Will Studying Economics Make You Rich? A Regression Discontinuity Analysis of the Returns to College Major

By Zachary Bleemer and Aashish Mehta*

We investigate the wage return to studying economics by leveraging a policy that prevented students with low introductory grades from declaring the major. Students who barely met the GPA threshold to major in economics earned $22,000 (46%) higher annual early-career wages than they would have with their second-choice majors. Access to the economics major shifts students' preferences toward business/finance careers, and about half of the wage return is explained by economics majors working in higher-paying industries. The causal return to majoring in economics is very similar to observational earnings differences in nationally representative data.
JEL: A22, I26, J24, J31

Forty-year-old U.S. workers with undergraduate degrees in economics earned median wages of $90,000 in 2018. By comparison, those who had majored in other social sciences earned median wages of $65,000, and college graduates with any major other than economics earned $66,000. Relative to workers with lower-wage majors, the observational premiums earned by workers with high-wage majors like engineering, nursing, and economics are similar in size to the wage gap between college graduates and non-graduates (Altonji, Blom and Meghir, 2012). These gaps have motivated a large literature examining the determinants of students' major choices (Zafar, 2013; Stange, 2015; Arcidiacono, Aucejo and Hotz, 2016; Wiswall and Zafar, 2018; Patnaik et al., 2020). However, average wage differences between majors do not necessarily reflect the causal effect of choosing one major over another. This study directly analyzes the treatment effects of earning an undergraduate degree in the popular high-earning field of economics.[1]

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[1]Economics is a particularly popular major at highly-selective universities. The 2020 federal College Scorecard shows that economics was the most-earned major at 11 of the top 20 highest-ranked American universities (as ranked by U.S. News & World Report), and was among the top five majors at 34 of the 50 highest-ranked universities.

Estimating the causal effects of earning specific college majors is challenged by students' non-random assortment across majors: most students self-select their college major, and many universities and departments use admissions and grade requirements to restrict entry into certain majors. As a result, observational wage differences across majors may reflect selection bias. We overcome this challenge by using a regression discontinuity design that exploits a fuzzy discontinuity in economics major access at a large moderately-selective public university (Angrist and Lavy, 1999).[2] We implement this design to estimate the effect of studying economics on students' early-career earnings and industries, as well as how the major's effect on earnings is mediated by changes in students' other educational outcomes, career preferences, and early-career industries. We then characterize and estimate the biases that arise when using observational average wage difference between economics and other majors as a proxy for the treatment effect of majoring in economics.

The specific case we analyze is the Department of Economics at the University of California, Santa Cruz. UCSC Economics imposed a GPA restriction policy in 2008: students with a grade point average below 2.8 in Economics 1 and 2 were generally prevented from declaring an economics major.[3] Students who just met the GPA threshold were 36 percentage points more likely to declare the economics major than those who just failed to meet it. Most of these students would have otherwise earned degrees in other social sciences. Students just above the threshold who majored in economics were surprisingly representative of *all* UCSC economics majors on observables; for example, their average SAT scores was at the 41^{th} percentile of economics majors.

Comparing the major choices and average wages of above- and below-threshold students shows that majoring in economics caused a $22,000 (46 percent) increase in the annual early-career wages of barely above-threshold students. It did so without otherwise impacting their educational investment – as measured by course-adjusted average grades and weekly hours spent studying – or outcomes like degree attainment and graduate school enrollment. The effect is nearly identical for male and female students, may be larger for underrepresented minority students, and appears to grow as workers age (between ages 23 and 28). About half of the wage effect can be explained by the effect of majoring in economics on students' industry of employment: relative to students who did not qualify for the major, economics majors became more interested in business and finance careers and were more likely to find employment in higher-wage economics-related industries like finance, insurance, and real estate (FIRE) and accounting. Most of the barely above-threshold economics majors would have otherwise earned degrees in lower-earning fields like psychology and sociology, and differences in either OLS-

[2]This design was recommended (but not implemented) by both Altonji, Blom and Meghir (2012) and Altonji, Arcidiacono and Maurel (2016).

[3]Like many universities, UCSC has multiple "tracks" for its economics major. Students just above the GPA threshold mostly chose its "Business Management Economics" track, in which about one-third of required courses are taken in business- and finance-related subdisciplines.

estimated average wages by major (with or without controls) or median wages by major (estimated at the university, state, or national level) slightly *underestimate* the estimated local average treatment effect. This suggests that the net magnitude of selection bias and treatment effect heterogeneity is small in this context.[4]

Our data include comprehensive 2000-2014 UCSC student and course records linked to biannual administrative student surveys, National Student Clearinghouse educational outcomes, and annual California UI employment records. These highly-detailed records allow us to test several alternative explanations for above-threshold students' higher postgraduate earnings. We show that detailed student characteristics are smooth across the GPA threshold and that grade distributions in economics courses remained unchanged in the period. There is no evidence of students bunching above the threshold, as might be expected if threshold-crossing was somehow manipulated. We also show that wages were smooth across the grade threshold prior to the policy's implementation but slightly discontinuous during an interstitial period with a less-binding major restriction policy, generating similar (but noisier) instrumental variable estimates to the main specification. While our main empirical strategy estimates linear regression discontinuity models with standard errors clustered by GPA (Lee and Card, 2008), we confirm the estimates using a number of other specifications, including "Honest RD" estimates following Kolesr and Rothe (2018).[5]

A small number of previous studies have analyzed major-specific returns in other countries by exploiting centralized field-specific enrollment assignment rules (Kirkeboen, Leuven and Mogstad, 2016; Hastings, Neilson and Zimmerman, 2013; Daly and Le Maire, 2019). However, the external validity of those estimates in the U.S. may be limited: American universities offer a broader core liberal arts curriculum, permit students to choose their majors years after their initial enrollment, and provide students with more discretion over their courses, all of which could narrow field-specific returns.[6] A large literature has employed selection-on-observables methods and structural estimation to identify major-specific returns (James et al., 1989; Rumberger and Thomas, 1993; Black, Sanders and Taylor, 2003; Arcidiacono, 2004; Hamermesh and Donald, 2008), generally arguing that selection bias explains a substantial portion of U.S. wage variation across majors.

This study's reduced-form regression discontinuity design provides unusually transparent evidence of postsecondary education's heterogeneous and persistent

[4]Our results mirror the well-known finding that causal estimates of the return to schooling slightly exceed the mean differences recovered from OLS (Angrist and Keueger, 1991; Card, 1999), with our study focusing on heterogeneity in the return to schooling.

[5]Because of the small number (20) of discrete GPAs available to students, these latter estimates are likely conservative.

