# Why Choose Career Technical Education? Disentangling Student Preferences from Program Availability*

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**Abstract**

This paper presents the first evidence of how students make career technical education (CTE) course-taking decisions. Among the universe of Michigan high-schoolers we find large disparities in CTE access and participation by gender, race, and income. We decompose participation gaps between supply (access) and demand (preferences) with a simple discrete choice model. We find that student preferences for CTE content drive participation gaps by gender, inequities in access drive gaps by income, and school-level supply and demand factors combine to create the gaps by race. Policy simulations highlight the importance of accessible CTE delivery models within comprehensive high schools.

**JEL Codes:** I21, J24, I24

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## I. Introduction

Amidst increasing income inequality, stagnating college completion rates, burdensome debt, and educational disruptions from COVID-19, there has been a growing interest in high-school career technical education (CTE), which prepare students with career-relevant skills and training. With secular trends and federal legislation (like the trillion-dollar Infrastructure, Investment, and Jobs Act) expected to expand labor demand in skilled trades and technology sectors, policymakers are working to increase and diversify the supply of skilled workers in technical fields like construction, IT, and healthcare (Sisson, 2021; Johnson, 2022; Dubay, 2022). As a result, interest in CTE and support for the training these programs provide only continue to increase.[1]

Research on CTE finds that participation in high school CTE programs can have substantial economic benefits, but that the returns vary dramatically by program field and by student demographics. Using a lottery-based and regression discontinuity design to estimate the causal effects of CTE, multiple papers have shown that attending specialized CTE-focused high schools boosts on-time high school graduation and quarterly earnings (Kemple and Willner, 2008; Dougherty, 2018; Hemelt et al., 2019; Brunner et al., 2021), but the effects are far from homogeneous. In fact, evidence suggests that the effects are completely driven by male students (Kemple and Willner, 2008; Brunner et al., 2021) and may be larger for lower-achieving students and those from lower-income families (Kemple and Willner, 2008; Dougherty, 2018). Furthermore, observational research suggests that the heterogeneous labor-market returns to CTE by gender are driven by choices regarding field of study (Ecton and Dougherty, 2023), a pattern reinforced by the fact that in national survey data completion of upper-level courses in technical (but not other) fields is associated with higher earnings (Kreisman and Stange, 2020).

The rich heterogeneity in returns and enrollment patterns suggests the need to understand why students from specific groups choose to participate (or not) in specific programs, but to our knowl-

[1] For example, In recent years, media mentions of "career technical education" increased more than five-fold from 2014 to 2019 (according to data from Meltwater), while at the same time many states have dramatically increased CTE funding (e.g., Montana doubled and Nevada tripled annual statewide appropriations for secondary CTE ACTE (2015)).

edge, however, there is *no* research on the determinants of CTE course-taking.[2] The lack of evidence on student demand for CTE is especially notable given the available research on many closely related questions. For example, researchers know a good deal about the demand for schools (e.g., Beuermann et al., 2018; Jacob et al., 2018; Pathak et al., 2020; Pathak and Shi, 2020) and the determinants of college major choice (Arcidiacono et al., 2012; Altonji et al., 2012, 2016; Patnaik et al., 2020, 2022), despite the fact that more high school students participate in CTE than will face a choice of which high school to attend or will graduate college.[3] There is even research on the demand for advanced academic classes in high school (DesJardins et al., 2018; Dahl et al., 2021)—but not for CTE classes.

In this paper, we study the determinants of CTE participation in high school using a rich student-level longitudinal dataset covering all students in the state of Michigan. We first describe access to and participation in CTE programs statewide, highlighting gaps in both participation and access across gender, race and income groups. For example, 42% of white students take at least two semesters of a CTE program compared with 28% of Black students; for high-wage programs, the rates are 25% and 15% respectively. Looking by gender, we see 35% of girls participate in CTE compared with 41% of boys. Moreover, there is considerable gender segregation across programs. For example, healthcare programs are dominated by girls (81%) while skilled trades are dominated by boys (90%). Consistent with these participation gaps, we document substantial gaps in *access* to CTE programs. For example, roughly 62% of white students have access to at least one CTE program in their school compared with 52% of Black students (65% and 50% for students from higher- versus lower-income families).

[2] Altonji et al. (2012) surveys the literature on the demand for high school and post-secondary education by field of study. Their theoretical model highlights the importance of preferences (along with uncertainty, ability, and human capital specificity), but the empirical studies reviewed focus on the *returns* to CTE rather than the *demand* for such programs. LaForest (Forthcoming) estimates the effects of participating in CTE using a dynamic structural model of high school and post-secondary course selection. Although this model could (in theory) provide some insight into student demand, the focus of the paper is again on understanding the economic returns to CTE student preferences are not discussed.

[3] Whereas 37.9% of adults 25 years and older have a BA degree (in the 2021 Current Population Survey), the Department of Education estimates that nearly 85% of high school graduates had at least one CTE course and that 19% completed a concentration in a CTE program (of Education, 2014). For school choice, 25 states allow for mostly unrestricted within-district high-school school choice (although some others allow flexibility for students in dangerous or low-performing schools).

Next, we develop and estimate a discrete choice model of student participation in CTE, with the goal of distinguishing the role of supply (program availability) versus demand (student preferences) factors in generating the participation gaps. Using the estimates from this model, we decompose the participation gaps to better understand their causes. Our analysis yields three main findings: (i) the male-female participation gap is driven entirely by demand factors (i.e., differences in student preferences); (ii) the income participation gap is driven entirely by supply factors (i.e., differential access to CTE programs); (iii) the Black-white participation gap is driven by factors operating at the school level—that is, all students (regardless of race) at predominantly Black schools participate less in CTE, due to what we conjecture is a combination of supply and demand factors.

Finally, using the estimates from our demand model, we conduct counterfactual simulations to explore how several commonly discussed CTE policies would influence student participation. Several findings emerge from these simulations. First, our results suggest that the ability to take CTE courses without traveling to a different school building is a critical determinant of student participation. This presents policymakers with a difficult tradeoff, as the creation of career centers that serve students across a district (or county) can be considerably less expensive that introducing identical programs within each comprehensive high school. Second, we see that policy impacts on participation *levels* often differ from impacts on *gaps*. For example, the expansion of career tech centers would increase participation rates equally for Black and white students, leaving the racial participation gap unchanged. The existence of such cases means that educators must clearly articulate the objective of CTE policies. Third, the introduction of new CTE options not only increases participation among students who had not previously participated in any CTE, but also induces students to shift from one program to another. Given the stark differences in labor market opportunities across programs, it is possible that the expansion of CTE programs could end up reducing economic prospects for some students even if it increases opportunities for others.[4] Together, these findings highlight a variety of important trade-offs that policymakers face.

[4] Similar to the debate on whether community colleges democratize postsecondary opportunities or divert students away from four-year institutions (see work by Mountjoy, 2019).

## II. Career Technical Education in Michigan

Over roughly the past decade, Michigan public schools offered 64 state-approved CTE programs grouped within 17 career clusters. Programs range from traditional vocational fields such as construction and automobile repair to high-demand fields such as health to more advanced science and technology areas.

CTE courses are electives that are not required by the state for graduation.[5] Most students take CTE courses during their junior or senior year of high school, although it is possible for students to start taking CTE courses earlier. Although some students only dabble in CTE (taking only one course possibly on multiple topics), most programs have a full series of courses (usually 2-4) which students complete by passing the courses and taking an assessment.[6]

Funding for CTE in Michigan comes from a variety of sources. Federal funding under the Perkins Act comprises roughly 9% of total funding. State and local funding comprise 25% and 66% respectively. State funding comes largely in the form of categorical aid that districts use to supplement general funding to defray the additional costs incurred in offering CTE programs.[7] Most funding is provided locally via county-wide millages. As of the 2019-20 academic year, slightly more than half of Michigan counties levied a property tax specifically dedicated to funding CTE.

The state defines the standards and content of CTE programs, approves district requests to offer programs, and then monitors the delivery of instruction to ensure that programs are meeting their objectives. Within this framework, however, local leaders have considerable latitude to determine which programs to offer and how to organize the instruction. The state is divided into 53 Career Education Planning Districts (CEPD), each of which is overseen by an administrator and a local director.[8] CEPD administrators coordinate program offerings across high schools and career

[5]Note that it is possible that some districts require students to take CTE courses.

[6]To complete the program, federal rules require students to take, but not necessarily pass, the assessment when one is available.

[7]State revenues used to fund CTE include taxes on property, commercial sales, corporate and personal income, and the state lottery.

[8]In more populous areas, CEPDs are often synonymous with counties. In more rural areas, multiple counties will

academies to reflect regional priorities. Educational and financial resources may be shared across regions under a consortium agreement.

Students typically take CTE courses in their home high school, another high school in their (or other) district, or a regional Career Tech Center. Career Tech Centers are schools that only offer CTE courses and typically serve all students in a particular county. While some school districts provide transportation for students taking CTE courses outside their home school, in many cases students must take public transit or provide their own transportation. To take CTE courses outside of their home high school, students usually schedule non-CTE courses during the morning or afternoon, so they can travel to CTE courses during the other part of the day. Unlike some other states, Michigan has only a handful of "Career Academies": high schools that fully integrate CTE and non-CTE instruction for all students in the school. As a result, many students need to travel out of their home high school to participate in CTE.

## III. Data and Sample

The data used in this analysis is drawn from student level longitudinal data files provided by the Michigan Department of Education (MDE), the Michigan Center for Education Performance and Information (CEPI), and the Michigan Office of Career and Technical Education (OCTE). In this section, we briefly describe construction of the sample and definition of key measures.

### A. Student Sample

Our sample begins with all first-time tenth graders attending Michigan public schools between SY2008-09 and SY2018-19 (n= 1,374,723 students). We drop 101,780 students enrolled in schools that were not traditional, vocational, or alternative high schools operated by public districts. The majority of these dropped students attended virtual or special education schools where career technical education, if present, may not be comparable to the rest of the state. We also drop an additional 7,612 students who were attending schools with fewer than 10 students on average per cohort be-

be housed within the same CEPD.

cause to simplify estimation of the demand model.[9]

We include a variety of student and school characteristics in our analysis. Student demographics and disability status come from MDE records and are based on a student's 11th grade year. To measure prior academic achievement, we use the average of a student's standardized 8th grade math and reading scores.[10] We retain observations with missing values for 8th grade test scores. For analysis purposes, we generate a missing value flag and replace missing values with the (student weighted) population mean.[11] School measures such as school type (e.g., vocational versus traditional, urbanicity) and school demographics (e.g., percent poor, percent white, average achievement) come directly from MDE records.

### B. CTE Program Sample

While Michigan operated 64 programs at some point during our sample period, many of these programs were tiny, existing for only a year or two, or offered in only a few schools. We drop 23 of the 64 programs that have fewer than 1,250 total student-year enrollments and programs that were discontinued before 2011. We also combine two programs that were re-branded versions of each other. These restrictions leave us with 40 programs of study in our sample.[12]

CTE programs also vary widely in terms of the skills they require and labor market opportunities they provide. For our analysis, we group programs into 10 groups based on the career clusters used by MDE (which is itself based on national groupings) as well as the programs' educational content and expected occupations. In most cases, we created groups by combining similar career clusters, such as combining Construction and Manufacturing into Skilled Trades. In some cases, we moved programs across clusters if they were outliers within the group in terms of ex-

[9] When we estimate the demand for CTE programs, student choice sets will be defined at the school-by-cohort level, thus schools with fewer than 10 students per cohort are small "markets" with possibly unreliable choice shares.

[10] Technically we use the average math and reading or English language arts scores since the test for eighth graders changed between reading and ELA in our sample period. If 8th grade scores are missing, we impute them with standardized scores from 11th grade tests with the following priority: state-administered ACT scores, state-administered SAT scores, end-of-year state exams.

[11] There is no missing data for the other variables in our analysis.

[12] As described in more the model section, this means that we treat the very small set of students who participated in these programs as not having participated in any CTE program.

pected wages, educational requirements or skills. For example, we placed the program "Drafting and Design Technology" (which is grouped within the Construction cluster) in a Technology group with other drafting courses as opposed to in the Skilled Trades group with the other Construction programs. The resulting 10 groups are Accounting, Business, Communications, Healthcare, Technology, Agriculture, Personal Services, Public Service, Skilled Trades, and Automotive.

We also characterize programs by whether they train students for high-wage jobs, which we define as earnings of at least $25 per hour. To determine expected wages for each program, we utilize a cipcode-to-occupation crosswalk developed by MDE that links each CTE program to the occupations for which it is intended to prepare students. For example, this crosswalk associates the Healthcare program (cipcode 51.0000) with occupations such as respiratory therapy technicians, physical therapy assistants, and radiation therapists. Importantly, it does not link this CTE program with occupations that require substantially higher levels of education such as registered nurse or physician. Using American Community Survey (ACS) data and the program-occupation link, we calculate the national median wage in occupations linked to the CTE program (weighted by the relative sizes of the occupations). Appendix Table C.1 lists all 40 programs included in our analysis, along with their group classification, expected wage and an indicator for whether each is a high-wage program.

### C. Measuring CTE Availability

As described in section II, students in Michigan can take CTE courses in a variety of locations, including their home-school, other comprehensive high schools, and dedicated Career Technical Centers. Ideally, we would be able to draw on an official directory that outlines program availability for each high school in the state. Unfortunately, due to the decentralized and heterogeneous ways in which CTE is offered in Michigan, no such list exists. Instead, we create availability measures using a combination of known rules and empirical attendance patterns.

We operationalize availability at the program-by-school level, which MDE refers to as a PSN (for program serial number). For example, students at Dexter High School near Ann Arbor can take the graphics and printing program in multiple different locations—in this case Dexter High School in Dexter (PSN 5425) or Saline High School in Saline (PSN 5426). In this case, both PSNs would appear in the choice set of Dexter students.

First, we assume that students have access to all programs offered at their home-school, or in another administrative unit located in the same physical building as the home-school. At a conceptual level, we think of the home-school as the place in which the student takes their non-CTE courses. Operationally, we begin by defining a student's home school as the school building in which the student spends most of their instructional time during the year. By assuming that all students who attend the same home school each year have equal access to CTE programs, we ignore situations in which students may not be able to participate in a CTE program because of physical restrictions, GPA requirements, or course prerequisites. In addition, this measure of availability implicitly assumes that CTE programs are not oversubscribed. While we recognize that this is not strictly true, our conversations with administrators and teachers suggests that few programs are oversubscribed in the state. We discuss the implications of this assumption in more detail in the following section.

Second, we assume that students can attend any CTE program offered in a Career Tech Center that is intended to serve the district or county in which the student's home-school is located. Finally, we consider a PSN available to students in a particular home-school if students from the home-school appear to have a sustained presence in the program (see details in Appendix A. Note that because this measure is based on empirical enrollment, it will not detect programs that are technically available but never attended because the travel time is so substantial.

Once we determine the set of programs available to students, we calculate the travel time required for a student to go from their home-school to the offering school using geocoded school information and the HERE.com API. We use this measure (rather than distance from the student's home, for example) because schools are generally responsible for the transportation of their students during school hours and for many programs students travel from school to school rather than traveling from or to their homes.

