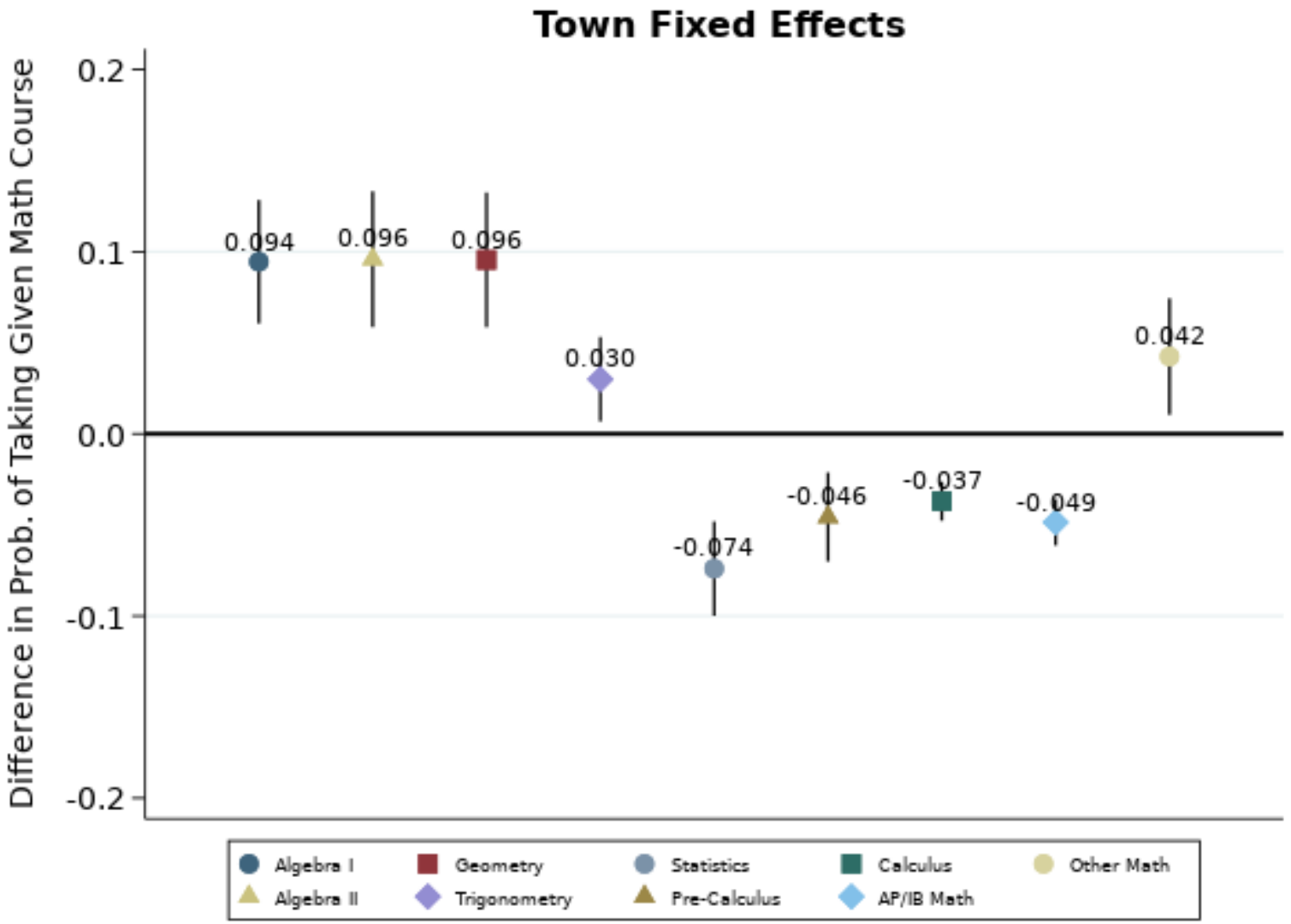
Notes: Estimates are the coefficient associated with a being a CTE Concentrator on the expected difference in the number of courses in each subject area, compared to non-CTE Concentrators who were otherwise similar on observable characteristics. CTE Concentrators are those students indicated by their school to be enrolled in CTE for two or more years. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 9. Differences in the # of Courses in Content Areas Predicted by An Additional CTE Course, by School Type