[6]The only known quasi-experimental study to previously identify heterogeneous returns by college major in the U.S. is Andrews, Imberman and Lovenheim (2017), who analyze the return to majoring in business by exploiting a GPA threshold policy at several University of Texas campuses. Their suggestive finding of a large wage return to business majors closely parallels our own estimates with regard to economics.

role in shaping students' labor market outcomes. Our estimated early-career wage return to economics rivals the baseline return to a college degree, implying that major choice is a first-order heterogeneity component in the return to higher education.[7] A related literature has used quasi-experimental research designs to highlight university selectivity as another important dimension of heterogeneous university treatment effects (Hoekstra, 2009; Zimmerman, 2014; Cohodes and Goodman, 2014; Bleemer, 2020*b*,*a*). However, even students who are quasi-randomly switched to enrolling at universities with 25 percentage points higher graduation rates – a large increase in selectivity – receive an early-career wage return 30 percent lower than the return to majoring in economics at UCSC (Bleemer, 2020*b*).[8] These findings imply that widespread but understudied university policies that shape student major choice – like GPA restrictions, variable tuition, and grade inflation – have important long-run efficiency and social mobility ramifications.[9]

While prior studies have documented that students select majors partly on the basis of career preferences (Wiswall and Zafar, 2018), we present quasi-experimental evidence that major choice causally affects students' career preferences or industry of employment. The correlation between college graduates' majors and their occupations and industries of employment is notably weak: fewer than 60 percent of most majors' students work in the top *ten* highest-employment (five-digit) occupations for that major (Altonji, Blom and Meghir, 2012).[10] Nevertheless, majoring in economics causes students to report a stronger preference for business and finance careers prior to labor market entry – likely in part as a result of perceived job availability – and to be more likely to ultimately work in related industries like FIRE and accounting. These changed industry preferences could reflect the fact that knowledge and skills acquired in the economics major may be particularly useful in these industries, providing students with industry-specific human capital (Altonji, Kahn and Speer, 2014; Kinsler and Pavan, 2015).

[7] One reason for the economics major's large return is the relatively-low return to economics majors' second-choice social science fields, highlighting the importance of counterfactual student choices in measuring educational returns (Kirkeboen, Leuven and Mogstad, 2016).

[8] As in nearly all previous studies on the return to education and university selectivity, we are unable to distinguish whether the observed returns result from changes in human capital or signaling. We discuss this further in Section 5. Other recent papers on heterogeneous university returns by university quality include Sekhri (2020) and Canaan and Mouganie (2018).

[9] The close correspondence between observational and causal estimates of major-specific returns also suggests the potential for private pecuniary gains resulting from providing students with locally-relevant information about average wages by majors, which has been shown to increase students' enrollment in high-wage majors (Berger, 1988; Beffy, Fougre and Maurel, 2012; Hastings, Neilson and Zimmerman, 2015; Wiswall and Zafar, 2015). See Bleemer and Mehta (2020*a*) on GPA restrictions, Andrews and Stange (2019) on variable tuition, and Ahn et al. (2019) on grade inflation. Policies encouraging economics major choice (e.g. Porter and Serra (2020)) are particularly likely to provide students with substantial pecuniary returns.

[10] A substantial academic literature studies how university policies shift students toward science and engineering majors (Sjoquist and Winters, 2015; Denning and Turley, 2017; Castleman, Long and Mabel, 2018), though none directly investigate whether this actually bolsters the STEM labor force.

I. Background

The University of California, Santa Cruz is a moderately-selective public research university in northern California. In 2010 UCSC admitted 64 percent of freshman applicants, resulting in a 3,290-student class largely split between white (38%), Asian (27%), and Hispanic (24%) students. Nearly all (98%) of its students were California residents. In many ways, UCSC is relatively representative of the average U.S. university; among four-year U.S. universities in the 2010 IPEDS database (weighted by enrollment), UCSC is at the 42nd percentile in admissions rate, the 59th percentile in average student SAT scores, the 42nd percentile in middle-income students' average net price of attendance, and the 53rd percentile in student-to-faculty ratio.[11] The UCSC Department of Economics had 25 ladder-rank faculty and 7 lecturers in 2010 and taught 8,800 student enrollments that academic year, implying that each faculty-member taught an average of 91 students per quarter, among the highest loads at the university.[12]

The UCSC Department of Economics's 2003 GPA restriction was the university's first policy limiting enrolled students' access to a particular college major (Bleemer and Mehta, 2020*a*). The restriction was first recorded in UCSC's 2003 Course Catalog, which stated that students with a GPA in Economics 1 and 2 ($EGPA$) below 2.8 would only be allowed to declare the major "at the discretion of the department". If students re-took one of the courses, only the initial grade was used to calculate $EGPA$. This policy hardly changed *de jure* over the following ten years, though the 2012 course catalog is the first to note that for students with below-2.8 $EGPA$s, "appeals are rarely granted". Starting in 2013, calculus grades were added to the $EGPA$ calculation.

However, the Department's "discretion" left substantial room for year-over-year *de facto* differences in below-2.8 students' access to the major.[13] The difference in the probability of majoring in economics above and below the $EGPA$ threshold remained small (below 15 percentage points) until the 2008 entering cohort, and then ranged from 25 to 60 percentage points until 2012.[14] As a result, this study focuses on these latter five cohorts of freshman UCSC students.

II. Data

The student database analyzed in this study (UC-CHP, 2020) was collected from the UCSC Office of the Registrar as part of the UC ClioMetric History

[11] Calculations from the Integrated Postsecondary Education Data System. Average SAT calculated as the summed averages of the 25th and 75th percentiles of each SAT test component. Average net price defined over federal financial aid recipients with family incomes between $48,000 and $75,000.

[12] Altonji and Zimmerman (2019) show that economics and business degrees have below-average educational costs.

[13] Figure A-1 shows 2000-2014 UCSC students' likelihood of majoring in economics by $EGPA$ for each cohort.

[14] This change was likely driven by increased demand after the 2007-2008 financial crisis; see Figure A-2.

Project (Bleemer, 2018). The sample covers all freshman-admit students who first enrolled at UCSC between 1999 and 2014.[15] For each student, we observe gender, ethnicity, cohort year, (pre-enrollment) home address, California residency status, high school, and SAT score as well as UCSC course enrollments and grades.[16] The $EGPA$ running variable is calculated by averaging students' grade point averages in Economics 1 and 2, using their earliest letter grades if they retook either course.

These student records are linked by name and birth date to the National Student Clearinghouse StudentTracker database (NSC, 2019), which contains undergraduate and graduate enrollment and degree attainment records for nearly all American colleges and universities, and by social security number to UI employment records from the CA Employment Development Department (EDD, 2019), which include annual wages and six-digit NAICS industry code.[17] We proxy family income by the mean adjusted gross income in the student's home ZIP Code in their first year of enrollment (IRS, 2018).[18]

UCSC students are also linked to survey responses from the biannual UC Undergraduate Experience Survey (UCUES), conducted online in the spring of even-numbered years (SERU, 2019). The 2nd/3rd and 3rd/4th year response rates among the 2008-2012 students in the main sample were 29 and 28 percent, with the response rates and respondent characteristics smooth across the GPA threshold.[19] Among the survey's many questions are responses about number of hours per week spent studying and students' intended careers.[20]

Non-economics majors are categorized into four disciplines: humanities, social sciences, natural sciences, and engineering. Combining the three tracks of the economics major — economics, business management economics, and global economics — it was the second-most-popular major at UCSC for the 2008-2012 cohorts (11.7 percent of students), below psychology (12.9 percent) but ahead of environmental studies (6.1 percent) and sociology (6.0 percent).