When combined with the travel times, these definitions of availability between schools and PSNs allow us to define other important access-related variables. For example, we can determine the number of programs available to students within their home-school building, within 10 minutes, 20 minutes, etc. We can also calculate whether students have any access to any programs that train students in each group of CTE programs or with expected wages above $25 (2015USD).

### D. Defining CTE Participation

Although students may participate in CTE programs at any time in their high school careers, the vast majority of CTE course taking occurs during students' junior and senior years of high school. Moreover, most students who take CTE courses early in their high school career continue to do so later in high school. For example, among students who take any CTE courses, about 80% take courses during their junior or senior year. Given this pattern of course taking, to simplify the discrete-choice model described below we limit our attention to CTE courses that are available to students in their junior year.[13] One implication of this is that if a student participates in CTE program that is only available in, for example, their first year of high school, they will remain in our sample, but we will consider them not to have taken CTE at all.

About 10% of students only take a single CTE course during their entire time in high school. For these students, CTE courses serve the role of an interesting elective rather than a serious pursuit. For this reason, we choose to focus on taking the equivalent of at least two one-semester courses in a single program, and we define participation accordingly.

To facilitate our discrete choice analysis, if a student enrolled in courses in multiple CTE programs, we define their chosen program as the one in which they enrolled in the most semesters. Although 10% of our sample take at least one course in multiple programs, for most students their choice is very clear. For the 2.7% students who took the exact same number of courses in more than one program, we randomly select the program to assign to the student.

[13] For tenth graders who drop out our leave the state, we assign them CTE courses based on the modal eleventh-grade school for other students in their cohort at their tenth-grade school.

## IV. CTE Access and Participation

Table 1 shows summary statistics on CTE participation by student subgroups. Roughly 38% of students participate in CTE, though only 22% participate in a program that will prepare them for a high-wage occupation. Average participation in three such high-wage programs is 3.9% for technology, 5.5% for healthcare and 3.6% for skilled trades. Black students are 10 percentage points less likely to participate in CTE than white students. Female students are 6 percentage points less likely to participate in any CTE than males, and 9 percentage points less likely to participate in high-wage programs. There is a non-linear relationship between student achievement and CTE participation, with middle quartile students being the most likely to participate.[14]

Broadly speaking, these gaps could be explained by differences in student demand for CTE and/or student access to CTE. Using the measures of CTE availability described above, we can calculate exactly the number of programs to which each student should have access. Figure 1 shows differences in access by student race and income.[15] Lower-income and Black students have substantially less access to CTE programs than their higher-income and white peers. This is true both within their own high schools and via traveling to other schools. For example, 46.6% of low-income students have *no* CTE programs in their own high schools compared with only 32.9% among higher-income students. Conversely, 37% of higher-income students have access to at least four CTE programs in their own schools compared with approximately 24% of lower-income students. The differences are roughly comparable between Black and white students. Looking at CTE programs available via travel, we see that almost 61% of higher-income students can access 10 or more programs compared with only 55% of lower-income students. Figure 2 shows the analogous differences for high-wage programs.

[14] We do not investigate the achievement-based gaps in-depth in this paper, although they do play an important role in our understanding the race and income gaps. There may be several explanations for this pattern. On one hand, lower-achieving students may be discouraged from taking CTE if they fail and thus need to retake core academic classes. On the other hand, higher-achieving students are likely to take Advanced Placement or academic-focused electives rather than CTE courses.

[15] Because access is based on high school, and there is little sex segregation across schools, access is virtually identical for boys and girls.

Figure 1: Availability of CTE Programs, by Student Subgroups

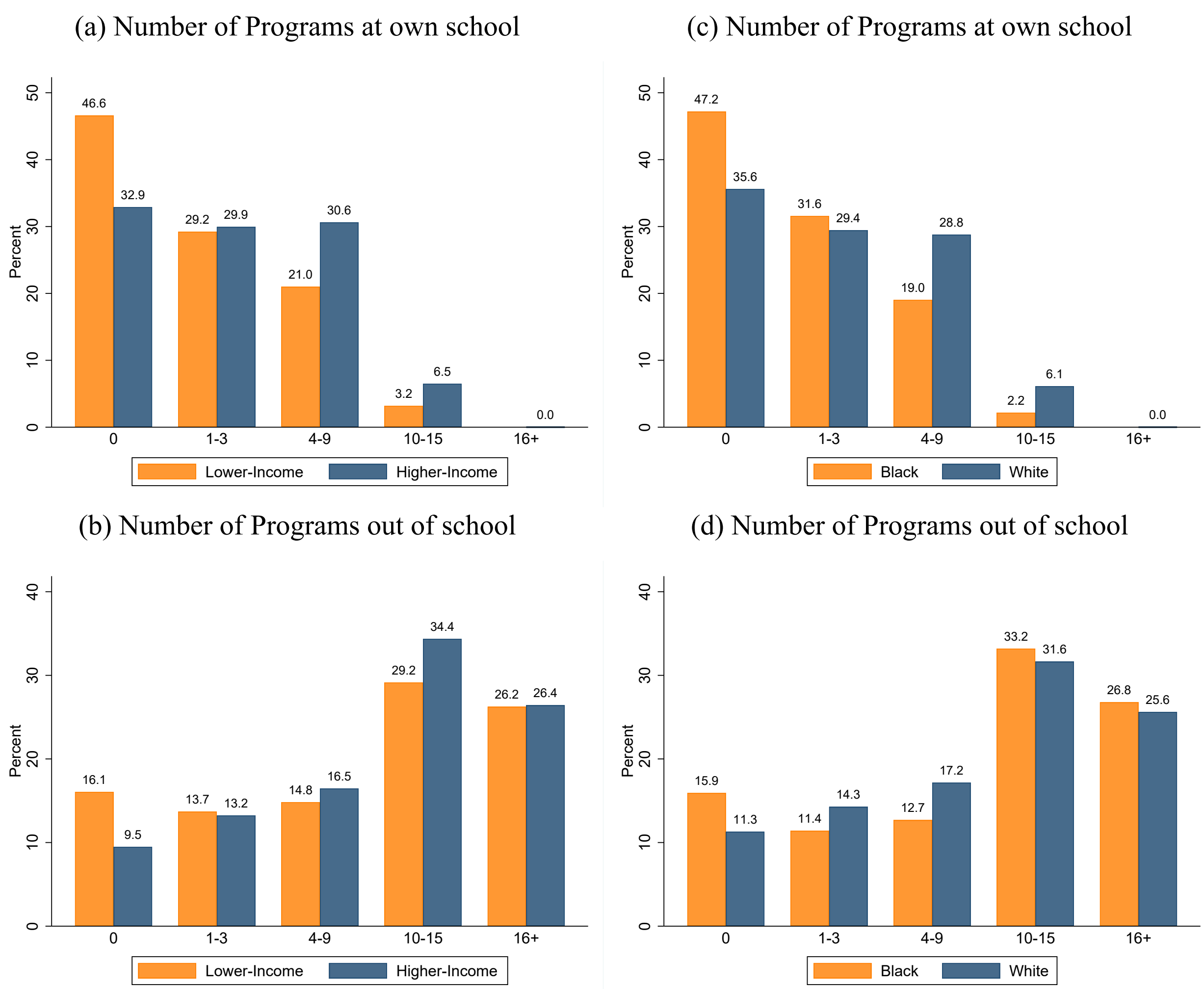


Figure 2: Availability of High-Wage CTE Programs, by Student Subgroups

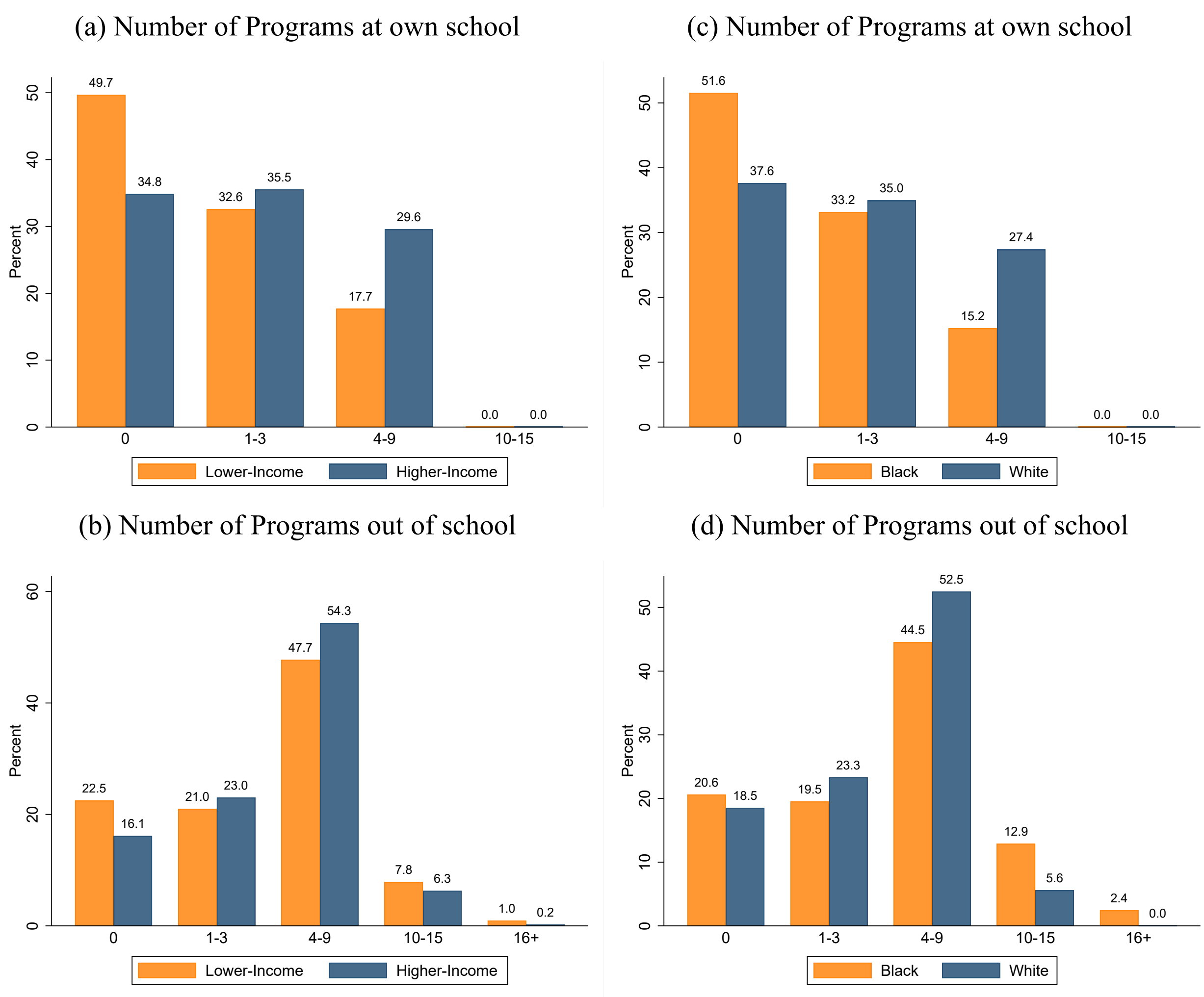


Table 1: CTE Participation Rates

| | Any CTE | High-Wage CTE | Healthcare | Technology | Skilled Trades |
|---|---|---|---|---|---|
| All students | 0.381 | 0.223 | 0.055 | 0.039 | 0.036 |
| Black | 0.276 | 0.153 | 0.043 | 0.016 | 0.018 |
| Hispanic/Asian/Other | 0.313 | 0.177 | 0.054 | 0.037 | 0.025 |
| White | 0.420 | 0.250 | 0.059 | 0.046 | 0.042 |
| Male | 0.410 | 0.268 | 0.020 | 0.063 | 0.064 |
| Female | 0.351 | 0.178 | 0.092 | 0.015 | 0.006 |
| Lower-Income | 0.353 | 0.187 | 0.054 | 0.027 | 0.038 |
| Higher-Income | 0.401 | 0.250 | 0.056 | 0.048 | 0.034 |
| Student Achievement (Grade 8) | | | | | |
| Bottom Quartile | 0.369 | 0.187 | 0.047 | 0.023 | 0.050 |
| Quartile 2 | 0.388 | 0.216 | 0.060 | 0.031 | 0.039 |
| Quartile 3 | 0.434 | 0.263 | 0.068 | 0.047 | 0.034 |
| Top Quartile | 0.338 | 0.233 | 0.047 | 0.057 | 0.018 |

Note: All rates are unconditional. For a list of high-wage CTE programs, see Table C.1

## V. Student Demand for CTE Courses

These descriptive statistics suggest that, while access cannot explain sex differences in CTE participation, they may play a role in the race and income gaps. However, these statistics do not allow us to disentangle supply constraints from preference differences because the composition of students varies substantially across schools. Thus, it is likely that student preferences for CTE will differ across schools.

To better understand the roles of preferences versus access, we develop a model of student demand for CTE. The model will allow us to more fully describe how students choose between CTE programs which, in turn, can help us explore the potential impacts of various CTE policies. In this section, we describe our model and estimation strategy, and provide evidence that our model fits the data well and captures relevant substitution patterns in the data.

## A. Model

We adopt the following model of utility for student $i$ enrolled in school $s(i)$ if they were to participate in program of study $p$ offered at offering school $o$:

$$u_{i,p,o} = \alpha_i z_{i,o} + \beta_i x_p + \epsilon_{i,p,o} \tag{1}$$

$$\begin{pmatrix} \beta_i \\ \alpha_i \end{pmatrix} \sim \mathcal{N}\left( D_i \cdot \begin{pmatrix} \Pi_x \\ \Pi_z \end{pmatrix}, \Sigma \right) \tag{2}$$

$$\epsilon_{i,p,o} \sim \mathrm{EV}(1) \tag{3}$$

In this model the $x_p$ are binary variables indicating each of the ten program groups identified above: Accounting, Business Communication, Health, Technology, Agriculture, Automotive, Personal Services, Public Service, and Skilled Trades. The availability measures $z_{i,o}$ captures the transportation cost for student $i$ to travel to school $o$ to participate in the program. This includes an indicator for whether the program is offered outside of the student's school ($o \neq s(i)$) and the total minutes of travel between school $s(i)$ and $o$. We assume a Type-1 Extreme Value distribution for the idiosyncratic error, $\epsilon_{i,p,o}$.

Because differences in preferences for programs and for travel are of first-order importance for our research questions, we allow the coefficients on $x_p$ and $z_{i,o}$ to vary based on $D_i$, a matrix of student characteristics including race (three groups: white—omitted—Non-Hispanic Black, and other), sex (female), a binary indicator for special education status, a linear measure of 8th grade achievement as discussed above,[16] and achievement interacted with sex. The matrix also includes the school characteristics percent non-white, percent poor, and average test scores, along with a binary indicator for non-traditional schools, which includes charter schools as well as other alternative high schools.[17]

[16] We also include a missing flag for individuals for whom we do not have achievement data as a nuisance parameter. None of the other variables had missing values.

[17] There are a small number of high schools in the state that are categorized as "vocational" despite the fact that they offer non-CTE as well as CTE courses and appear similar to most other "regular" high schools. For this reason, we do code them as alternative schools in our analysis.