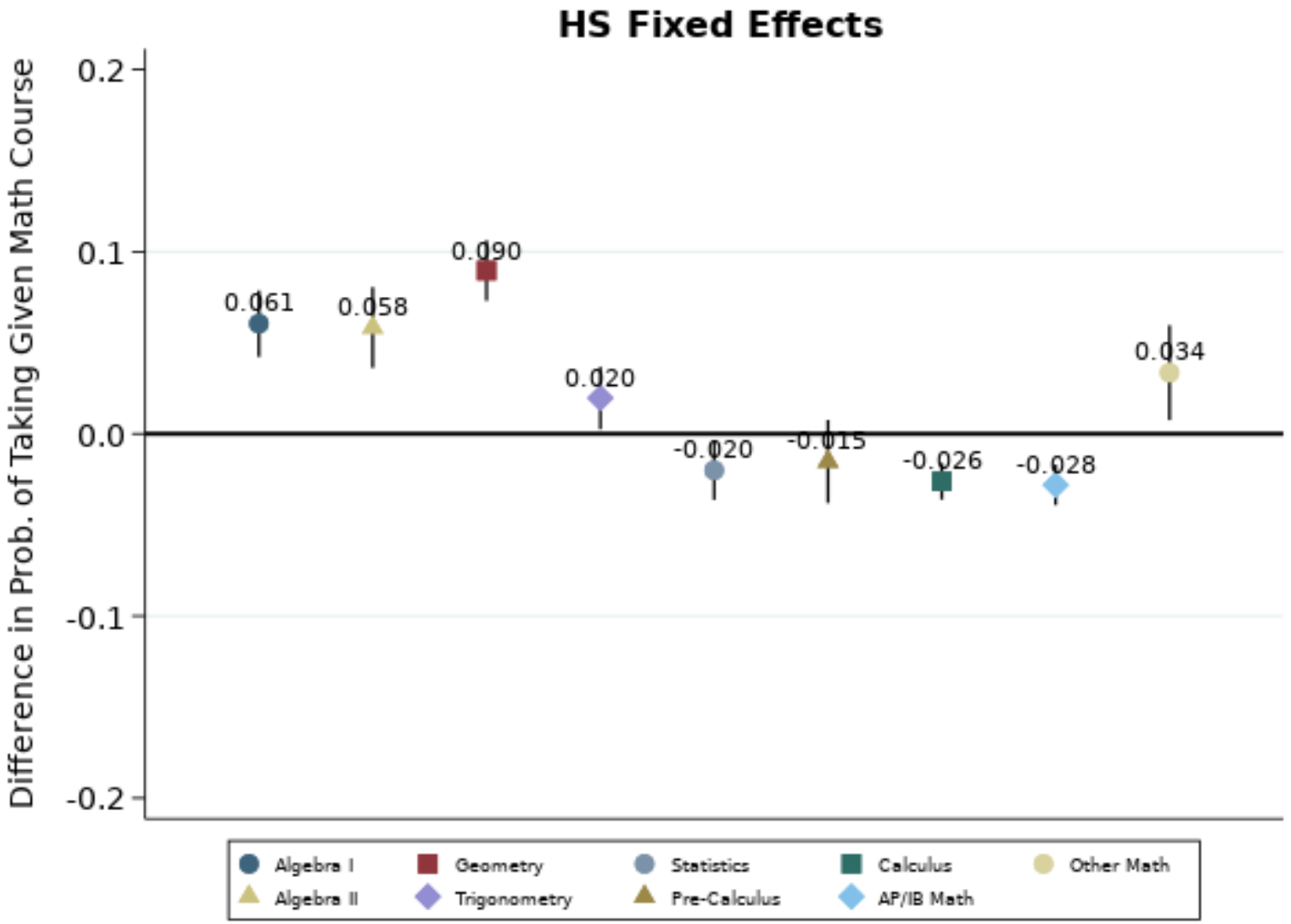
Notes: Estimates are the coefficient associated with an additional CTE course on the expected difference in the number of courses in each subject area. The top panel only includes those students enrolled in a comprehensive high school in 9th grade, and the bottom panel only includes those students in CTE-dedicated high schools in 9th grade. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 10. Differences in the # of Courses in Content Areas Predicted by An Additional CTE Course, by School Type