Table 1 presents descriptive statistics for 2008-2012 UCSC freshman-admit students. Relative to the full sample of 15,400 UCSC students, the 3,053 students who complete Economics 1 and 2 are more likely to be male and Asian and come from slightly higher-income neighborhoods. Of those students, the 55 percent who actually declare the Economics major are 41 percent female (compared to

[15] Community college transfer students are omitted from our analysis because they followed a different admission rule into the economics major.

[16] ACT test scores (submitted by 4% of applicants instead of SAT scores) and SAT scores on a 1600 point basis are converted to 2400-point SAT scores using standard concordance tables.

[17] NSC match quality is near-complete but missing for some students who opt out of coverage. For example, 97 percent of UCSC undergraduate degrees awarded to the 2008-2012 cohorts appear in NSC (see Appendix C of Bleemer (2020*b*)). EDD NAICS code reflects the industry of employment from the year's latest non-missing quarter (Census, 2019). UI employment records exclude out-of-state, federal, and self-employment. All EDD-related analysis was originally conducted for the purpose of institutional research (see Bleemer and Mehta (2020*b*)).

[18] Income statistics are from the IRS Statistics of Income (SOI). Wage and income statistics are winsorized at the top and bottom 2% and CPI inflation-adjusted to 2019 (BLS, 2019).

[19] See Figure A-3. UCUES data were provided by the Survey Experience in the Research University (SERU) Consortium at UC Berkeley's Center for Studies in Higher Education and linked by student ID.

[20] Full questions and responses are provided in the Survey Appendix.

Table 1—Descriptive Statistics of 2008-2012 UCSC Enrollment Cohorts

	Freshman Students	Econ 1 & 2 Enrollees	Economics Majors	Near-Threshold Economics Majors	(s.e.)
Female (%)	55.7	41.3	40.9	35.6	(7.3)
White (%)	40.8	32.4	32.8	27.9	(6.5)
Asian (%)	26.5	41.4	43.7	41.1	(8.1)
Hispanic (%)	24.3	19.2	16.7	18.3	(7.1)
Black (%)	2.9	1.9	1.7	6.2	(1.8)
CA Resident (%)	97.1	97.4	97.2	99.7	(2.5)
SAT Score (2400 scale)	1720	1697	1716	1667	(14)
Mean ZIP Code Inc. ($)	92,060	95,819	99,477	86,770	(7,309)
Number of Students	15,423	3,053	1,689		

Note: This table presents mean demographic and socioeconomic statistics for 2008-2012 UCSC freshman-admit students, those who take Economics 1 and Economics 2, and those who then declare the economics major. The final columns present the average characteristics of the students who majored in economics because of their barely above-threshold $EGPA$s, estimated following Equation 1 by treating the interaction between each characteristic and economics major indicator as the outcome (Abadie, 2002). Mean ZIP Code Income measures the mean adjusted gross income of tax-filers in the student's home ZIP Code in the year they graduated high school.
Source: The UC-CHP Student Database and IRS Statistics of Income (SOI).

56 percent across UCSC), 44 percent Asian (compared to 27 percent), and have similar average SAT scores to the average UCSC student (1716 out of 2400).

III. Empirical Design

We identify the relationship between economics major choice (the treatment) and resulting outcomes (Y) by exploiting a discrete fuzzy grade discontinuity in economics major access (Hahn, Todd and van der Klaauw, 2001). Figure 1 shows the first stage estimate of the impact of meeting the 2.8 GPA threshold on economics major choice for the 2008-2012 cohorts. Above-threshold students were about 36 percentage points more likely to declare the economics major. Some below-threshold students were nevertheless able to declare the major — "at the discretion of the department" — and about 20 percent of above-threshold students chose not to declare the major. Each bubble is scaled by the proportion of students who earned that $EGPA$; because the $EGPA$ is calculated over only two letter grades, students could earn one of only 14 common or 6 uncommon $EGPA$s.

Let $Y_i(1)$ denote the outcome that UCSC student i would experience if they majored in economics, and $Y_i(0)$ denote the outcome they would experience if they did not. Outcomes of interest include (for example) post-graduation earnings, industry of employment, study time, and graduate school attendance. Let C be the group of policy compliers: the subset of students who major in economics

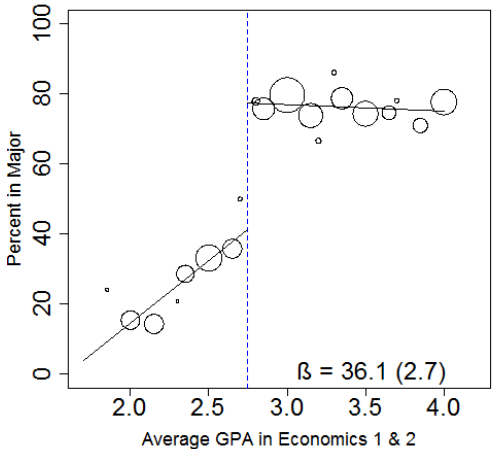


FIGURE 1. THE EFFECT OF THE UCSC ECONOMICS GPA THRESHOLD ON MAJORING IN ECONOMICS

Note: Each circle represents the percent of economics majors (y axis) among 2008-2012 UCSC students who earned a given $EGPA$ in Economics 1 and 2 (x axis). The size of each circle corresponds to the proportion of students who earned that $EGPA$. $EGPA$s below 1.8 are omitted, leaving 2,839 students in the sample. Fit lines and beta estimate (at the 2.8 GPA threshold) from linear regression discontinuity specification; standard error (clustered by $EGPA$) in parentheses. Source: The UC-CHP Student Database.

if they are above the GPA threshold but not if they are below it. The effect of the major on policy compliers whose $EGPA$ was near the threshold (the local average treatment effect) is given as:

$$(1) \quad LATE_{RD}(Y) \equiv \lim_{EGPA \downarrow 2.8} E[Y_i(1)|EGPA, i \in C] - \lim_{EGPA \uparrow 2.8} E[Y_i(0)|EGPA, i \in C]$$

so long as $E[Y_i(1)|EGPA, i \in C]$ and $E[Y_i(0)|EGPA, i \in C]$ are smooth at $EGPA = 2.8$.