## B. Identification

For the parameters to be identified, we need to assume full information about choice sets and no omitted relevant supply factors. For example, if a particular program has limited available seats or rigorous prerequisites, we might mistakenly say students do not prefer the program. Although we are aware of some circumstances like this, our conversations with administrators lead us to believe that these are not major concerns.

These coefficients will be identified by differences in participation rates over $D$ and $Z$. For example, if a larger fraction of girls than boys participate in health programs, the coefficient on the female x health interaction term $\beta$ will be positive. Similarly, difference in participation rates (conditional on $D$) in programs offered at different locations or different distances, identify the coefficients $\alpha$. Including these rich student characteristics interacted with programs and traveling has the added advantage of overcoming the inconvenient "independence of irrelevant alternatives" property of $\epsilon_{i,p,o}$'s EV(1) distribution.

## C. Estimation

To estimate these preferences, we begin by defining choice sets. Define the set of available programs $\mathscr{P}_i = \{0, ..., P\} \subset \{0, 1, ...40\}$. For each of these programs, $p_i$, let the set of schools where the student can take that program be $\mathscr{O}(p_i) = \{o_1, ..., o_N\}$. Together these sets define a set of program-by-offering-school pairs in which the student can choose to participate. Let $p = 0$ be the choice to not participate in any CTE program.[18] We use the availability measures described in the data section to define choice sets empirically, defining each student's choice set as all programs available from their own school in their junior year of high school, including the option to not take CTE. Note that this means that the school $s$ and year $t$ fully characterize a student's choice set. We define $p^*$ as the chosen program and $o^*(p^*)$ as the chosen location by each student. For notational simplicity we can also denote the chosen option as $j^*$.

With the choice sets defined, we use the properties of the Type 1 Extreme Value distribution to

[18]We implicitly assume that students only take no CTE in their home school: $\mathscr{O}(p_i = 0) = \{s_i\} \, \forall i$.

characterize the probability of a student $i$ choosing program $p$ at school $o$ as follows:

$$P_{i,p,o} = \frac{\exp(\alpha_i z_{i,o} + \beta_i x_p)}{\sum_{p' \in \mathscr{P}_i} \sum_{o' \in \mathscr{O}(p'_i)} \exp(\alpha_i z_{i,o'} + \beta x_{p'})} \tag{4}$$

This in turn allows us to specify a log likelihood function that encapsulates the likelihood of seeing the observed set of choices and data given parameter values $\theta = (\Pi, \Sigma)$. Given a set of parameter guesses, the likelihood of the observed choice is

$$\mathscr{L}(\theta) = \sum_i \log \left( \int P_{i,p^*,o^*(p^*)} \, \mathrm{d}(\boldsymbol{\alpha}_i \boldsymbol{\beta}_i) \right) \tag{5}$$

which we estimate by simulated maximum likelihood. Below we report cases where $\Sigma = \mathbf{0}$ and all coefficients are linear functions of characteristics $D_i$. Inference is conducted with cluster-robust standard errors with clusters at the level of students' eleventh grade school.

### D. Model Diagnostics

In this section, we present several diagnostic checks to assess the fit of our model. For one to have confidence in the decompositions and counterfactual policy simulations, it is important to demonstrate that our model estimates capture relevant substitution patterns in the data.

To begin, we perform some standard exercises to assess how well the model fits patterns not directly targeted in the estimation. Appendix Figure C.1 presents two such comparisons. First, we show that the variables $D$ largely capture the participation patterns for race-by-gender-by-achievement groups even though this intersectionality is not included in the model. These relationships are important for considering the relevant enrollment gaps. The exception to this involves high-achieving Black students, for which we underestimate participation, and low-achieving Black students, for which we slightly overestimate participation. While we could improve the fit of the model by including additional interaction terms (e.g., achievement x sex x race), the differences are small enough that we believe that this would not influence the empirical findings and choose to keep a more parsimonious model. Second, we show that the participation decision for individual programs of study within each group are also closely captured. These relationships are important for considering choices and policy counterfactuals altering choice sets. Model fit is just as accurate even as the size of choice sets varies—something else that will change in the policy counterfactuals.

Second, we explore the substitution patterns implied by the model. This is important because differences in participation across students may be driven by differences in program availability and program substitution will matter immensely for evaluating counterfactual policies. We approach this objective in two ways. First, we compare our model estimates with quasi-experimental evidence about how participation changes when program availability within a given school changes. To do this we estimate a regression of the following form:

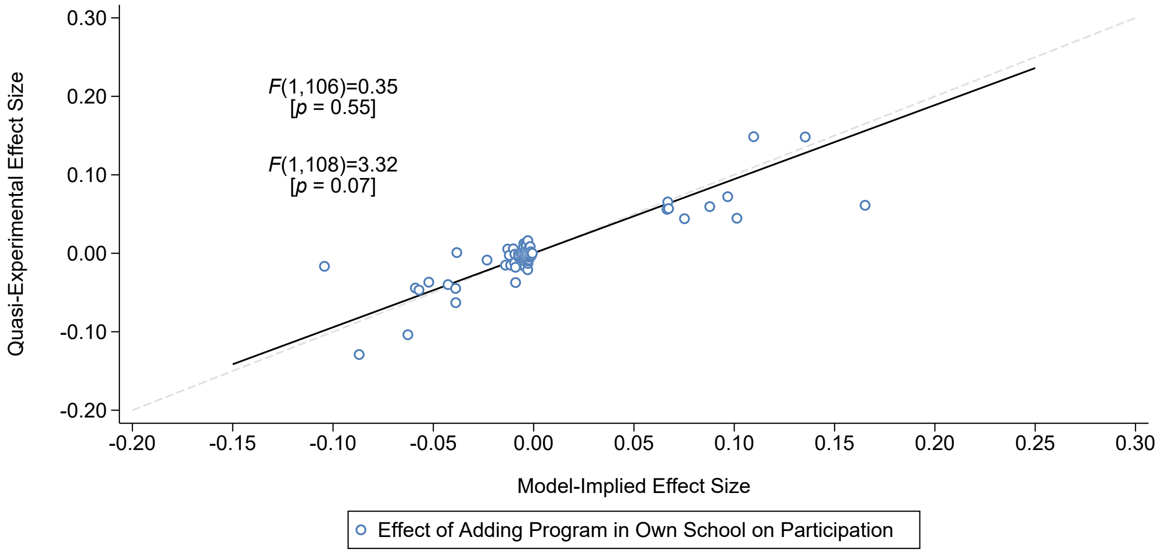
$$\text{Participation}(g)_{i,s} = \sum_{g \in \mathcal{G}} \tau_g \text{Own School}(g)_{i,s} + \psi_s + \nu_{i,s} \tag{6}$$

where $\text{Participation}(g)_{i,s}$ refers to whether student $i$ participated in a CTE program in each of the ten groups $g \in \mathcal{G}$. We regress this participation decision on indicators for whether each of the ten groups was available in the student's home school $s$. By including school fixed effects $\psi_s$, we identify the effects using changes in availability *within* a school over time.

We compare these quasi-experimentally estimated changes in participation with the changes predicted by the model and find them to be very similar. Figure 3 reports the results. For each group $g$ the changes in participation implied by the model are calculated by simulating the addition of a program from group $g$ in schools that did not offer $g$ in the data. All simulations are run on a subset of schools with at least some within-school variation in own-school availability in our 11 years of data.[19] The simulated and quasi-experimental measures are highly correlated, and the slope of the regression line is close to one. The F-test of the null hypothesis that the slope is one is marginally significant (p-value 0.07). Closer examination finds that this is driven by two programs at the left and right tails of the model-implied estimates. If we drop these observations, the F-test

[19] This restriction is to make the results comparable to the regression estimates that include school fixed effects. Schools with no variation tend to be smaller and have different types of students so the average effect implied by the model may be slightly different from the (local) average on students with within-school variation.

Figure 3: Model Estimates Capture Quasi-Experimental Substitution Patterns




Note: This figure compares quasi-experimental and model implied substitution patterns between the ten program groups. The regression estimates the change in participation in various CTE programs resulting from a change in own-school availability for each of the ten programs. The regressions include interactions with (demeaned) student characteristics as in the model and school fixed effects to maintain a causal, partial equilibrium interpretation. The model-implied estimates report the average change in participation resulting from an identical simulated change excluding the few schools where there are no changes over time. Two F-tests are reported testing whether the slope is different from one: one on all observations and one dropping the two extreme values on the $x$-axis.

has a p-value of 0.55, far from conventional levels of significance. This suggests that the model is capturing the intended patterns of participation.

Finally, we present a list of simulated "second choices" implied by the parameter estimates and the existing choice sets. These results reflect more nuanced substitution patterns captured by the model and provide a check of the face validity of the estimates. Table **??** reports this distribution for 20 example programs. Because these estimates represent the most common second choices students would make given their existing choice sets, they combine both supply and demand features. For example, collision repair and autoshop may be very close substitutes, but collision repair is not widely offered, making it an uncommon second choice for autoshop. One of the undesirable properties of using a simple logit model would be that the most common second choice for all options would be the same—based on the most popular choices. In our setting this would mean the most common second choices for *all* programs would be business, marketing, and then healthcare. Table

Table 2: Second Choices Reveal Intuitive Substitution Patterns

| Program | CIPcode | Participants | Most Common Second Choice: | | | |
|---|---|---|---|---|---|---|
| No CTE | 0.0000 | 744,547 | Health (14.1) | Marketing (11.8) | Business (9.5) | Cooking (6.1) |
| Business | 52.0299 | 104,205 | Marketing (15.4) | Health (14.6) | Accounting (13.8) | Agriculture (5.0) |
| Marketing | 52.1999 | 89,688 | Business (17.0) | Health (15.0) | Accounting (9.2) | Autoshop (5.7) |
| Health | 51.0000 | 76,322 | Marketing (17.3) | Business (14.9) | Cooking (8.9) | Accounting (6.8) |
| Accounting | 52.0800 | 39,960 | Business (23.6) | Marketing (17.3) | Health (12.1) | Agriculture (3.8) |
| Agriculture | 1.0000 | 33,453 | Health (17.8) | Business (11.1) | Marketing (9.2) | Construction (5.1) |
| Autoshop | 47.0604 | 33,025 | Marketing (13.4) | Business (11.8) | Health (9.1) | Construction (7.0) |
| Cooking | 12.9999 | 30,986 | Health (18.7) | Marketing (15.9) | Business (11.0) | Autoshop (4.6) |
| Construction | 46.0000 | 25,086 | Business (10.7) | Marketing (10.7) | Autoshop (9.5) | Health (7.4) |
| Graphics | 10.0301 | 23,835 | Health (17.1) | Marketing (13.2) | Business (10.5) | Cooking (6.3) |
| Drafting | 15.1301 | 18,977 | Business (18.9) | Marketing (16.1) | Health (8.6) | Accounting (8.4) |
| Public Safety | 43.0100 | 13,052 | Health (15.0) | Marketing (10.1) | Business (8.6) | Agriculture (6.9) |
| Welding | 48.0508 | 11,619 | Autoshop (11.2) | Business (9.5) | Construction (8.8) | Marketing (8.7) |
| Programming | 11.0201 | 9,201 | Marketing (17.9) | Business (12.8) | Multimedia Design (7.3) | Accounting (7.0) |
| Machinist | 48.0501 | 7,874 | Business (9.7) | Autoshop (9.3) | Construction (8.6) | Agriculture (8.5) |
| Cosmetology | 12.0400 | 7,489 | Health (24.0) | Marketing (12.9) | Business (10.8) | Cooking (9.8) |
| Collision Repair Technician | 47.0603 | 6,592 | Marketing (11.6) | Autoshop (8.9) | Business (8.5) | Construction (5.7) |
| Woodwork | 48.0701 | 3,512 | Business (13.0) | Agriculture (10.9) | Construction (10.5) | Marketing (9.6) |
| Child Care | 19.0700 | 2,339 | Health (24.0) | Business (15.5) | Marketing (14.4) | Cooking (9.2) |
| Truck Technician | 47.0613 | 2,115 | Agriculture (12.2) | Autoshop (10.3) | Construction (9.0) | Welding (7.1) |
| Small Engine Repair | 47.0606 | 1,696 | Autoshop (10.6) | Business (8.5) | Marketing (7.8) | Construction (7.0) |
| Veterinary Science | 1.0903 | 1,139 | Health (19.2) | Business (14.5) | Agriculture (7.7) | Marketing (7.6) |
| Conservation | 3.0000 | 1,082 | Agriculture (20.0) | Health (12.3) | Marketing (9.7) | Business (8.0) |
| Electrician | 46.0301 | 904 | Marketing (10.6) | Business (7.8) | Autoshop (7.5) | Public Safety (6.1) |
| HVAC | 47.0201 | 896 | Marketing (10.9) | Autoshop (8.6) | Business (7.9) | Construction (7.4) |

Note: This table shows the most common model-predicted second choices for students who chose a given program. Results are based off of the estimated logit model of program choice. We simulate student choices then report the fraction choosing each alternative (net of the outside option) conditional on the first choice. We hold student choice sets fixed for this exercise. We report 20 programs including the largest program in each group and 10 others that have received relatively more policy attention.

**??** tells a very different story, suggesting that we capture rich substitution patterns that will enable us to decompose the gaps and run policy counterfactuals appropriately.

The largest programs do show up as substitutes for many others since they are so widely offered, but other patterns are quite intuitive. Autoshop and construction show up as substitutes for many manufacturing programs, whereas accounting and multimedia design are show up as substitutes for "white-collar" technical programs. Overall, these substitution patterns suggest that the model is capturing student preferences well. A second interesting point to note from this exercise is that for students who do not participate in CTE, health is the most common second choice. The availability of health programs will turn out to be a key determinant of participation gaps and a central feature of our policy simulations discussed below.

## VI. Results

In this section, we discuss the main findings of our estimation. We first examine how preferences for CTE vary by student and school characteristics. We next conduct several decomposition exercises to explore the degree to which both demand and supply factors can explain the participation gaps highlighted above.

### A. Willingness to Participate Varies by Students and Programs

Because the raw logit coefficients (shown in Appendix Table C.3 ) are hard to interpret, we present the implications of these demand estimates in terms of a student's willingness to travel to attend different programs. We calculate the predicted willingness to travel (in minutes) for student $i$ to a program in CTE group $g$ as:

$$\widehat{WTT}_{i,g} = -\frac{\hat{\beta}_{i,g} + \bar{\alpha}_{Out}}{\bar{\alpha}_{Time}} \tag{7}$$

where $\hat{\beta}_i$ captures the predicted utility associated with attending a CTE program, $\bar{\alpha}_{Out}$ measures the average disutility associated with leaving one's home school, and $\bar{\alpha}_{Time}$ measures the average disutility per minute of travel time. Hence, the $WTT$ captures the utility of participating, net of leaving one's own school, denominated in minutes.[20] To focus on heterogeneity in student demand for different programs we use average costs (so the numerator and denominator are not both changing simultaneously), but Appendix Table C.5 reports analogous results using individual-level $\alpha_i$ and find qualitatively similar patterns in differences across programs with harder-to-interpret level shifts for each group based on the cost.

