University Production Functions and the Choice of College Major: Evidence from California*

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Abstract

The low number of science and engineering majors–particularly for under-represented minorities–is of growing concern. This paper examines how universities produce graduates in different fields. Using student-level data on the University of California (UC) system during a period in which racial preferences were in place, we show significant sorting into majors based on academic preparation, with science majors at each school having on average stronger credentials than their non-science counterparts. Students with relatively weaker academic preparation are significantly more likely to leave the sciences and take longer to graduate at each school. We show the vast majority of minority students would be more likely to graduate with a science degree and graduate in less time had they attended a lower ranked university. Similar results do not apply for majority students.

1 Introduction

Increasing the number of Science, Technology, Engineering, and Math (STEM) majors is seen as one of the key components to keeping the U.S. competitive in a global economy (Carnevale, Smith, and Melton 2011). In a 2012 report, the President's Council of Advisors on Science and Technology suggested that the number of STEM majors needed to increase by 34% over current rates to meet the demand for STEM professionals. The lack of STEM

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majors occurs despite STEM majors earning substantially more than other college degrees with the exception of perhaps business (Arcidiacono 2004, Kinsler and Pavan 2012, Melguizo and Wolniak 2012) and that the STEM premium has increased over time (Gemici and Wiswall 2011).

Of particular concern is the lack of representation of minority students (Council of Graduate Schools 2007). At college entry, black and Hispanic students exhibit preferences for STEM fields that are similar to white preferences, yet their probabilities of persisting in STEM fields are much lower (Anderson and Kim 2006). Data from the University of California system between 1995 and 1997 show similar patterns. Namely, the percentage of college enrollees expressing an interest in science majors is 35% for both minorities and whites.[1] Yet, 19% of white enrollees compete a degree in the sciences with the corresponding number for minorities at less than 11%. Among those who complete a degree in five years, 31% of whites graduate in the science and 17% of minorities.

While these and other types of policies may help to reduce the current racial disparities in shares of the U.S. workforce with STEM degrees, very little is known about the role that college campuses have in "producing" STEM degrees, especially for underrepresented minority groups. For example, we know little about the differences between selective institutions and less selective ones in the production of graduates in certain type of fields.[2] And, how successful are different types of colleges in producing STEM graduates with students of poor versus strong pre-college academic preparation? For example, do selective selective colleges have a comparative advantage over less selective ones in producing STEM degree holders and does this hold for minorities as well as other racial groups? Or, is there more heterogeneity in the production of STEM degree holders across types of universities? Determining the answers to these questions can inform the likely effectiveness of alternative policies aimed at increasing minority representation of the U.S. workforce with STEM backgrounds. For example, will attempts to increase minority representation at elite universities, through the use of affirmative action and increased minority financial aid, increase minority representation among STEM degree holders, or might encouraging students to attend schools better matched to their academic preparation do a better job of reducing the racial disparities in STEM degrees noted above?

Making use of a rich database that contains information on applicants, enrollees and

[1] Minorities refers to blacks, Hispanics, and Native Americans.

[2] Griffith (2010) constitutes an exception. She finds that institutional characteristics play a key role in the decision of students to "persist" in a STEM major and obtain a STEM degree. For example, she finds that students at selective colleges with large research expenditures relative to total educational expenditures have lower persistence rates of students in the sciences, especially minority students.