We test several implications of this smoothness assumption. First, we find that the empirical grade distribution does not spike at or near the 2.8 $EGPA$ threshold, and the 2008-2012 distribution is highly similar to the 2003-2007 grade distribution, years when the $EGPA$ threshold was loosely enforced.[21] This pattern implies that students did not manipulate their course grades to meet the GPA threshold. Second, we find that detailed student socioeconomic characteristics are smooth across the GPA threshold, as is a one-dimensional summary of student characteristics generated by flexibly predicting each student's 2017-2018 average wages by socioeconomic observables. This indicates that effects estimated across

[21] See Figure A-4. Both distributions share the same shape as the 2000-2002 grade distribution (prior to the $EGPA$ restriction's implementation), though average $EGPA$s trended downward over time. Students' Economics 2 grades are smooth across the threshold.

the threshold are unlikely to be driven by anything other than qualification for the major. [22] Finally, as a placebo test, we find that economics major selection and early-career wages are smooth across the 2.8 $EGPA$ threshold in 2000-2002, before the GPA restriction was introduced.[23]

Our baseline specification for estimating Equation 1 is linear in the running variable ($EGPA$) on either side of the threshold and clusters standard errors by the 20 observed $EGPA$s above 1.8 (Lee and Card, 2008). We also check that our results are robust to using a number of alternative specifications. These include (1) allowing quadratic running variable terms, (2) adding demographic controls and high school fixed effects, (3) narrowing the bandwidth to 0.5 $EGPA$ points on either side of the threshold, and (4) estimating "honest" local linear RD coefficients with optimal bandwidth and triangular kernel following Kolesr and Rothe (2018).[24] We note below the rare occasions in which any of the alternative specifications result in coefficients that differ substantially or statistically from those presented in the figures.[25]

The last columns of Table 1 present estimated characteristics of the students who majored in economics as a result of their barely above-threshold $EGPA$s (estimated following Abadie (2002)). These students' observable characteristics are surprisingly similar to those of the average UCSC economics student: 36 percent are female, 41 percent are Asian, and essentially all of them are California residents. Despite their low introductory course grades, there is no indication that they were much less prepared for success than other economics majors: their mean SAT score is at the 41^{th} percentile of all economics majors, while the mean income of their ZIP Codes of residence is at the 48^{th} percentile of their economics peers.[26] The representativeness on observables of our above-threshold policy compliers suggests that our estimated local average treatment effects may be similar to the average treatment effect of majoring in economics at UCSC.

[22] See Figure A-5. Predicted wages are estimated by OLS on the 2017-2018 wages of 2008-2012 UCSC students who did not complete Economics 1 and 2. Predicted wages are imputed only for students with observed 2017-2018 wages to match our main labor market estimation sample.

[23] See Figure A-6. We also exploit the small increase in economics major choice across the less-binding 2003-2007 GPA threshold to noisily replicate the instrumental variable wage results in the main specification below (first-stage 6.2 percentage points (2.9 s.e.), IV $32,500 ($19,600)).

[24] The small number of running variable values suggests that these last estimates will be conservative. Tables A-1 to A-4 present regression coefficients from these alternative specifications for all main results.

[25] All OLS and IV regressions are estimated using the *felm* function in the *lfe* R package, version 2.8-5. Honest local linear regressions are estimated by the *RDHonest* R package, version 0.3.2.

[26] This absence of significant positive selection may result from the substantial noise in introductory course grades, which reflect a host of professor, TA, and extracurricular determinants (e.g. Sacerdote (2001); Fairlie, Hoffmann and Oreopoulos (2014)). A linear regression of $EGPA$ on high school fixed effects and gender-ethnicity indicators interacted with SAT score, mean ZIP Code GPA, and cohort provides an adjusted R^2 of only 0.15.

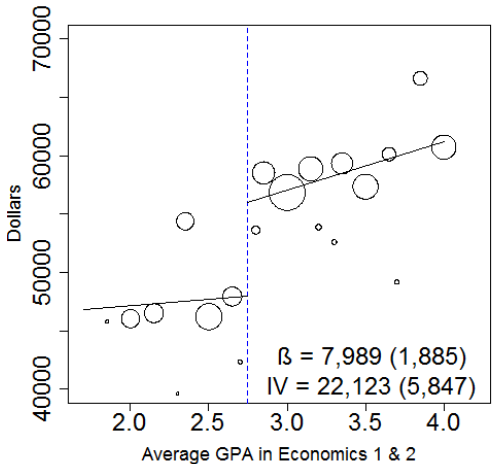


FIGURE 2. THE EFFECT OF THE UCSC ECONOMICS GPA THRESHOLD ON ANNUAL WAGES

Note: Each circle represents the mean 2017-2018 wages (y axis) among 2008-2012 UCSC students who earned a given $EGPA$ in Economics 1 and 2 (x axis). The size of each circle corresponds to the proportion of students who earned that $EGPA$. 2017-2018 wages are the mean EDD-covered California wages in those years, omitting zeroes. Wages are CPI-adjusted to 2018 and winsorized at 2% above and below. $EGPA$s below 1.8 are omitted, leaving 2,446 students with observed wages. Fit lines and beta estimate (at the 2.8 GPA threshold) from linear regression discontinuity specification and instrumental variable specification (with majoring in economics as the endogenous variable); standard errors (clustered by $EGPA$) in parentheses. Sources: The UC-CHP Student Database and the CA Employment Development Department.

IV. Baseline Return to the Economics Major

Figure 2 shows that 2008-2012 UCSC students with above-threshold $EGPA$s had far higher early-career wages than their below-threshold peers.[27] Measuring average California wages in 2017 and 2018 – when students in the sample were 23 to 28 years old – above-threshold students earned about $8,000 higher wages than below-threshold students, with a standard error of $1,900.[28] Given that they were also 36 percentage points more likely to major in economics, the IV estimator suggests that students who just met the GPA threshold earned higher early-career wages by about $22,000 if they declared the economics major, rising from $37,000 to over $59,000. Measuring wages in log dollars provides a similar 0.58 log dollar estimated treatment effect, though that estimate is statistically noisy in the Kolesr and Rothe (2018) specification.

The estimated returns to majoring in economics are nearly identical when estimated separately by student gender: $21,700 (s.e. $8,800) for men, $22,600

[27] Impacted students mostly graduated between 2012 and 2016, implying that their early-career earnings and industries were not shaped by a postgraduate recession (Altonji, Kahn and Speer, 2016).

[28] Students with earnings in only one of the two averaged years are assigned their observed year's wages; students with no observed wages in either year are dropped. Some RD specifications provide somewhat larger wage return estimates.