To interpret the information from the logit coefficients, we report the marginal difference between the willingness to travel of a target group (e.g., female students) and a reference category (e.g., male students), holding all other characteristics of these groups constant. To calculate the

[20] We measure utility net of leaving one's own school because measuring disutility in minutes traveled does not make sense for students attending programs in their own school.

marginal impacts of student characteristics on willingness to travel, we regress each student $i$'s predicted willingness to travel to participate in program $g$ on their characteristics:

$$\widehat{WTT}_{i,g} = \gamma_g D_i + u_{i,g} \tag{8}$$

Table 3 presents the results for selected groups and Appendix Table C.4 shows the WTT estimates for all ten. The number in each cell reflects the marginal effect of a student having a characteristic on their willingness to travel. For each program, we estimate the number of minutes that a student with a given characteristic would be willing to travel to participate, relative to a hypothetical "reference" student. We define this reference student as a white male who is not eligible for subsidized meals, has average achievement and attends an "average" non-alternative school in terms of achievement, poverty rates and racial composition. For example, a poor student would be willing to travel 5 minutes less to attend a business program relative to an observably similar student from a higher income family. Conversely, a Black student would be willing to travel 7 more minutes to participate in a personal services program compared with an otherwise identical white student.

The results show a great deal of heterogeneity. For example, we see that relative to an observably identical male student, female students on average are willing to travel 38 minutes farther to participate in a healthcare program. On the other hand, the average female student would need to be 77 minutes closer to a skilled trades program to be as willing to participate as an otherwise identical male student. To help gauge the magnitude of these differences, we report the standard deviation of each outcome in the bottom row. Among student characteristics, sex and disability status appear to be most important in determining preferences. Interestingly, the school characteristics (particularly percent low-income and percent nonwhite) appear to be even larger drivers of preferences. We will discuss this result more below.

Note that these results reflect not only preferences for programs, but also the disutility associated with travel. The rightmost column provides a sense of the differential cost of travel across groups

Table 3: Willingness to Travel Varies by Student and Program Characteristics

| | Minutes willing to travel to do a program in each CTE group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Business | Healthcare | Technology | Skilled Trades | Automotive | Personal Service | Disutility of traveling 15 min away for CTE |
| Student Demographics | | | | | | | |
| Lower-Income | -5 | -2 | -7 | -2 | 1 | 4 | 0.1 |
| Black | 2 | 1 | -12 | -20 | -27 | 7 | 0.0 |
| Other Race | -8 | -2 | -6 | -16 | -14 | -4 | 0.0 |
| Female | -9 | 38 | -51 | -77 | -80 | 17 | 0.2 |
| Student Academic Characteristics | | | | | | | |
| Test Scores (SD) | -3 | 1 | 4 | -13 | -16 | -9 | 0.0 |
| Female * Score | -5 | -9 | -1 | 0 | 2 | -4 | -0.1 |
| Special Educ | -24 | -28 | -16 | -7 | -7 | -6 | 0.4 |
| School Characteristics | | | | | | | |
| Percent Poor (SD) | 6 | 11 | 12 | 12 | 9 | 11 | -0.1 |
| Percent Nonwhite (SD) | -11 | -13 | -13 | -12 | -5 | -8 | -0.3 |
| Average Scores (SD) | -3 | 0 | -6 | -4 | 1 | 1 | 0.0 |
| Non-Traditional | -20 | -2 | -12 | -11 | -11 | -8 | -0.5 |
| Outcome Mean | -89 | -82 | -117 | -125 | -123 | -97 | -2.2 |
| Outcome SD | 14 | 24 | 30 | 44 | 45 | 18 | 0.4 |

Note: This table reports how student characteristics affect willingness to travel to different types of CTE. These estimates come from regressing predicted willingness to travel on student characteristics. Coefficients can be interpreted as the compensating change in travel time that would make an individual with a given characteristic equally likely to participate in a program of a given type relative to the omitted group. Estimates are reported in minutes and are calculated from the model estimates in Appendix Table C.3.

- specifically, the disutility associated with traveling 15 minutes to a program.[21] The mean of this measure is -2.2 reflecting the fact that, on average, students receive *disutility* from traveling outside of their own school. Because the utility metric itself is not particularly intuitive, we present the standard deviation (0.4) to gauge the magnitude of the estimates. Positive coefficients reflect more utility (i.e., less disutility) from traveling; negative coefficients reflect the opposite. We see that poor students, female students, and students with disabilities experience slightly less disutility from traveling relative to their peers. Compared to the mean disutility, however, these effects are relatively small. On the other hand, students attending nontraditional schools or schools with more poor and nonwhite students tend to experience more disutility from travel. Here the differences are slightly larger, a one standard deviation increase in the percent nonwhite (which is roughly 28 percentage points) corresponds to a nearly a full standard-deviation increase in the disutility of travel.

Considering a concrete example, female students' willingness to travel to health programs is due to a combination of their stronger preference for health programs *and* their smaller disutility of travel. Therefore, comparing their willingness to travel to different programs gives a sense of the *relative* preferences for different programs. For example, the difference between the 38 WTT for health programs and the -77 WTT to travel for skilled trades programs highlights that girls have a much stronger preference for health relative to skilled trades.

### B. Decomposition Results

To explore the sources of the participation gaps, we next conduct a series of decomposition exercises. Using the model estimates, we recalculate participation gaps under various assumptions to understand the role of demand factors (preferences) versus supply factors (program availability).

[21] This is calculated as $\hat{\alpha}_{i,Out} + 0.25 \cdot \hat{\alpha}_{i,Time}$.

### 1. The Role of Preferences Versus Access

To simulate equal access, we randomly select one student at a time, and then calculate the participation rates and gaps that would occur if all students in the state faced the choice set of that student. We do this for 1,000 randomly selected students and report the average participation rates and gaps across all simulations. To simulate identical preferences, we assign all students to have the average characteristics of the reference group and then recalculate the predicted probabilities of participation in each CTE program for each student. For example, to eliminate preference differences that arise from differing student achievement across boys and girls, we assign all girls and boys the average achievement level of boys in our sample. We do the same with all other student and school characteristics. Following the notation from our model above, we calculate identical $\bar{\alpha}_i = \hat{\Pi}_{d,z}\bar{\boldsymbol{d}}_i$ or $\bar{\beta}_i = \hat{\Pi}_{d,x}\bar{\boldsymbol{d}}_i$, using the reference group's average characteristics: $\bar{d} = \mathbb{E}[d_i|c_i == 1]$, where $c$ is an indicator for membership in the reference group. Hence, the results we show account for the *total* preference differences across groups.

Table 4: The Role of Preferences vs. Access in Explaining Participation Gaps

| | Any CTE | | | High-Wage | | |
|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Gap** | **Male** | **Female** | **Gap** |
| Baseline | 41.0 | 35.1 | 6.0 | 26.0 | 18.7 | 7.3 |
| Equal preferences | 38.6 | 38.9 | -0.3 | 24.8 | 25.0 | -0.2 |
| Equal access | 41.0 | 35.1 | 6.0 | 25.8 | 18.3 | 7.5 |
| Equal preferences and access | 39.3 | 39.3 | 0.0 | 25.2 | 25.2 | 0.0 |
| | **White** | **Black** | **Gap** | **White** | **Black** | **Gap** |
| Baseline | 42.0 | 27.6 | 14.4 | 25.1 | 15.3 | 9.8 |
| Equal preferences | 37.5 | 32.0 | 5.6 | 24.3 | 19.8 | 4.5 |
| Equal access | 41.0 | 30.8 | 10.2 | 24.0 | 17.5 | 6.5 |
| Equal preferences and access | 36.7 | 36.7 | 0.0 | 23.5 | 23.5 | 0.0 |
| | **Higher Income** | **Lower Income** | **Gap** | **Higher Income** | **Lower Income** | **Gap** |
| Baseline | 40.1 | 35.3 | 4.8 | 25.1 | 18.7 | 6.4 |
| Equal preferences | 35.8 | 29.2 | 6.6 | 24.2 | 18.9 | 5.3 |
| Equal access | 37.5 | 38.9 | -1.4 | 22.9 | 21.0 | 1.9 |
| Equal preferences and access | 33.5 | 33.5 | 0.0 | 22.1 | 22.1 | 0.0 |

Note: This table reports the gaps implied from decomposition exercises of supply factors, demand factors, and both in driving participation gaps. Estimated gaps are reported in percentage points and are calculated from the model estimates in Appendix Table C.3.

Table 4 presents the results. Note that the gaps shown in the bottom row of each panel, which is labeled ”Equal preferences and access,” are zero by construction. Looking first at the Male-Female gap, we see that it is driven entirely by differences in preferences: the raw gap of 6 percentage points is virtually unchanged if one assumes equal access but drops to -0.3 if one assumes equal preferences. This is not surprising given that access is school-based and, for the most part, boys and girls attend the same high schools. When looking at the race and income gaps, on the other hand, preferences and access are both important determinants of participation.

Assuming Black students have preferences identical to white students reduces the white-Black gap from 14.4 percentage points to 5.6 percentage points.[22] Assuming Black and white students have equal access to CTE reduces this gap to 10.2 percentage points.

Looking at the Higher-Lower income gap, we see that both preferences and access are important factors, but not in the same way that was true for the race gap. Assuming that lower-income students have the same preferences as their higher-income peers actually **increases** the gap, reflecting the fact that lower-income students prefer CTE *more* than their peers. Assuming equivalent access flips the sign of the gap, such that lower-income students are predicted to participate in CTE 1.4 percentage points more often than higher-income students. This reflects the stark differences in access across income groups.

For the sex and race gaps, the results for high-wage CTE programs mirror those for all CTE programs. The Male-Female gap is explained entirely by preferences, whereas both preferences and access play an important role in the white-Black gap. The findings for the income gap are somewhat different. First, the baseline gap for high-wage CTE is more than 50% larger than the gap for any CTE, due largely to the fact that higher-income students are more likely to participate in technology programs. Second, while the equalization of preferences *increased* the participation gap for any CTE, it slightly decreases the gap for high-wage CTE programs. The assumption of

[22] About half of this change is from a decrease in the predicted participation rate of white students, which changes from 42% at baseline to 37.5% when assuming equal preferences. This occurs because we assign the *average* preferences of white students to *all* white students as well as all black students. Because changing preferences affects both the numerators and denominators of the individual choice probabilities (see equation 4), this assignment affects the predicted participation rate of white students despite not changing their preferences on average. This is a feature of the non-linear model we utilize.

equal access dramatically reduces but does not eliminate the participation gap for high-wage CTE programs, whereas it reversed the gap for participation in any CTE.

### 2. The Role of Student and School Preferences for Programs and Traveling

The results above indicate that preferences play a large role in the race and income gaps, and completely explain the sex gaps. Given the importance of preferences, it is worth exploring exactly which preferences are most salient in each case. We consider preferences for traveling as well as preferences for the programs themselves. We also distinguish between the *direct* preferences of the subgroup as well as *total* preferences, which incorporate preferences that groups have due to their associated characteristics such as individual achievement levels, school poverty rates, etc.

Table 5 presents the results. The top row shows the raw or baseline gap. The subsequent rows present the predicted gap assuming identical preferences for traveling, for programs, or for both traveling and programs. In the first column, the gap only accounts for the direct preferences of the subgroup. The subsequent columns also adjust for indirect preference differences due to student (column 2), school (column 3) and both student and school (column 4) characteristics. See Appendix B for details.

These estimates reveal several interesting findings. First, the gender participation gap is driven largely by the difference in preferences for different programs (as opposed to different preferences for travel). Comparing row 1 to row 3 in the first column, we see that the gap would drop from 6.0 to -1.5 percentage points if girls had the same utility for participating in each program as observably similar boys. As discussed earlier, girls are more willing to travel for CTE than boys. If girls were assigned boys' disutility of traveling (row 2), the gap would actually increase to 7.7 percentage points. We also note that there is very little difference between the "direct" gender gap (column 1) and the gender gap that accounts for correlated characteristics (columns 2-4). This is not surprising in that individual (school) characteristics are mostly (entirely) similar across boys and girls. Patterns for the gender gap in high-wage CTE programs are similar (see Table C.6).

Note that these differences in preferences do not mean that gaps are inevitable. Instead, the gaps

Table 5: The Role of Preferences in CTE Participation Gaps

| **CTE Participation** | Direct Effect | Direct + Student Characteristics | Direct + School Characteristics | Direct + All Characteristics |
|---|---|---|---|---|
| **Male-Female Gap** | | | | |
| Baseline | 6.0 | 6.0 | 6.0 | 6.0 |
| Net of Preferences for Traveling | 7.7 | 7.3 | 7.6 | 7.3 |
| Net of Preferences for Programs | -1.5 | -1.6 | -1.7 | -1.7 |
| Net of Preferences for Both | 0.3 | -0.1 | 0.1 | -0.3 |
| **White-Black Gap** | | | | |
| Baseline | 14.4 | 14.4 | 14.4 | 14.4 |
| Net of Preferences for Traveling | 14.5 | 15.2 | 9.9 | 10.9 |
| Net of Preferences for Programs | 12.2 | 13.0 | 8.1 | 8.9 |
| Net of Preferences for Both | 12.3 | 13.7 | 2.8 | 5.6 |
| **Higher-Lower Income Gap** | | | | |
| Baseline | 4.8 | 4.8 | 4.8 | 4.8 |
| Net of Preferences for Traveling | 5.7 | 6.6 | 4.2 | 5.1 |
| Net of Preferences for Programs | 3.3 | 4.5 | 5.3 | 6.4 |
| Net of Preferences for Both | 4.2 | 6.0 | 4.6 | 6.6 |

Note: This table reports the gaps implied from decomposition exercises exploring which student characteristics affect the gaps. Column one explores how participation gaps would change if the direct effects (for traveling or for programs) of a given student characteristic were equal across groups. Columns 2 and 3 add correlated student or school characteristics, and column 4 makes all characteristics identical. See Appendix B for details. Estimated gaps are reported in percentage points and are calculated from the model estimates in Appendix Table C.3.

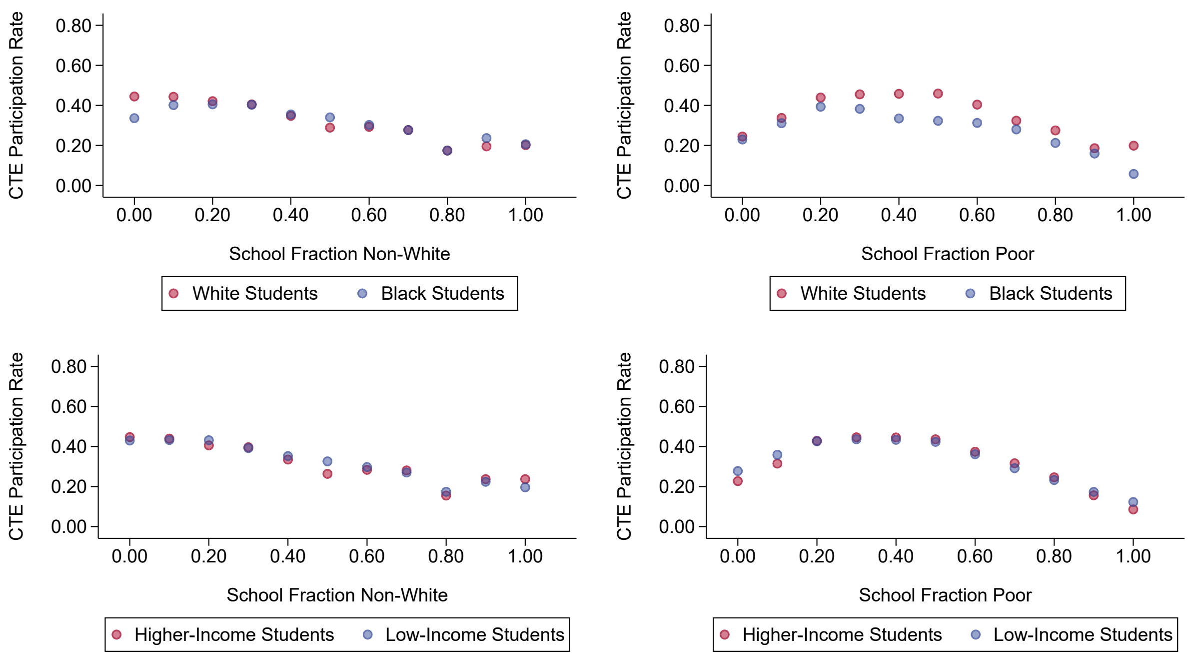
arise because the types of programs that give female students the most utility are not as accessible (on average) as the type of programs that give observably similar male students utility. This is particularly true of programs offered in stand-alone tech centers. For example, over 45% of programs offered outside of traditional schools are in Technology, Skilled Trades, and Automotive–the three programs for which boys express the greatest relative preferences.