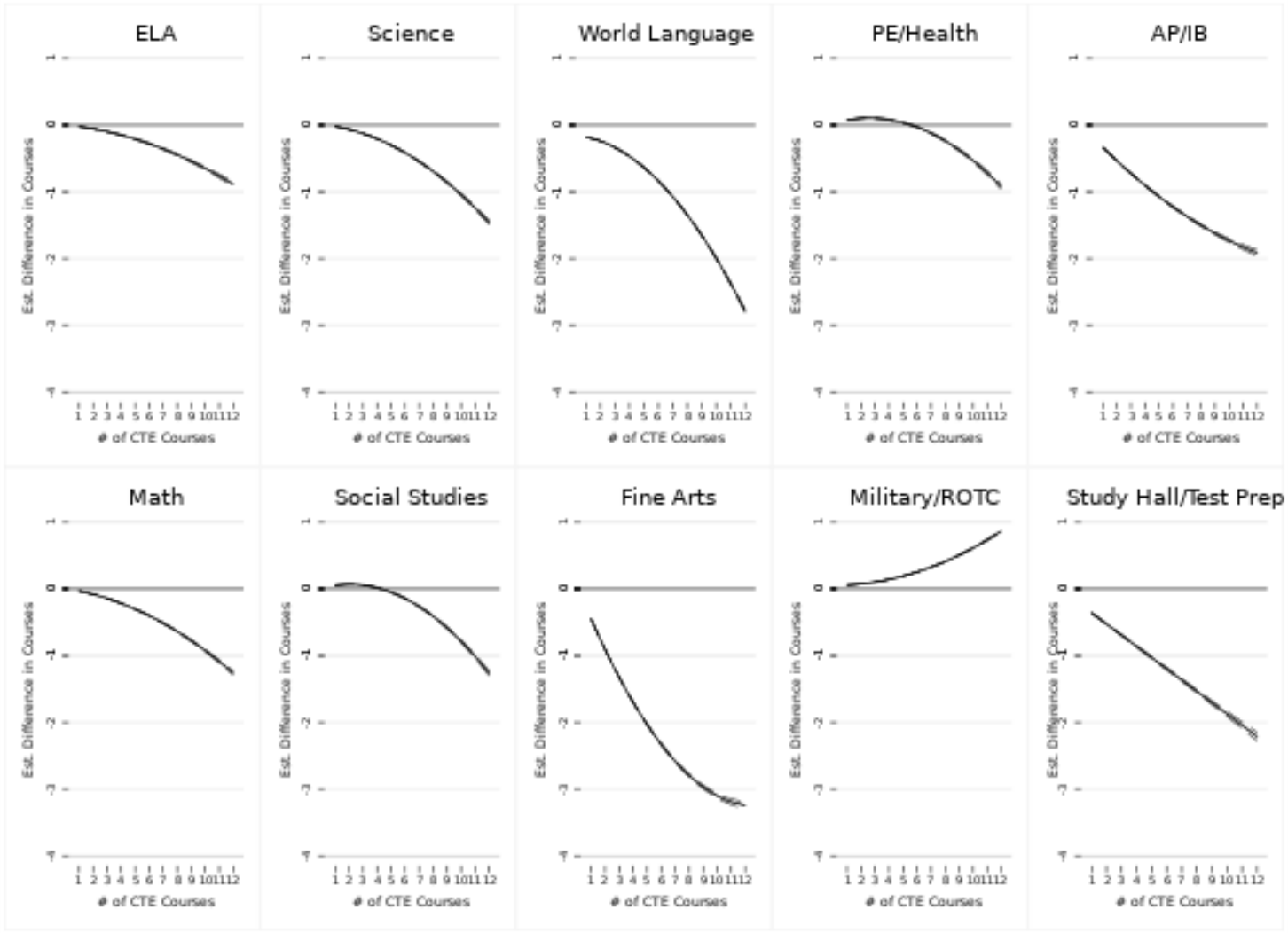
Notes: Estimates are the coefficient associated with an additional CTE course on the expected difference in the number of courses in each math course area. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 11. Differences in the # of Courses in Content Areas Predicted by An Additional CTE Course, by School Type



Notes: Estimates are the coefficient associated with an additional CTE course on the expected difference in the number of courses in each math course area. All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort fixed effects as well as fixed effects for the high school a student attended in 9th grade, with errors clustered by high school. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018.

Figure 12. Differences in the # of Courses in Content Areas Predicted by Varying Levels of CTE Coursetaking



Notes: Lines represent the ATE(t) associated with an additional CTE course on the expected difference in the number of courses in each subject area, at a given level of treatment (number of CTE courses). All models include controls for gender, race & ethnicity, lower-income status, English language learner status, immigrant status, disability status, 8th grade school attendance rates, and 8th grade performance on state assessments (both Mathematics and English Language Arts). Models also include cohort and town of residence fixed effects, with errors clustered by town of residence. Analytic samples include first-time 9th graders in cohorts that would have graduated on-time from public high schools in the spring years of 2015 through 2018. While a small number of students took more than 12 CTE courses, 12 courses represent approximately 99% of CTE course takers; for this analysis, those students taking more than 12 CTE courses were coded as taking 12 courses. Estimates are from the Stata "ctreatreg" package (Cerruli, 2015).