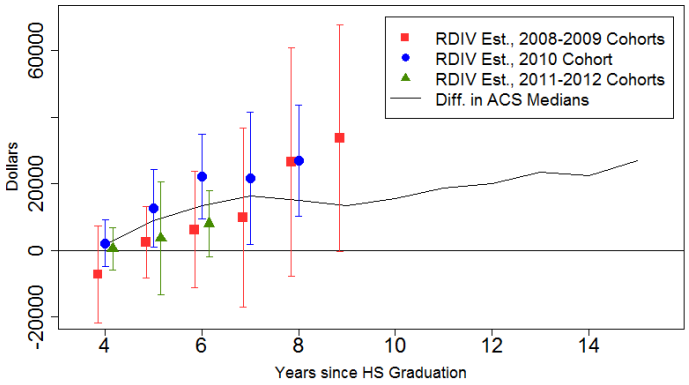


FIGURE 3. ESTIMATED WAGE RETURN TO ECONOMICS MAJOR BY AGE

Note: This figure shows regression discontinuity instrumental variable β estimates at the 2.8 GPA threshold of the effect of majoring in economics on earnings in each of 4-9 years after high school graduation, splitting the sample into the 2008-2009, 2010, and 2011-2012 UCSC incoming-class cohorts. The bars show 95% confidence intervals from standard errors clustered by $EGPA$. The black line shows the difference between the national median wages of economics majors and those of college graduates with majors in barely above-threshold UCSC students' second-choice majors, as measured in the ACS; see Figure A-8. Wages are CPI-adjusted to 2018 and winsorized at 2% above and below. Sources: The UC-CHP Student Database, the CA Employment Development Department, and the American Community Survey (Ruggles et al., 2020).

($5,700) for women. The unexpectedly high observed earnings of students with $EGPA = 2.35$ visible in Figure 2 obtains only for male students, driving those estimates' higher standard errors. The return is also similar in magnitude among underrepresented minority (Black, Hispanic, and Native American) students: $27,600 ($13,500).[29]

These estimates do not appear to be solely driven by college graduates' first employment after graduation. Figure 3 presents estimates of the annual wage return to majoring in economics 4-9 years after graduating high school for three partitions of our baseline sample: the 2008-2009 cohorts, 2010 cohort, and 2011-2012 cohorts. It shows suggestive evidence that the wage return grows larger as workers age from 23 to 28, though the small number of cohorts challenges separate identification of age and cohort effects. Figure A-8 contextualizes this finding by using American Community Survey wage data (Ruggles et al., 2020) to visualize the median wages of U.S. economics majors annually from ages 22 to 62 along with the weighted median wages of U.S. college graduates who earned the second-choice majors that UCSC's policy-complying economics majors would have earned if economics had been unavailable (discussed further below). The relative observational return to economics increases with age in workers' 20s and

[29]See Figure A-7. California wages are observed for 80-90 percent of the sample, likely the result of nearly all UCSC freshman students being California residents. There is some evidence that students' likelihood of 2017-2018 California employment rises at the GPA threshold, though the estimates are not robust across different specifications; see Figure A-9.

30s and remains large throughout workers' careers, resulting in a $536,000 observational net present value of majoring in economics.[30]

V. Why do Economics Majors Earn Higher Salaries?

A. Educational Performance, Resources, and Attainment

Figure 4 shows how the characteristics of UCSC students' postsecondary education differed as a result of being provided access to the economics major. Panels (a) and (b) show that access to the economics major does not change students' likelihood of earning a college degree or enrolling in a graduate degree program (within seven years of matriculating).[31] Above-threshold students also have similar time-to-degree as below-threshold students. Economics major access does not provide students with smaller class sizes; if anything, average class sizes grow larger.[32] It does not lead students to earn higher or lower grades when adjusted for course difficulty (c), nor does it change the weekly amount of time students report studying outside of class.[33]

Instead, the primary estimable difference in students' postsecondary education is the content of that education. Barely above-threshold economics majors completed 13 more economics courses than non-majors, for a total of 17 economics courses on average. This caused the economics majors to take 9 fewer courses in other social sciences and about 4 fewer courses across other disciplines. About 7 of the additional economics courses were in traditional economics sub-disciplines, while almost 6 were in sub-disciplines related to business, finance, and accounting also offered by UCSC's economics department. Access to the economics major did not change the number of mathematics and statistics courses that students completed, but they did complete an average of two additional courses in quantitative methodology.[34]

If there was no signal value of economics degree attainment, then these estimates would imply a wage elasticity of economics course-taking of about 0.3.[35] However,

[30]The observational wage return to economics shrinks (though remains large) after age 50, possibly reflecting informational obsolescence (Deming and Noray, 2020).

[31]Near-threshold students had a 96 percent Bachelor's attainment rate – including degrees earned at other institutions by 2018 – compared to 94 percent across the 2008-2012 UCSC freshman cohorts.

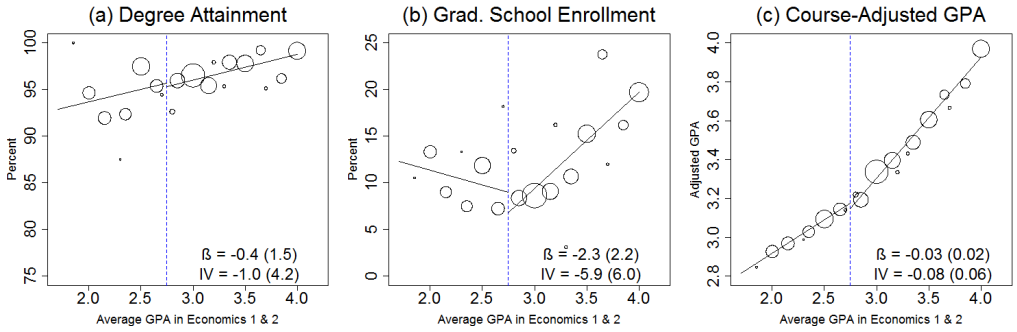
[32]For plots showing estimates for additional educational outcomes like time to degree and class size, see Figure A-10.

[33]Above-threshold students earn slightly lower unadjusted grade point averages than below-threshold students as a result of relatively lower grading standards in UCSC's economics department; see Figure A-10.

[34]Quantitative methodology courses include any course that mentions 'statistics', 'econometrics', 'psychometrics' or 'quantitative/math/research/information methods' in its title. See Figures A-11 and A-12.

[35]Arteaga (2018) finds that, in the setting of a Colombian university, a policy change that resulted in a 15 percent reduction in course-taking among economics majors caused a 16 percent decline in students' early-career wages, implying a unit wage elasticity of economics course-taking. It is unsurprising that we estimate a lower elasticity, given that: (1) below-threshold UCSC students excluded from the economics major took other courses instead of economics courses, whereas the Colombian students graduated having completed fewer aggregate courses; and (2) below-threshold UCSC students earned a different college major instead, which could change the signal value of their degree.