Second, unlike the gender gap, direct preferences differences explain little of the race gap. Looking down the rows in column 1, we see that the raw white-Black gap of 14.4 percentage points would change at most by 2 percentage points if Black students had equivalent preferences as observably similar white students. Moreover, netting out preference differences associated with other correlated student characteristics (e.g., achievement, disability status) hardly changes the size of the gaps. One can see this by the fact that the predicted gaps shown in column 2 are very similar to those in column 1. However, reading across the columns, we see that *school* characteristics associated with student race explain 30-80% of the participation gap. For example, considering the preferences for traveling in the second row, the predicted gap shrinks from 14.5 in column 1 to 9.9 in column 3. This tells us that Black students disproportionately attend schools in which all students exhibit a strong aversion to traveling for CTE.

Following a similar pattern, the differences in program utility also vary across schools in ways that perpetuate racial participation gaps. We see that the white-Black participation gap would shrink from 12.2 to 8.1 percentage points if Black and white students attended similar schools. This shows that Black students disproportionately attend schools in which all students experience less utility from the CTE programs available to them. Indeed, we calculate that Black students are 20 percentage points less likely to have access to their most preferred CTE program relative to white students. When taken together, the sum of the effects of school characteristics through both travel disutility and program preferences accounts for roughly 9 percentage points (or 62%) of the overall gap.[23]

[23] Interestingly, including correlated student characteristics moves the total effect somewhat in the opposite direction. This seems to be driven by the fact that students who receive special education services are much less likely to participate in CTE and black students are more than 35% more likely to be in this group (0.14, relative to 0.11 for white students).

Figure 4: Within-School Race and Income Gaps in CTE Participation are Small




Note: This figure shows the program participation rates of students at schools along the distribution of fraction minority (left) and fraction poor (right). The top two panels show the participation rates of white and black students, and the bottom two panels show the participation rates of higher- and lower-income students. All figures are scatter plots where schools are split into 10-percentage-point bins and points are weighted by the number of students of each group in each bin.

Figure 4 illustrates the importance of school characteristics for understanding racial participation gaps in CTE. Here we plot the raw participation rates of Black and white students over the distributions of school percent non-white and percent poor. Two facts stand out: (i) participation rates of *both* Black and white students decline as the school fraction non-white or school fraction poor increases; (ii) at each level of school race or income, the participation rates of Black and white students are quite similar. Together, this implies that the large gaps in participation between Black and white students is occurring *across* rather than *within* schools. Similar results for high-wage participation are shown in Appendix Figure C.3.

While it is possible that this result reflects actual preference differences that vary by school type, we believe this finding is more likely due to what one would probably describe as supply constraints. Specifically, we hypothesize that this result is picking up hard-to-observe factors such as the ease of transportation, the attitudes of school counselors, and the challenge of adjusting student schedules to allow them to attend CTE programs at other locations. In several informal conversations, school administrators reported to us that schools with large Black populations tend to have less reliable transportation to CTE programs. Also, counselors may be more reluctant to facilitate placement into CTE because they want to prioritize college enrollment and they view CTE as a "dumping ground" for poor, low-achieving or minority children.

Finally, the results presented in Table 5 indicate that differences in preferences alone (in any form) cannot fully explain the white-Black participation gap. For example, looking at the bottom cell in column 4, we see that even if all Black and white students had completely identical preferences, the gap in participation would still be 5.6 percentage points overall. This reflects the systematic differences in access between Black and white students. For example, Figure 1 shows that Black students not only have less access to CTE programs in their own school, but also have access to fewer programs via travel.

Preferences are equally ineffective in explaining participation gaps between higher- and lower-income students. Looking at column 1, we see that higher-income students incur more disutility from traveling so that equalizing travel preferences would actually increase the participation gap from 4.8 to 5.7 percentage points. Reading across row 3, we see that accounting for program preferences increases about 66% to 5.3 percentage points. This reflects the fact that higher-income students have weaker preferences for CTE programs. The results are somewhat different for high-wage CTE participation gap (see Table C.6). Holding constant travel and program preferences would reduce the gap from 6.4 percentage points to 5.3 percentage points, largely due to direct differences in program preferences. This is due mostly to the fact that higher-income students have stronger preferences for the high-wage CTE programs.

## VII. Policy Counterfactuals

One key takeaway from the previous section is that policymakers hoping to address gaps in CTE participation will need to address inequities in access. In this section, we use the model estimates to examine how CTE participation patterns would change under different expansions of CTE availability. These policy simulations are based on the three major modes of high-school CTE delivery: offering programs in traditional high schools, creating stand-alone "tech centers", and instituting "career academies."

The first three policies we examine involve adding program offerings within comprehensive high schools. Specifically, we simulate the effect of adding a program in health science (Therapeutic Services, cipcode 51.0000), a program in construction trades (Construction Trades, cipcode 46.0000) , or both programs to each high school that does not already have such programs (keeping all other choices the same). The fourth policy we examine is an expansion of career tech centers. As described in Section II, tech centers offer CTE classes to students from multiple schools and districts. Students usually travel to the center to attend classes for half a day. In Michigan, tech centers are typically funded by local millages and are operated by Intermediate School Districts (ISDs). For each of the 18 ISDs that do not have tech centers, we assume that one is built in the geographic center of the district and offers the 20 most common programs offered at other tech centers in Michigan. We then include these 20 additional CTE options to the choice sets of students in the affected districts, with the travel time implied by the location of the imaginary tech center relative to the student's school.

The fifth policy we examine is the introduction of career academies, a model that is growing in popularity in some other states. Career academies are separate (typically magnet) schools that offer general education but also have a CTE-focused curriculum. Students can receive a regular high school diploma and access a wide range of CTE courses without traveling to a separate building. For this simulation, we use our model estimates to identify the 3% of students in each school with the strongest preferences for each of the 10 CTE program groups. Because preferences are correlated across programs, this results in a total of about 12% of students. We then replace these students' choice sets with 20 CTE programs that do not require any traveling to simulate their enrollment in the academy. The demographics of predicted academy students are broadly similar to the demographics of academy students in other states (e.g., in Connecticut, Brunner et al., 2021). For example, Black and poor students are slightly over-represented (20% and 55%) whereas female and other race students are quite underrepresented (32% and 10%).

The results from these policy simulations are reported in Figure 5. Several important findings stand out. First, the results highlight the importance of own-school access to CTE. The addition of health or construction programs in a school increases predicted participation by 12 and 5 percentage points respectively. On the other hand, introducing programs in tech centers to which students must travel increases participation by only 4 percentage points. The creation of Career Academies would increase participation slightly more (e.g., from 38% to 46% overall), but still less than the addition of a popular program like health in traditional high schools.

One reason for the differential impact is because placing programs within comprehensive high schools affects a much larger proportion of students statewide, relative to other policies. For example, only 10.5% (14.2%) of students attend schools that offer construction (therapeutic service), so adding these programs would affect most students in the state. On the other hand, because roughly 55% of students live in counties with tech centers now, the expansion of these facilities statewide would impact less than half of the student population. In other words, the simulation results presented here do not reflect the participation impacts per *affected* student, but rather the overall statewide impact of the policy. As we discuss below, the differential reach of the policies has important cost implications.

Another reason for the differential impact is that new tech centers and/or career academies attract students who are eager to participate in CTE and, for this reason, would have participated in CTE even if they had attended a traditional high school. At the same time, it is possible that these types of stand-alone CTE schools may be valuable for other reasons. For example, career academies may provide valuable specialization, motivation, and social interactions that students would not have received in their traditional high school. Indeed, prior research finds that admission to a career academy increases academic attainment and/or earnings, although the effects tend to be more robust for boys than for girls (Dougherty, 2018; Brunner et al., 2021; Kemple and Willner, 2008; Hemelt et al., 2019).[24]

Second, the simulations reveal that effects on participation *rates* do not always mirror effects on participation *gaps*. For example, the expansion of career centers would increase participation of Black and white students by roughly 4 and 3 percentage points respectively, which would actually increase the Black-white gap. Similarly, we predict the addition of a construction program in each school would increase participation rates by roughly 5 percentage points for White and Black students, thus leaving the racial gap unchanged. On the other hand, the addition of construction programs would shrink the income gap from 5 to 3 percentage points, a decrease of roughly 40%, and the addition of both construction and health programs would essentially eliminate the gap.

Third, the introduction of any program not only increases participation among students who had not previously participated in any CTE, but also induces some students to shift from one program to another. This can have important implications for the relative participation rates in high-wage programs, as shown in Figure C.2. The health program we simulate adding, which accounts for virtually all CTE health enrollments statewide, has an expected wage of $22 per hour and, thus, is not classified as a high-wage program. Because this program is quite popular, if it is introduced into a school, we predicted that it would *reduce* participation in high-wage CTE programs from

[24] In fact, even if it were not about the career training, there is robust research showing that there are many academic and employment gains from attending small specialized schools in general (e.g., Bloom and Unterman, 2014).

22% to 19%. Because health programs are most popular among girls, this shift is particularly acute for female students. Figure 6 shows that the introduction of health programs in comprehensive high schools would reduce participation in high-wage programs among girls from 19% to 14%, a relative decline of 26 percent.

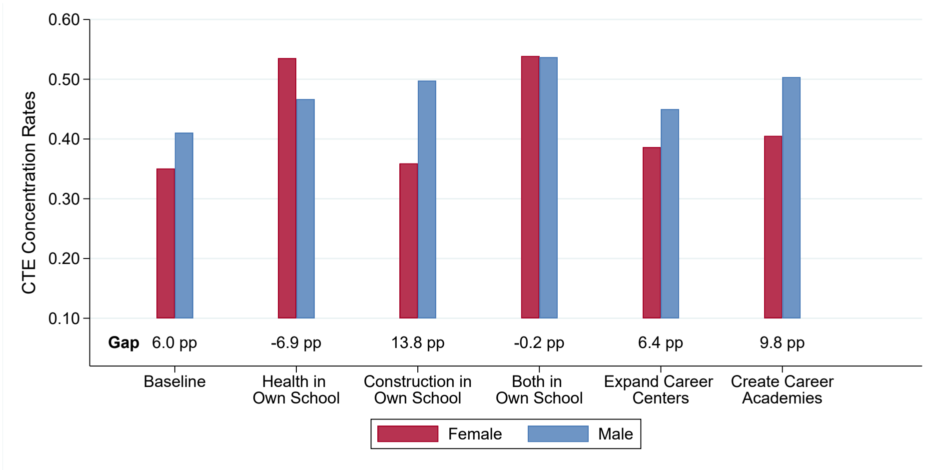
Just as they reach different students, each of the policies have different cost implications. For example, adding both health science and construction trades to every high school would require creating nearly 2,400 new programs, doubling the number of unique programs in our sample. On the other hand, constructing tech centers in every ISD would only require the addition of 360 new programs, although it would also entail the construction/renovation of 18 new buildings. Based on publicly available documents and conversations with state and local officials, we estimate that the annual cost of one program in a single school ranges from $100,000 to $200,000, which includes staff salaries and benefits, materials, equipment and funds for students to participate in some outside events. Single year costs can be as high as $300,000 when it is necessary to purchase new machinery or equipment. Perhaps more importantly, districts typically cannot offer automotive or skilled trade programs due to the amount of heavy equipment and space they require.

## VIII. Conclusion

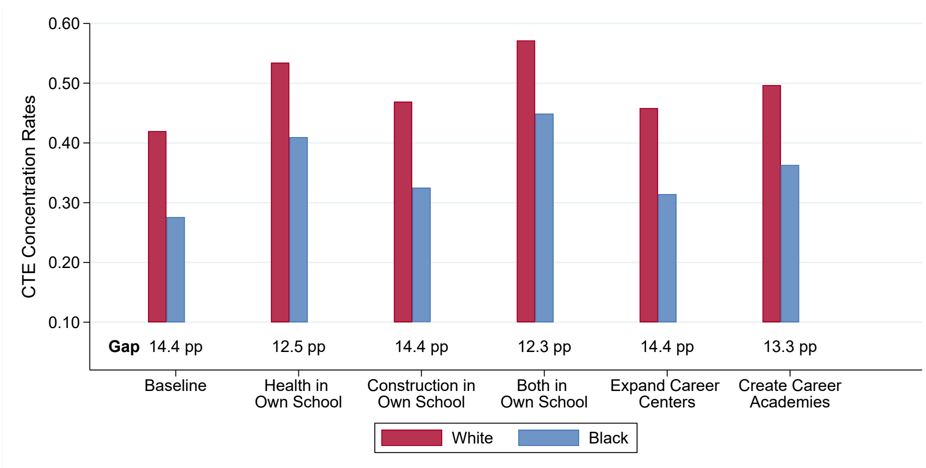
In this paper, we develop and estimate a discrete choice model to explore the determinants of student participation in secondary CTE programs. Utilizing student-level administrative data covering the entire state of Michigan, we develop a model that accurately predicts CTE participation rates by student demographics and field of study. Our analysis focuses on understanding the relative contribution of supply versus demand factors in explaining differences in participation rates by sex, race and income.

Our analysis yields several important findings. First, the Male-Female gap is driven entirely by differences in student preferences - namely, boys are more interested in the set of CTE programs that are available to high school students in Michigan. Second, the gap between higher- and lower-income students is driven entirely by the fact that more affluent students have more access to CTE

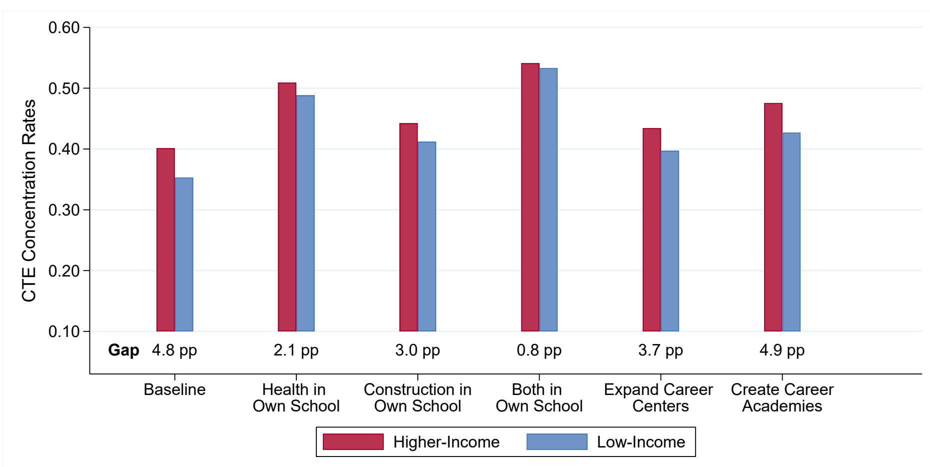
Figure 5: Counterfactual Policies Change Participation in CTE




(a) Participation Rates by Sex




(b) Participation Rates by Race

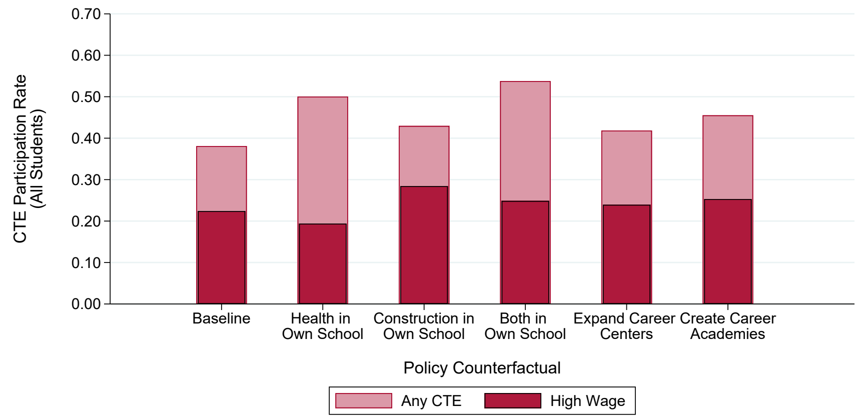



(c) Participation Rates by Poverty

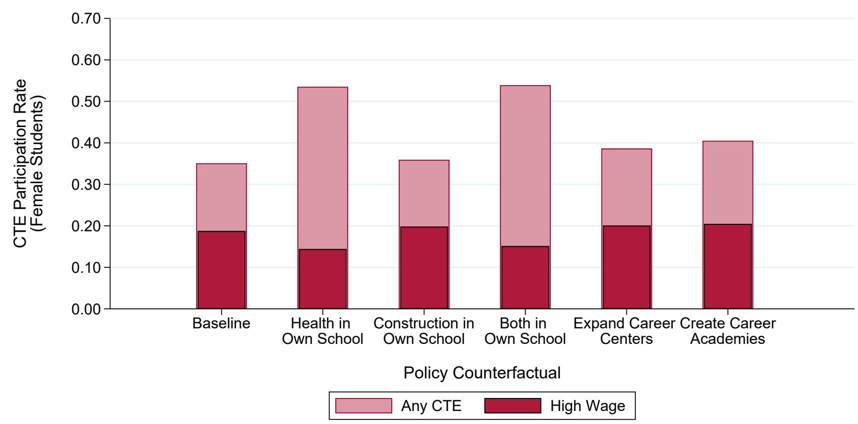
Note: This Figure shows the CTE participation patterns predicted under various policies. Each panel presents the participation rates for the groups of interest under each policy and lists the gaps in percentage point terms.

Figure 6: Participation Rates for Counterfactual Policies

(a) All Students




(b) Female




(c) Male

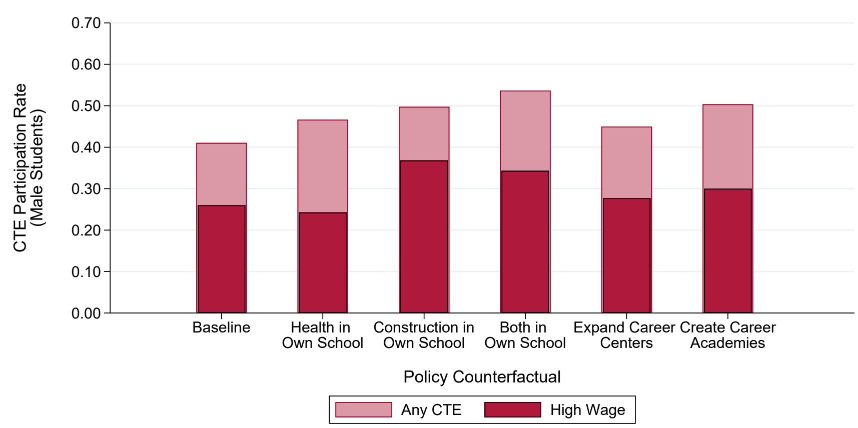
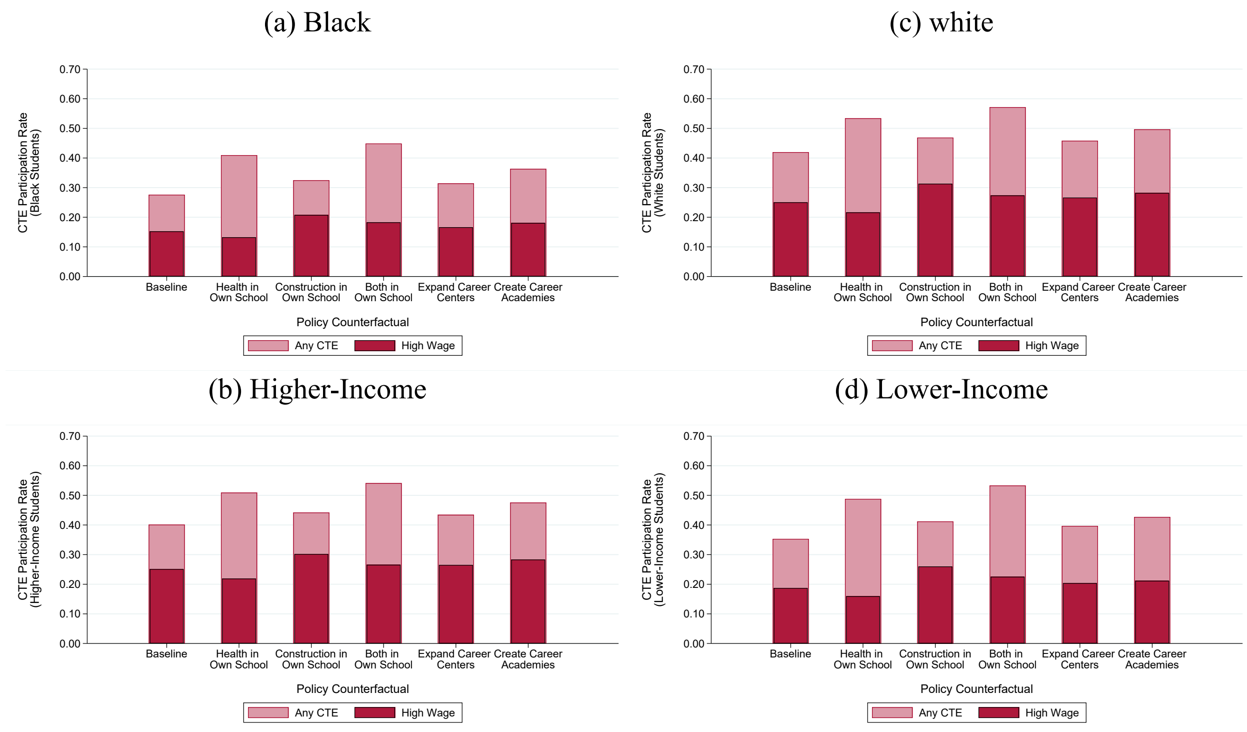


Figure 7: Participation Rates for Counterfactual Policies by Race and Poverty




programs, including more access to the most popular and high-wage programs. Third, both supply and demand factors contribute to the CTE participation gap between white and Black students. More interestingly, factors operating at the school level are particularly important. Specifically, all students (regardless of race) at predominantly Black schools participate less in CTE, due to what we conjecture is a combination of supply and demand factors.

The counterfactual policy simulations we conduct illustrate that policymakers seeking to expand CTE programs will face a variety of important trade-offs. Virtually all avenues of expansion would increase participation, but the least costly ones cannot reduce participation gaps (at least not in percentage point terms). Hence, a constrained policy maker who cares about enrollment **levels** would prefer tech centers, but a constrained policymaker who cares more about **gaps** might consider targeting CTE resources toward traditional high schools with low participation rates in high-wage programs.

One important choice facing policymakers is *which* CTE programs to expand. Our simulations show that students will shift across programs depending on availability, so the creation of new programs could end up diverting students from participating in high-wage programs. Unfortunately, there is not good information on the economic returns associated with participation in the different CTE programs in Michigan. Estimating the economic returns to secondary CTE by field of study in Michigan is an important area for future research.

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## A. Data Appendix

We utilize the following rules to determine whether a PSN (a program by offering school combination) is available to students in each home-school:

1. Drop a PSNs that (a) come from programs of study that had fewer than 1,250 enrollments overall years or that were discontinued before 2010,[25] (b) enrolled fewer than 20 students, or (c) had no students complete the program. This restriction drops one percent of program-year CTE enrollments, but shrinks the choice sets in our analysis by over ten percent. Students who participate in these programs are treated as not participating in any CTE.

2. Taking the set of all PSNs enrolled in by all students at each home-school, keep school-PSN pairs that either (a) have at least 5 student-year enrollments (across all years), (b) have at least 2 student-year enrollments and meet one of the following conditions: (i) students from the school are more than 20% of students enrolled in the PSN in a year, or (ii) more than 50% of schools send 2 or fewer students to the PSN.

3. Finally, we also code a PSN as being available in a given year if it was available in the years immediately before and after by the above rules

Our aim in determining program availability is to minimize both false positives (programs we'd define as "empirically" available but are not—for example because students moved during a school year) with and false negatives (programs we'd miss but are technically allowed—for example because they have very low take up). Of the two, this measure is more likely underrepresent true availability—if for example no student from a small school chooses to enroll in a program that was technically available but never observed.

In the end these restrictions say that 99% of observed student enrollments are "allowed," 86% of pairs in the data are "allowed," and covers 93% of PSNs (many are small. 10% of PSNs never have more than 15 students.

[25] For PSNs in discontinued programs that were obviously relabeled or transitioned to a new programs of study, we treat the PSN as if they had always had the later classification.

## B. Decomposition Details

We consider two dimensions in our demand-side decomposition: preferences (either for travel, programs and both) and characteristics (student-level, school-level, or both). Based on the model estimates and observed choice sets we calculate the participation gap that would be implied by slowly equalizing the demand for CTE.

First, we calculate the implied gaps if students in the minority group had the same marginal preferences as students in the majority group. For example, for female students we simulate demand assuming that these students had the same characteristics except for gender in the interaction term of gender and the two travel-related program variables. This is equivalent to simulating demand assuming that the partial effects $\alpha_{d,z}$ or $\beta d, g$ are equal to zero. We do this separately for travel disutility, program utility, and the combination of both.

Second, we calculate the implied gaps if students in the minority and majority group all had the average student-level characteristics of the majority group. For example, for black and white students we simulate demand assuming that they all have the average test scores, disability status, poverty status, etc. as the average white student. Again, we implement this exercise separately for travel disutility, program utility, and the combination of both.

Third, we calculate the implied gaps if students in the minority and majority group all had the average *school*-level characteristics of the majority group. For example, for poor and non-poor students we simulate demand assuming that they all have the same school poverty race, school racial composition, etc. as the average non-poor student. Once more we implement this exercise separately for travel disutility, program utility, and the combination of both.

Finally, we calculate the implied gaps is students in the minority and majority group all had the exact same characteristics (those of the average in the majority group). This comparison only leaves differences that could be attributable to supply in the residual gaps. Again, we implement this exercise separately for travel disutility, program utility, and the combination of both.

## C. Additional Figures and Tables

Table C.1: CTE Program Groups

| Group | Cipcode | Program | Cluster | Hourly Wage (rounded) | High-Wage |
|---|---|---|---|---|---|
| Accounting | 52.0800 | Finance and Financial Management Services | Finance | 26 | 1 |
| Agriculture | 01.0000 | Agriculture, Agricultural Operations and Related Sciences | Agriculture, Food & Natural Resources | 25 | 1 |
| Agriculture | 01.0601 | Applied Horticulture and Horticultural Operations | Agriculture, Food & Natural Resources | 19 | 0 |
| Agriculture | 03.0000 | Natural Resources and Conservation | Agriculture, Food & Natural Resources | 20 | 0 |
| Automotive | 47.0399 | Heavy Industrial Equipment Maintenance Technologies | Transportation, Distribution & Logistics | 23 | 0 |
| Automotive | 47.0603 | Collision Repair Technician | Transportation, Distribution & Logistics | 19 | 0 |
| Automotive | 47.0604 | Automobile Technician | Transportation, Distribution & Logistics | 19 | 0 |
| Automotive | 47.0606 | Small Engine & Related Equipment Repair | Transportation, Distribution & Logistics | 18 | 0 |
| Automotive | 47.0613 | Medium/Heavy Truck Technician | Transportation, Distribution & Logistics | 19 | 0 |
| Business | 52.0299 | Business Administration Management and Operations | Business, Management & Administration | 25 | 1 |
| Business | 52.1999 | Marketing, Sales and Service | Marketing | 27 | 1 |
| Communications | 10.0202 | Radio & TV Broadcasting Technology | Arts, A/V Technology & Communications | 26 | 1 |
| Communications | 10.0301 | Graphics and Printing Technology and Communications | Arts, A/V Technology & Communications | 22 | 0 |
| Communications | 11.0901 | Computer Systems Networking and Telecommunications | Information Technology | 44 | 1 |
| Communications | 13.0000 | Education General | Education & Training | 20 | 0 |
| Communications | 19.0906 | Fashion Design | Arts, A/V Technology & Communications | 27 | 1 |
| Communications | 50.0101 | Visual & Performing Arts | Arts, A/V Technology & Communications | 24 | 0 |
| Health | 01.0903 | Animal Health & Veterinary Science | Agriculture, Food & Natural Resources | 15 | 0 |
| Health | 51.0000 | Therapeutic Services | Health Science | 22 | 0 |
| Health | 51.1000 | Diagnostic Services | Health Science | 28 | 1 |
| Personal Services | 12.0400 | Cosmetology | Human Services | 16 | 0 |
| Personal Services | 12.9999 | Personal and Culinary Services | Hospitality & Tourism | 13 | 0 |
| Personal Services | 19.0700 | Child and Custodial Care Services | Human Services | 17 | 0 |
| Public Service | 28.0301 | Army (JROTC) | Government & Public Administration | 22 | 0 |
| Public Service | 43.0100 | Public Safety/Protective Services | Law, Public Safety, Corrections & Security | 28 | 1 |
| STEM | 11.0201 | Computer Programming/Programmer | Information Technology | 42 | 1 |
| STEM | 11.0801 | Digital/Multimedia and Information Resources Design | Information Technology | 33 | 1 |
| STEM | 11.1001 | System Administration/Administrator | Information Technology | 38 | 1 |
| STEM | 14.4201 | Mechatronics | Science, Technology, Engineering and Mathematics | 31 | 1 |
| STEM | 15.0000 | Engineering Technology | Science, Technology, Engineering and Mathematics | 25 | 1 |
| STEM | 15.1301 | Drafting and Design Technology | Architecture & Construction | 25 | 1 |
| STEM | 15.1306 | Mechanical Drafting | Science, Technology, Engineering and Mathematics | 25 | 1 |
| Skilled Trades | 46.0000 | Construction Trades | Architecture & Construction | 25 | 1 |
| Skilled Trades | 46.0301 | Electrical and Power Transmission Installation | Architecture & Construction | 28 | 1 |
| Skilled Trades | 47.0101 | Electrical/Electronics Equipment Installation and Repair | Manufacturing | 24 | 0 |
| Skilled Trades | 47.0201 | Heating, Air Conditioning, Ventilation and Refrigeration | Architecture & Construction | 21 | 0 |
| Skilled Trades | 47.0608 | Power Plant Technology (Aircraft) | Transportation, Distribution & Logistics | 27 | 1 |
| Skilled Trades | 48.0501 | Machine Tool Technology/Machinist | Manufacturing | 19 | 0 |
| Skilled Trades | 48.0508 | Welding, Brazing and Soldering | Manufacturing | 20 | 0 |
| Skilled Trades | 48.0701 | Woodworking General | Manufacturing | 20 | 0 |