FIGURE 4. THE EFFECT OF ECONOMICS MAJOR ACCESS ON EDUCATION AND ATTAINMENT



Note: Each circle represents the mean educational outcome (y axis) among 2008-2012 UCSC students who earned a given $EGPA$ in Economics 1 and 2 (x axis). The size of each circle corresponds to the proportion of students who earned that $EGPA$. Undergraduate degree attainment is measured in 2018. Graduate school enrollment indicates enrollment at a four-year university after undergraduate degree attainment within seven years of UCSC matriculation. Course-Adjusted College GPA is calculated as the mean of the differences between students' grades and each course's fixed effect from a two-way student-course fixed effect model (see Figure A-10). $EGPA$s below 1.8 are omitted, leaving 2,839 students in the sample. Fit lines and beta estimate (at the 2.8 GPA threshold) from linear regression discontinuity specification and instrumental variable specification (with majoring in economics as the endogenous variable); standard error (clustered by $EGPA$) in parentheses. Sources: The UC-CHP Student Database and the National Student Clearinghouse.

this estimate is likely upwardly-biased by the potentially high signal value of economics degrees relative to students' second-choice majors. We are unable to directly distinguish between the degree's signal value and the value of additional human capital accumulation in this setting.[36]

B. Employment by Industry

Majoring in economics causally impacts the industries in which students are employed in their early careers. This could reflect either industry-specific human capital formation or changes in students' preferences across industries. Panel (a) of Figure 5 suggests that part of the effect arises from student preferences; survey responses from students' sophomore and junior spring quarters (prior to labor market entry) show that barely above-threshold economics majors became more than 50 percentage points more likely to report an interest in a business or finance career than non-majors, though this could in part reflect increased employment opportunity in those industries.[37] Panel (b) shows that economics

[36] One potential strategy to directly estimate the signal value of UCSC's economics degree would be to compare the wages of economics majors and non-majors who took comparable numbers of economics courses. Unfortunately, as at many U.S. public universities, many UCSC economics courses were formally or informally restricted to economics majors. Figure A-13 shows that there is essentially no overlap between the distribution of economics courses completed by 2008-2012 UCSC economics majors and non-majors, thwarting that design.

[37] First-year career-intention survey responses (prior to majoring in economics) are smooth across the threshold. We examine sophomore and junior responses because those students have (likely) already

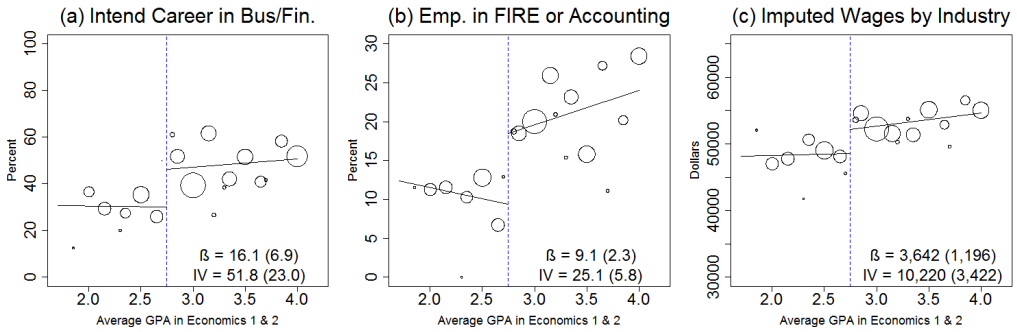


FIGURE 5. EFFECT OF ECONOMICS MAJOR ACCESS ON INDUSTRY PREFERENCES AND EMPLOYMENT

Note: Each circle represents the mean outcome measure (y axis) among 2008-2012 UCSC students who earned a given $EGPA$ in Economics 1 and 2 (x axis). The size of each circle corresponds to the proportion of students who earned that $EGPA$. Intended career in business/finance indicates selecting "Business, finance-related professions" on a survey asking "Career hope to eventually have after education complete" (see the Survey Appendix) among the 834 in-sample second- and third-year UCUES respondents. Employment in FIRE and accounting indicates 2017 or 2018 employment in the finance, insurance, and real estate (NAICS codes 52 and 531) or accounting (541211) industries; see Figure A-5. Imputed wages by industry (6-digit NAICS) are calculated as the mean 2017-2018 wages of all 2008-2012 freshman-admit UCSC students. Imputed wages are CPI-adjusted to 2018 and winsorized at 2% above and below. Fit lines and beta estimate (at the 2.8 GPA threshold) from linear regression discontinuity specifications and instrumental variable specifications (with majoring in economics as the endogenous variable); standard error (clustered by $EGPA$) in parentheses. Six 2012 sophomore respondents were omitted from estimation; see Figure A-14. Sources: The UC-CHP Student Database, the SERU database, and the CA Employment Development Department.

major access increases students' early-career likelihood of working in the most-impacted finance, insurance, and real estate (FIRE) and accounting industries by 25 percentage points, split two-thirds/one-third between the two. Economics majors became 17 percentage points less likely to work in the education, healthcare, and social assistance industries in 2017-2018.[38]

Panel (c) of Figure 5 shows the effect of majoring in economics on the average wages earned in students' industries of employment. Industries are defined by six-digit NAICS codes, and industry mean wages are measured using the 2017-2018 wages of all 2008-2012 UCSC students. Barely above-threshold economics majors work in industries with higher mean wages by about $10,000, implying that just under half of the $22,000 wage return to majoring in economics can be explained by economics majors working in higher-paying industries.[39]

declared the economics major but have not yet been hired into postgraduate employment. Six 2012 sophomore respondents – economics majors with 2.7 $EGPA$s – are omitted from estimation as outliers; see Figure A-14.

[38]See Table A-5, which shows estimated changes for each two-digit NAICS code. Accounting – in which UCSC Economics offers several courses – is the most-impacted six-digit NAICS code outside of FIRE industries.

[39]This conclusion is supported by a $15,400 estimated IV wage coefficient in the presence of 6-digit-NAICS fixed effects, though that estimate is statistically noisy (s.e. $8,000). If industries are partitioned into just three groups – FIRE, accounting, and all other industries combined – the two can explain only a $2,300 (IV) wage increase at the threshold. Mean industry wages calculated using earlier UCSC cohorts

VI. Average Wage-by-Major Statistics

Differences in the average wages earned by college graduates with different majors are often presented as useful for students' major selection (Carnevale, Cheah and Hanson, 2015; U.S. Department of Education, 2019), but they could be misleading as a result of self-selection into majors. To examine this concern empirically, this section compares the causal return to majoring in economics at UCSC to observational differences in wages by major estimated using data from various reference populations (e.g., all UCSC graduates or college graduates in California).

Denote the average wage of college graduates in reference population R who completed major m by $\widetilde{w}_m^R$. Among students at UCSC who have taken Econ 1 and 2, let m_i be student i's chosen major, $w_i(m)$ be the latent wages they would have earned if they had selected major m, and $w_i = w_i(m_i)$ be their observed wage given that they chose m_i. T is the treatment major (economics). Let P_m^0 be the probability of choosing non-economics major m for the barely below-threshold students who would have earned economics majors if their $EGPA$s had been slightly higher (that is, below-threshold policy compliers); P_m^R be the probability of a student in R selecting m conditional on not selecting economics; and $\overline{w}_m^0$ and $\overline{w}_m^1$ be the expected latent wages in major m of UCSC policy compliers just below and above the GPA threshold. We can then estimate Equation 1 in our sample of UCSC Econ 1 and 2 takers either using each student's observed wage as the dependent variable, or replacing it with the $\widetilde{w}_m^R$ of their chosen major. These regressions yield estimates, respectively, of:

$$LATE_{RD}(w) = \overline{w}_T^1 - \sum_{m \neq T} P_m^0 \overline{w}_m^0 \tag{2}$$

$$LATE_{RD}(\widetilde{w}_m^R) = \widetilde{w}_T^R - \sum_{m \neq T} P_m^0 \widetilde{w}_m^R \tag{3}$$

These equations show that wage-by-major statistics from R can be used to predict the treatment effect of earning an economics major for barely above-threshold UCSC students if they are similar to policy compliers' latent wages by major near the GPA threshold.