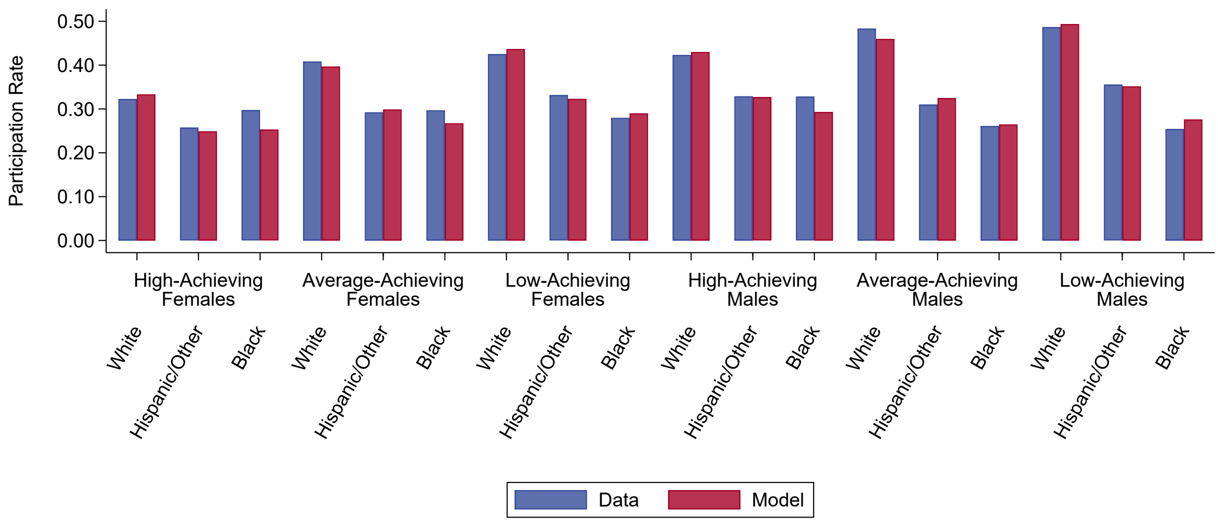
Note: This table shows the correspondence between individual CIP codes and the 10 CTE program groups used in our analysis.

Table C.2: CTE Program Groups

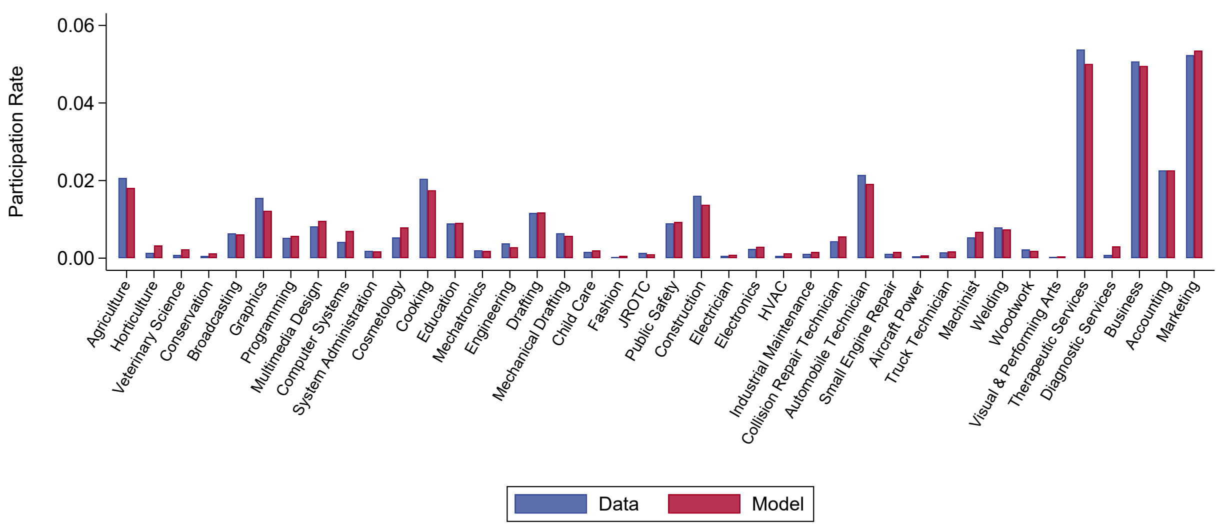
| Group | Cipcode | Program | Participation Rate | Percent of Participants Traveling |
|---|---|---|---|---|
| Accounting | 52.0800 | Finance and Financial Management Services | 0.022 | 0.035 |
| Agriculture | 01.0000 | Agriculture, Agricultural Operations and Related Sciences | 0.020 | 0.201 |
| Agriculture | 01.0601 | Applied Horticulture and Horticultural Operations | 0.001 | 0.706 |
| Agriculture | 03.0000 | Natural Resources and Conservation | 0.001 | 0.502 |
| Automotive | 47.0399 | Heavy Industrial Equipment Maintenance Technologies | 0.001 | 0.910 |
| Automotive | 47.0603 | Collision Repair Technician | 0.004 | 0.955 |
| Automotive | 47.0604 | Automobile Technician | 0.021 | 0.553 |
| Automotive | 47.0606 | Small Engine & Related Equipment Repair | 0.001 | 0.859 |
| Automotive | 47.0613 | Medium/Heavy Truck Technician | 0.001 | 1.000 |
| Business | 52.0299 | Business Administration Management and Operations | 0.049 | 0.046 |
| Business | 52.1999 | Marketing, Sales and Service | 0.051 | 0.097 |
| Communications | 10.0202 | Radio & TV Broadcasting Technology | 0.006 | 0.323 |
| Communications | 10.0301 | Graphics and Printing Technology and Communications | 0.015 | 0.659 |
| Communications | 11.0901 | Computer Systems Networking and Telecommunications | 0.004 | 0.818 |
| Communications | 13.0000 | Education General | 0.009 | 0.656 |
| Communications | 19.0906 | Fashion Design | 0.000 | 0.342 |
| Communications | 50.0101 | Visual & Performing Arts | 0.000 | 0.127 |
| Health | 01.0903 | Animal Health & Veterinary Science | 0.001 | 0.894 |
| Health | 51.0000 | Therapeutic Services | 0.052 | 0.665 |
| Health | 51.1000 | Diagnostic Services | 0.001 | 0.960 |
| Personal Services | 12.0400 | Cosmetology | 0.005 | 0.938 |
| Personal Services | 12.9999 | Personal and Culinary Services | 0.020 | 0.663 |
| Personal Services | 19.0700 | Child and Custodial Care Services | 0.001 | 0.394 |
| Public Service | 28.0301 | Army (JROTC) | 0.001 | 0.458 |
| Public Service | 43.0100 | Public Safety/Protective Services | 0.009 | 0.892 |
| STEM | 11.0201 | Computer Programming/Programmer | 0.005 | 0.459 |
| STEM | 11.0801 | Digital/Multimedia and Information Resources Design | 0.008 | 0.233 |
| STEM | 11.1001 | System Administration/Administrator | 0.002 | 0.825 |
| STEM | 14.4201 | Mechatronics | 0.002 | 0.829 |
| STEM | 15.0000 | Engineering Technology | 0.004 | 0.400 |
| STEM | 15.1301 | Drafting and Design Technology | 0.011 | 0.153 |
| STEM | 15.1306 | Mechanical Drafting | 0.006 | 0.206 |
| Skilled Trades | 46.0000 | Construction Trades | 0.016 | 0.607 |
| Skilled Trades | 46.0301 | Electrical and Power Transmission Installation | 0.001 | 1.000 |
| Skilled Trades | 47.0101 | Electrical/Electronics Equipment Installation and Repair | 0.002 | 0.759 |
| Skilled Trades | 47.0201 | Heating, Air Conditioning, Ventilation and Refrigeration | 0.001 | 0.907 |
| Skilled Trades | 47.0608 | Power Plant Technology (Aircraft) | 0.000 | 0.702 |
| Skilled Trades | 48.0501 | Machine Tool Technology/Machinist | 0.005 | 0.569 |
| Skilled Trades | 48.0508 | Welding, Brazing and Soldering | 0.008 | 0.762 |

Note: This table shows the correspondence between individual CIP codes and the 10 CTE program groups used in our analysis.

Figure C.1: Our Estimates Even Fit Patterns Not in Model




(a) Details on Demographic Intersectionality Not in Model




(b) Details on Within-Group Programs of Study Not in Model

Note: This figure shows the empirical and model implied participation rates for 18 demographic groups (Panel (a)) and 41 CTE programs of study (Panel (b)).

## Table C.3: Model Estimates

| | Travel Time | Out of Own School | Accountig | Business | Communication | Health | Technology/Engineering | Agriculture | Trades | Auto | Personal Service | Public Service |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | -2.072 | -1.676 | -2.141 | -1.39 | -1.718 | -1.149 | -2.358 | -1.564 | -2.65 | -2.557 | -1.677 | -1.583 |
| | (0.089) | (0.012) | (0.003) | (0.003) | (0.003) | (0.005) | (0.003) | (0.011) | (0.004) | (0.004) | (0.005) | (0.006) |
| Poor | 0.039 | 0.082 | -0.217 | -0.177 | -0.103 | -0.063 | -0.226 | -0.066 | -0.072 | 0.041 | 0.124 | 0.01 |
| | (0.007) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | 0.000 | 0.000 | 0.000 | (0.001) |
| Black | -0.415 | 0.124 | -0.104 | 0.084 | -0.151 | 0.026 | -0.408 | -0.386 | -0.701 | -0.925 | 0.249 | -0.353 |
| | (0.094) | (0.007) | (0.005) | (0.001) | (0.002) | (0.003) | (0.002) | (0.006) | (0.003) | (0.004) | (0.002) | (0.005) |
| Hispanic/Asian/Other | 0.234 | -0.017 | -0.186 | -0.269 | -0.304 | -0.061 | -0.197 | -0.476 | -0.536 | -0.494 | -0.125 | -0.314 |
| | (0.038) | (0.005) | (0.003) | (0.002) | (0.002) | (0.003) | (0.001) | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) |
| Female | 0.123 | 0.158 | -0.215 | -0.3 | 0.039 | 1.305 | -1.754 | 0.005 | -2.65 | -2.76 | 0.597 | -0.682 |
| | (0.012) | (0.002) | (0.001) | (0.001) | (0.003) | (0.002) | (0.003) | (0.002) | (0.003) | (0.002) | (0.002) | (0.003) |
| Special Education | -0.217 | 0.015 | 0.028 | -0.117 | -0.113 | 0.02 | 0.142 | -0.302 | -0.443 | -0.535 | -0.302 | -0.312 |
| | (0.005) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | 0.000 | 0.000 | (0.001) | (0.001) |
| Test | 0.077 | -0.073 | -0.178 | -0.176 | -0.174 | -0.293 | -0.031 | 0.000 | 0.001 | 0.052 | -0.15 | -0.124 |
| | (0.004) | (0.001) | 0.000 | 0.000 | 0.000 | 0.000 | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Female *Test | 0.233 | -0.008 | -0.095 | -0.17 | -0.187 | -0.192 | -0.081 | -0.128 | -0.118 | -0.149 | -0.137 | -0.15 |
| | (0.032) | (0.003) | (0.004) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) | (0.001) | (0.001) | (0.001) | (0.002) |
| Missing Test | 0.257 | 0.362 | -1.22 | -0.836 | -0.341 | -0.962 | -0.541 | -0.174 | -0.229 | -0.236 | -0.203 | -0.611 |
| | (0.027) | (0.004) | (0.006) | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) | (0.005) |
| Bcode Av Test | 0.508 | -0.266 | -0.508 | -0.265 | 0.048 | -0.014 | -0.527 | -0.295 | -0.354 | 0.101 | 0.138 | 0.057 |
| | (1.036) | (0.171) | (0.092) | (0.058) | (0.077) | (0.089) | (0.054) | (0.169) | (0.078) | (0.093) | (0.073) | (0.102) |
| Bcode Pct nonwhite | -2.261 | -0.31 | -1.39 | -1.279 | -1.105 | -1.477 | -1.534 | -2.583 | -1.408 | -0.634 | -0.914 | -1.291 |
| | (0.944) | (0.162) | (0.108) | (0.058) | (0.070) | (0.098) | (0.074) | (0.164) | (0.096) | (0.119) | (0.081) | (0.089) |
| Bcode Pct poor | 4.144 | -1.326 | 1.008 | 0.864 | 1.755 | 1.717 | 1.859 | 1.791 | 1.807 | 1.407 | 1.606 | 1.627 |
| | (1.410) | (0.312) | (0.374) | (0.260) | (0.258) | (0.235) | (0.211) | (0.241) | (0.322) | (0.456) | (0.284) | (0.263) |
| Non-Traditional School | 0.886 | -0.77 | -0.767 | -0.682 | -0.326 | -0.067 | -0.398 | -0.296 | -0.392 | -0.382 | -0.265 | -0.105 |
| | (0.611) | (0.088) | (0.014) | (0.034) | (0.054) | (0.069) | (0.034) | (0.176) | (0.048) | (0.049) | (0.044) | (0.149) |

Note: This table shows the model estimates and standard errors (cluster corrected at the school level).

Table C.4: Willingness to Travel Varies by Student and Program Characteristics (All Groups)

| | Minutes willing to travel to do a program in each CTE group | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Accounting | Business | Communication | Healthcare | Technology | Agriculture | Skilled Trades | Automotive | Personal Service | Public Service | Disutility of traveling (util/hour) | Disutility of Leaving Own School | Disutility of traveling 15 min away for CTE |
| Student Demographics | | | | | | | | | | | | | |
| Lower-Income | -6 | -5 | -3 | -2 | -7 | -2 | -2 | 1 | 4 | 0 | 0.0 | 0.1 | 0.1 |
| Black | -3 | 2 | -4 | 1 | -12 | -11 | -20 | -27 | 7 | -10 | -0.4 | 0.1 | 0.0 |
| Other Race | -5 | -8 | -9 | -2 | -6 | -14 | -16 | -14 | -4 | -9 | 0.2 | 0.0 | 0.0 |
| Female | -6 | -9 | 1 | 38 | -51 | 0 | -77 | -80 | 17 | -20 | 0.1 | 0.2 | 0.2 |
| Student Academic Characteristics | | | | | | | | | | | | | |
| Test Scores (SD) | 1 | -3 | -3 | 1 | 4 | -9 | -13 | -16 | -9 | -9 | -0.2 | 0.0 | 0.0 |
| Female * Score | -5 | -5 | -5 | -9 | -1 | 0 | 0 | 2 | -4 | -4 | 0.1 | -0.1 | -0.1 |
| Special Educ | -35 | -24 | -10 | -28 | -16 | -5 | -7 | -7 | -6 | -18 | 0.3 | 0.4 | 0.4 |
| School Characteristics | | | | | | | | | | | | | |
| Percent Poor (SD) | 7 | 6 | 12 | 11 | 12 | 12 | 12 | 9 | 11 | 11 | 0.9 | -0.3 | -0.1 |
| Percent Nonwhite (SD) | -12 | -11 | -9 | -13 | -13 | -22 | -12 | -5 | -8 | -11 | -0.7 | -0.1 | -0.3 |
| Average Scores (SD) | -5 | -3 | 1 | 0 | -6 | -3 | -4 | 1 | 1 | 1 | 0.2 | -0.1 | 0.0 |
| Non-Traditional | -22 | -20 | -9 | -2 | -12 | -9 | -11 | -11 | -8 | -3 | 0.9 | -0.8 | -0.5 |
| Outcome Mean | -111 | -89 | -98 | -82 | -117 | -94 | -125 | -123 | -97 | -94 | -2.1 | -1.7 | -2.2 |
| Outcome SD | 17 | 14 | 12 | 24 | 30 | 22 | 44 | 45 | 18 | 19 | 0.8 | 0.4 | 0.4 |

Note: This table reports how student characteristics affect willingness to travel to different types of CTE. These estimates come from regressing predicted willingness to travel on student characteristics. Coefficients can be interpreted as the compensating change in travel time that would make an individual with a given characteristic equally likely to participate in a program of a given type relative to the omitted group. Estimates are reported in minutes and are calculated from the model estimates in Appendix Table C.3.

Table C.5: Willingness to Travel Varies by Student and Program Characteristics (All Groups—Individual Estimates)

| | Minutes willing to travel to do a program in each CTE group | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Accounting | Business | Communication | Healthcare | Technology | Agriculture | Skilled Trades | Automotive | Personal Service | Public Service | Disutility of traveling (util/hour) | Disutility of Leaving Own School | Disutility of traveling 15 min away for CTE |
| Student Demographics | | | | | | | | | | | | | |
| Lower-Income | -9 | -7 | -4 | -3 | -9 | -3 | -4 | 0 | 4 | 0 | 0.0 | 0.1 | 0.1 |
| Black | 39 | 37 | 31 | 32 | 31 | 22 | 20 | 13 | 40 | 22 | -0.4 | 0.1 | 0.0 |
| Other Race | -34 | -32 | -34 | -22 | -35 | -39 | -47 | -44 | -27 | -33 | 0.2 | 0.0 | 0.0 |
| Female | -8 | -9 | 1 | 44 | -58 | 0 | -89 | -93 | 19 | -22 | 0.1 | 0.2 | 0.2 |
| Student Academic Characteristics | | | | | | | | | | | | | |
| Test Scores (SD) | 14 | 7 | 9 | 14 | 14 | 2 | -5 | -9 | 4 | 0 | -0.2 | 0.0 | 0.0 |
| Female * Score | -11 | -10 | -12 | -21 | 0 | -6 | 5 | 7 | -14 | -7 | 0.1 | -0.1 | -0.1 |
| Special Educ | -58 | -37 | -19 | -41 | -33 | -10 | -17 | -16 | -12 | -27 | 0.3 | 0.4 | 0.4 |
| School Characteristics | | | | | | | | | | | | | |
| Percent Poor (SD) | -51 | -42 | -40 | -34 | -48 | -37 | -50 | -52 | -40 | -39 | 0.9 | -0.3 | -0.1 |
| Percent Nonwhite (SD) | 16 | 10 | 15 | 7 | 17 | 1 | 20 | 26 | 16 | 13 | -0.7 | -0.1 | -0.3 |
| Average Scores (SD) | -12 | -8 | -6 | -7 | -13 | -9 | -10 | -6 | -5 | -6 | 0.2 | -0.1 | 0.0 |
| Non-Traditional | -119 | -104 | -94 | -78 | -107 | -98 | -107 | -104 | -86 | -84 | 0.9 | -0.8 | -0.5 |
| Outcome Mean | -130 | -104 | -113 | -94 | -135 | -105 | -142 | -139 | -110 | -107 | -2.07 | -1.68 | -2.19 |
| Outcome SD | 129 | 106 | 101 | 89 | 123 | 90 | 124 | 128 | 97 | 92 | 0.82 | 0.40 | 0.37 |

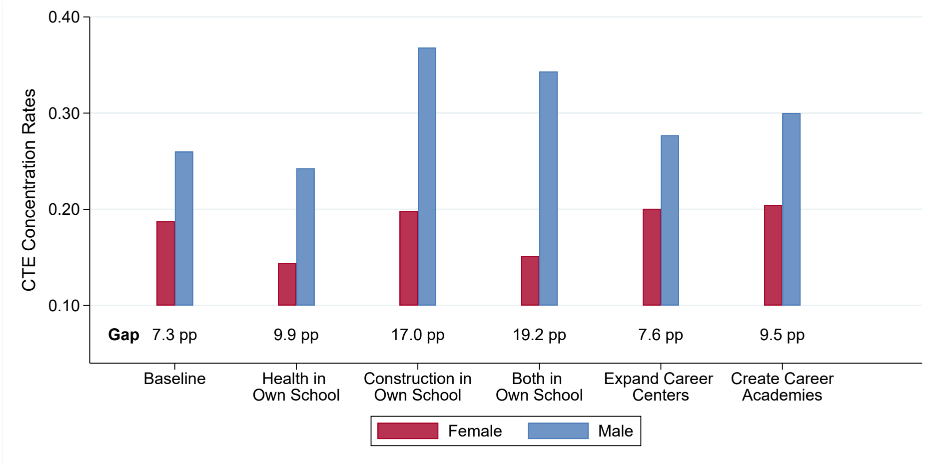
Note: This table reports how student characteristics affect willingness to travel to different types of CTE. These estimates come from regressing predicted willingness to travel on student characteristics. Coefficients can be interpreted as the compensating change in travel time that would make an individual with a given characteristic equally likely to participate in a program of a given type relative to the omitted group. Rather than use average preferences for travel and individual predicted preferences for programs, this table uses individual predictions for the numerator and denominator with willingness to travel is windsorized at the 1st and 99th percentiles because some values of $\hat{\alpha}_{i,Time}$ are very close to zero. Estimates are reported in minutes and are calculated from the model estimates in Appendix Table C.3.

Table C.6: The Role of Preferences in Participation Gaps for High-Wage CTE Programs

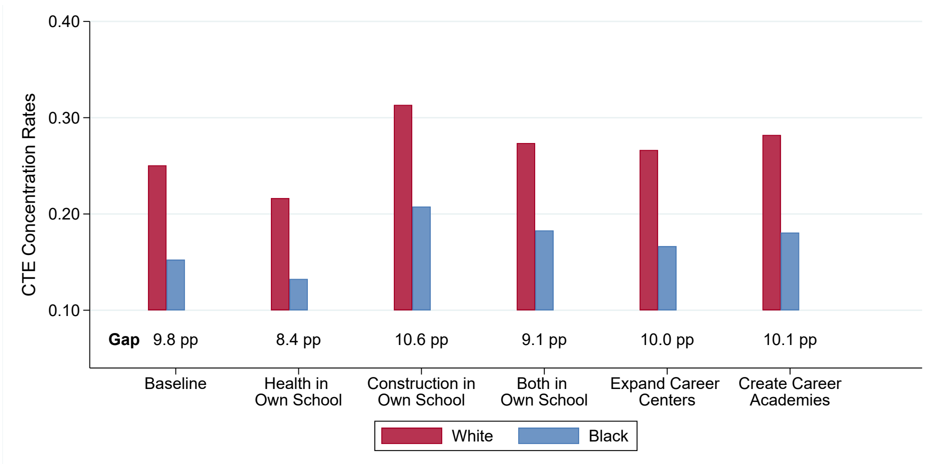
| **High Wage Participation** | Direct Effect | Direct + Student Characteristics | Direct + School Characteristics | Direct + All Characteristics |
|---|---|---|---|---|
| **Male-Female Gap** | | | | |
| Baseline | 7.3 | 7.3 | 7.3 | 7.3 |
| Net of Preferences for Traveling | 7.6 | 7.6 | 7.6 | 7.5 |
| Net of Preferences for Programs | -0.9 | -0.6 | -1.0 | -0.7 |
| Net of Preferences for Both | -0.3 | -0.1 | -0.4 | -0.2 |
| **White-Black Gap** | | | | |
| Baseline | 9.8 | 9.8 | 9.8 | 9.8 |
| Net of Preferences for Traveling | 9.8 | 10.0 | 8.5 | 8.8 |
| Net of Preferences for Programs | 9.3 | 9.0 | 6.3 | 5.9 |
| Net of Preferences for Both | 9.3 | 9.3 | 4.6 | 4.5 |
| **Higher-Lower Income Gap** | | | | |
| Baseline | 6.4 | 6.4 | 6.4 | 6.4 |
| Net of Preferences for Traveling | 6.6 | 6.9 | 6.2 | 6.4 |
| Net of Preferences for Programs | 4.5 | 4.3 | 5.3 | 5.3 |
| Net of Preferences for Both | 4.7 | 4.9 | 5.1 | 5.3 |

Note: This table reports the gaps implied from various decomposition exercises. Column one explores how participation gaps would change if the direct effects for traveling or for programs were equal across groups. Columns two and tree add correlated student or school characteristics, and column four nets out both. Estimated gaps are reported in percentage points and are calculated from the model estimates in Appendix Table C.3.

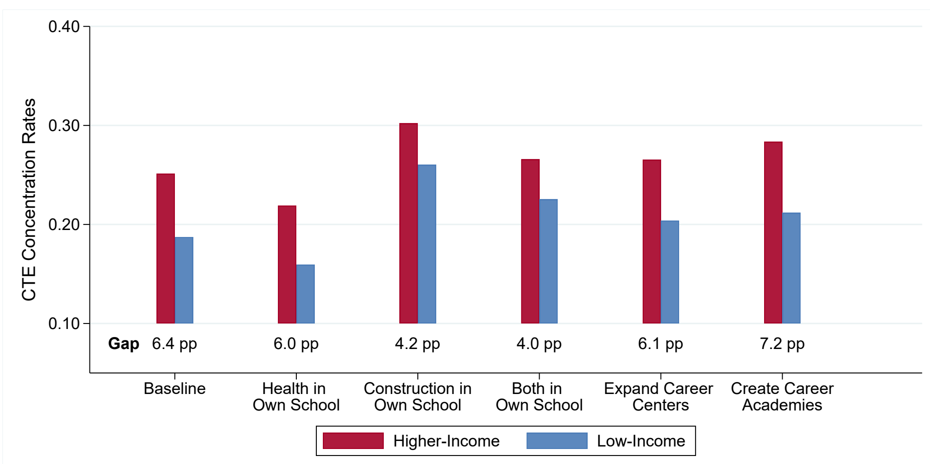
Figure C.2: The Impact of Counterfactual Policies on Participation in High-Wage CTE




(a) Participation Rates by Sex



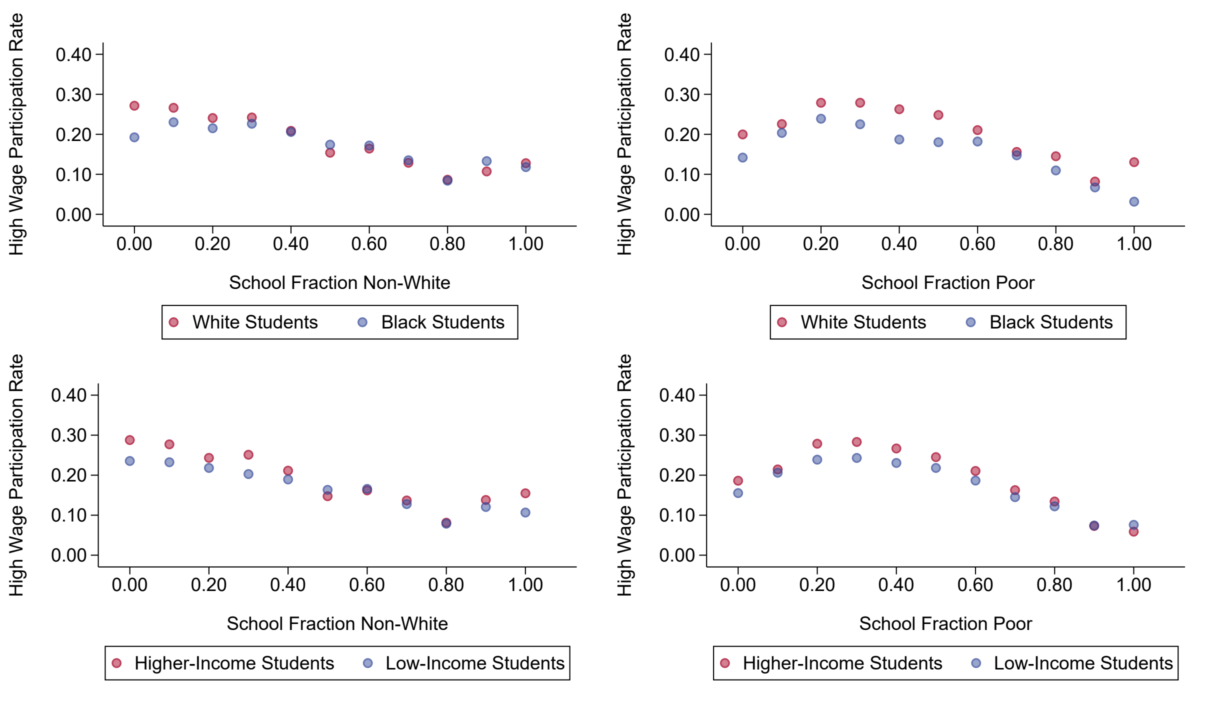

(b) Participation Rates by Race




(c) Participation Rates by Poverty

Note: This Figure shows the CTE participation patterns for high-wage CTE predicted under various policies. Each panel presents the participation rates for the groups of interest under each policy and lists the gaps in percentage point terms.

Figure C.3: Within-School Race and Income Gaps in High-Wage CTE Participation are Small




Note: This figure shows the high-wage program participation rates of students at schools along the distribution of fraction minority (left) and fraction poor (right). The top two panels show the participation rates of white and black students, and the bottom two panels show the participation rates of higher- and lower-income students. All figures are scatter plots where schools are split into 10-percentage-point bins and points are weighted by the number of students of each group in each bin.