Figure 6 shows the average early-career wages by major for barely above-threshold economics majors' ten most common second-choice majors — led by psychology (20%), environmental studies (14%), and "technology and information

and 2009-2010 wages provide nearly identical estimates, suggesting this information *could* have been partly known by students. NAICS codes with fewer than 10 observed workers are omitted.

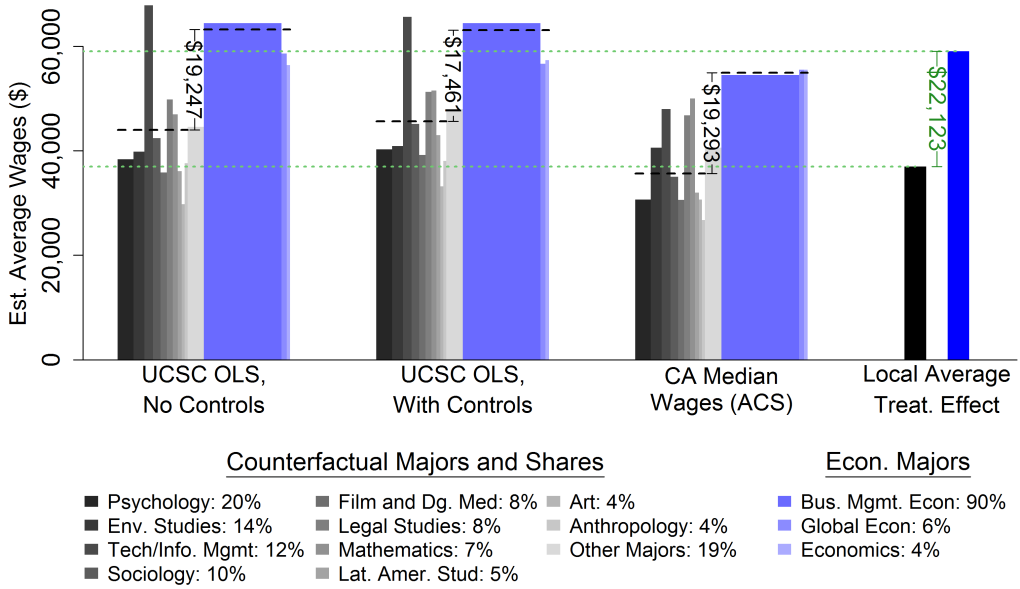


FIGURE 6. AVERAGE WAGE DIFFERENCES BETWEEN ECONOMICS AND COUNTERFACTUAL MAJORS

Note: This figure shows average early-career 2017-2018 wages by major of UCSC students (estimated by OLS, with and without control variables) and all California college graduates (ACS medians) for UCSC's three economics tracks and for the ten most common counterfactual majors earned by below-threshold UCSC policy compliers, juxtaposed with the causally-identified local average treatment effect on early-career wages for below- and above-threshold UCSC policy compliers (following Abadie (2002)). The black dotted lines show the average wages of the majors chosen by below- and above-threshold policy compliers, calculated by assigning each 2008-2012 UCSC student to their corresponding majors' average wage – leave-one-out in the UCSC no-controls sample – and using the linear RD IV model on the resulting imputed wages. Counterfactual major shares are estimated by the linear RD IV model predicting an indicator for earning that major; the shares sum to over 100% because below-threshold policy compliers earn more multiple majors. Bar widths are proportional to the major shares. UCSC statistics from 2008-2012 UCSC students matched to 2017-2018 wages; California statistics calculated from age 23-28 2017-2018 ACS respondents. OLS coefficients from regressions of wages on major indicators with or without covariates (gender-ethnicity, SAT score, ZIP Code average AGI, cohort year, and high school fixed effects), partitioning students by their highest-earning major. See Figure A-7 for UCSC-ACS major mapping. Wages and wage-by-major averages are CPI-adjusted to 2018 and winsorized at 2% above and below. Sources: The UC-CHP Student Database, the CA Employment Development Department, and the American Community Survey (Ruggles et al., 2020).

management" (TIM, 12%) — and for UCSC's three economics tracks.[40] Average wages by major ($\widetilde{w}_m^R$) are calculated in three ways: by linear regression of UCSC students' early-career wages on major dummies with and without detailed student controls, and by the median wages of all early-career college graduates in Califor-

[40] Above-threshold policy compliers are more likely to choose the business management economics track than the average economics major. The fraction of economics majors on the BME track only increases slightly and statistically-insignificantly across the GPA threshold (10.5 percentage points, s.e. 6.1), suggesting that the large share of policy compliers on that track largely results from local student demand, not department policy. See Figure A-15.

nia.[41] The figure also shows estimates of $LATE_{RD}(\widetilde{w}_m^R)$ for each set of average wage statistics as the difference between two dashed horizontal lines. These are estimates of Equation 3, which implicitly weights the average wage in each counterfactual major by the likelihood that a below-threshold policy complier would select it. They are juxtaposed, at the far right, with the causally-identified return to majoring in economics — our estimate of Equation 2.[42]

At UCSC and across the state, economics majors have substantially higher average wages than college graduates who earned the observed counterfactual majors.[43] Using either OLS estimates or median wages, the difference between the average wages of economics majors and the weighted-average wage among the counterfactual majors *underestimates* the causally-estimated return to majoring in economics by up to 21 percent.

Why might wage-by-major estimates differ from the treatment effect of majoring in economics? To see the possible sources of bias, note that linear regression of observed wages on treatment in population R estimates $\beta_{OLS}^R(w) \equiv \widetilde{w}_T^R - \sum_{m \neq T} P_m^R \widetilde{w}_m^R$, and that it is generically true in a Rubin Causal Model that

$$\beta_{OLS}^R(w) = \overbrace{E(w_i(T)|m_i = T) - E(w_i(\sim T)|m_i = T)]}^{\text{Average Treatment Effect on Treated in } R \ (ToT^R)} + \underbrace{[E(w_i(\sim T)|m_i = T) - E(w_i(\sim T)|m_i \neq T)]}_{\text{Selection Bias}} \tag{4}$$

Equation 4 shows that OLS overestimates economics majors' true wage gains if those selecting economics would have earned more in non-economics majors than those who did not select economics — due to, e.g., stronger prior quantitative training or stronger preferences for high wages. Combining Equations 2, 3, and 4 yields

[41] National wage-by-major medians display a similar pattern; see Table A-6. CA and U.S. statistics from the American Community Survey (Ruggles et al., 2020). See Table A-7 for a UCSC-ACS major crosswalk.

[42] The imputed wage estimates partition students by their *set* of majors to calculate averages, whereas the major-specific estimates assign multi-major students to their higher-earning major; see Figure A-16. Estimates of below- and above-threshold UCSC policy compliers' imputed and actual wages follow Abadie (2002).

[43] Business management economics (BME) majors have somewhat higher average wages than other economics majors at UCSC, but not elsewhere. UCSC's high-wage TIM major includes the economics department's core course sequence as required courses.

$$
\begin{aligned}
LATE_{RD}(\widetilde{w}_m^R) - LATE_{RD}(w) \\
&= \underbrace{[LATE_{RD}(\widetilde{w}_m^R) - \beta_{OLS}^R(w)]}_{\text{Counterfactual Major Correction}} \\
&\quad + \underbrace{[ToT^R - LATE_{RD}(w)]}_{\text{Treatment Effect Heterogeneity}} + [\text{Selection Bias}]
\end{aligned} \tag{5}
$$

Equation 5 decomposes the difference between the observational difference in average wages by major in population R and our estimated treatment effect of majoring in economics at UCSC. The counterfactual major correction is positive whenever the majors selected by below-threshold UCSC policy compliers are systematically higher-earning than those selected by non-economics majors in R - as is clear from comparing the definition of $\beta_{OLS}^R(w)$ to Equation 3. The treatment effect heterogeneity term is positive whenever economics majors in R have larger latent treatment effects than those of policy compliers near the GPA threshold. Selection bias is positive when economics majors in R would have earned higher wages in non-economics majors than non-majors in R.

The left-hand side of Equation 5 is negative and small when R consists of all UCSC graduates, and the counterfactual major correction is very small. This implies that the treatment effect heterogeneity and selection bias terms must roughly cancel each other out.[44] Figure 6 shows this clearly: above-threshold policy compliers have lower average earnings than the average UCSC students on their economics tracks, but their wages would have been even lower — to an even greater degree than the difference in average wages by major — if they'd earned their second-choice majors instead.[45,46] Combined with the fact that selection bias resulting from observable characteristics is positive ($\$19,247 - \$17,461 > 0$), this suggests that $ToT^{UCSC} < \beta_{OLS}^{UCSC} < LATE_{RD}(w)$: the average economics major earned a return smaller than the observational wage difference, while students who were barely unable to declare the economics major may have earned a return larger than the observational wage difference.

Together, these results suggest that OLS and wage-by-major medians well-approximate, and in fact slightly underestimate, the causal effect of majoring in economics identified by our instrumental variable design.

[44] With all UCSC graduates as R, we estimate $LATE_{RD}(\widetilde{w}_m^R) = \$19,427$ (Figure 6), $LATE_{RD}(w) = \$22,123$ (Figure 6), and $\beta_{OLS}^R(w) = \$20,039$ (Table A-6). The LHS is then -$2,876, the counterfactual major correction is -$792, and the heterogeneity and selection terms sum to -$2,084 — less than 10% of the estimated treatment effect by magnitude.

[45] This is consistent with students having comparative advantage in their preferred major (Kirkeboen, Leuven and Mogstad, 2016), one dimension of treatment effect heterogeneity.

[46] Using the CPI-adjusted 2009-2010 wage-by-major medians of earlier UCSC cohorts to impute the 2008-12 cohorts' wages yields $LATE_{RD}(\widetilde{w}_m^R)$ estimates strikingly similar to the true local average treatment effect (Figure A-17), suggesting that those effects are relatively stable over time.

VII. Conclusion

The UC Santa Cruz Department of Economics's 2008-2012 binding major restriction policy provides an unusual opportunity to transparently identify the personal early-career wage return to earning an economics major in college. We show that the wage return to economic education is very high relative to education in students' second-choice social science disciplines, causing a 46 percent increase in mid-20s earnings despite no change in educational investment or degree attainment. About half of the observed effect can be attributed to economics majors' specialization in particular high-wage industries, in part reflecting changes in students' reported preferences across professions. Mirroring a similar finding from studies of the return to additional years of education (Card, 1999), we show that major-specific OLS estimates and differences in median wages by major both slightly underestimate the observed wage return to economics. For reference, a comparison between the national median wages of college graduates with economics degrees and those of graduates with degrees in UCSC economics students' second-choice majors suggests that majoring in economics raises the net present value of a student's college education by $536,000, with the early-career annual wage difference widening over time.

These findings imply that students' major choices could have financial implications roughly as large as their decision to enroll in college (Autor, 2014), highlighting the centrality of heterogeneity in the private returns to higher education. They also point to students' college major choice as a key decision point where policy-makers can intervene to substantially impact youths' long-run labor market outcomes.[47] Finally, these findings highlight the relationship between major-specific returns and industrial composition, suggesting an important role for preferences and industry-specific human capital acquisition in postsecondary education.

These findings come with four caveats. First, our results are estimated for students at a moderately-selective public university — at the 60th percentile of the university average SAT distribution — where nearly all students eventually earn a Bachelor's degree (at UCSC or elsewhere); the findings may not be representative of the average university student. Second, our analysis is restricted to students who already choose to take introductory economics courses, and may not extend to other students. Third, there are many U.S. states (unlike California) where economics majors do not earn above-average early-career wages, suggesting an important role for local labor demand in shaping major-specific returns.[48] Finally, higher education's broad public and non-pecuniary returns imply that wage

[47] Indeed, Bleemer and Mehta (2020*a*) show that GPA-based major restrictions regressively shape students' major choices, tending to decrease disadvantaged students' access to universities' high-demand majors.

[48] For example, in the 15 states where industries' employment shares among college graduates are least similar to California's, 2017-2018 ACS statistics show that economics majors do not have higher median wages than other college graduates, and earn lower wages than non-majors in most two-digit industries. See Figure A-18.

returns are insufficient in themselves for drawing conclusions about the efficiency of educational policies (e.g. see McMahon (2009)).

Survey Appendix

We analyze students' responses to two UCUES survey questions. The first question asks: "How many hours: -Studying and other academic activities outside of class," and respondents are provided eight radio-button alternatives: "0; 1-5; 6-10; 11-15; 16-20; 21-25; 26-30; More than 30". We code each range to its mean, and code "More than 30" to 35.

The second question asks: "Career hope to eventually have after education complete". Students available responses are: "Agricultural/agribusiness; Artistic, creative professions; Business, finance-related professions; Civil service/government; Education; Engineering, computer programming; Law; Medicine, health-related professions; Military; Psychology, helping professions; Researcher, scientist; I have no idea whatsoever; Other". Our analysis uses an indicator for whether the student selected the third response, "Business, finance-related professions".

*

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