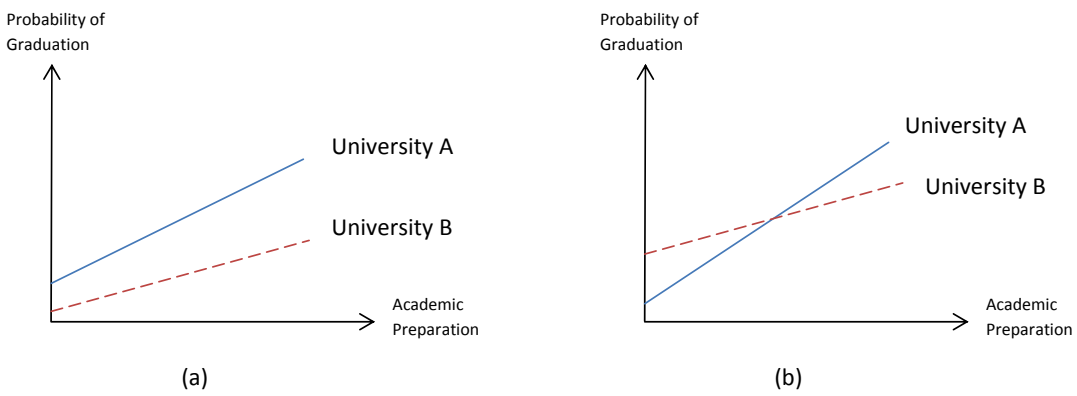

Figure 1: Panel (a) shows graduation rates in the humanities, where university A has an absolute advantage in graduating students. Panel (b) shows graduation rates in the sciences, where university B is better at graduating less-prepared students with university A better at graduating the most-prepared students.

graduates of the various campuses within the University of California (UC) system, we estimate campus-specific graduation "production functions" for different fields. Some colleges may be better at graduating students in particular fields regardless of the student's academic background. Alternatively, some colleges may be better at graduating students with strong academic backgrounds and other colleges may be better at graduating students with weaker academic background. This too may vary by major.

We illustrate potential patterns for the heterogeneity in the production functions in Figure 1. Panel (a) shows an example where the college A has higher graduation rates for all individuals in the humanities relative to college B, though a comparative advantage in graduating students with stronger academic backgrounds. Panel (b) shows that college A also is better at graduating high academic background students in the sciences, but now college B has higher graduation rates for those with less preparation. Our models then allow for the returns to academic background to vary by college and major.

The data reveal substantial sorting across majors between freshmen and senior year. Those with SAT scores that are high relative to the school average are more likely to persist in the sciences. This is especially true for minority students. For example, at UC Berkeley minorities who persisted in the sciences had SAT scores over 100 points higher than those who switched to a major outside of the sciences. For majority students the gap was only 30 points. These differences are also reflected in persistence to graduation. At UC Berkeley, minorities students had less than a 31% probability of persisting to graduation in the sciences in five years under the affirmative action regime, with the corresponding four year graduation

rate of 11%.

Estimates of our graduation model reveal that large differences in relative preparation matter for persistence in STEM fields. We find that minority students who begin in the sciences at Berkeley would graduate in the sciences at a much higher rate had they attended a lower tier school such as UC Santa Cruz or UC Riverside. This is particularly true for minority students at Berkeley who are in the bottom quartile of the SAT score distribution of UC applicants as their five-year graduation probabilities in the sciences would be almost twice as high at UC Santa Cruz or UC Riverside.[3] In contrast, majority students at Berkeley generally have higher probabilities of persisting in the sciences at Berkeley than at the bottom two UC schools.

The rest of the paper is organized as follows: section 2 describes the data and presents summary statistics. Section 3 presents the econometric model. Section 4 presents the results of campus graduation production functions in different fields. Section 5 present counterfactual simulations. Section 6 concludes.

2 Data

2.1 Overview

The data we use were obtained from the University of California Office of the President (UCOP) under a California Public Records Act request. These data contain information on applicants, enrollees and graduates of the UC system. Due to confidentiality concerns, some individual-level information was suppressed. In particular, the UCOP data have the following limitations:[4]

1. The data are aggregated into three year intervals from 1995-2006.

2. The data provide no information on gender, and race is aggregated into four categories: white, Asian, minority, and other

3. Academic data, such as SAT scores and high school grade point average (GPA), were only provided as categorical variables, rather than the actual scores and GPAs.

Weighed against these limitations is having access to the universe of students who applied to school in the UC system and also whether they were accepted or rejected at every UC

[3]The fraction of minority students in the bottom quartile of the applicant distribution was 34% for the years 1995-1997, the period of our study.

[4]See Antonovics and Sander (2012) for a more detailed discussion of this data set.

school where they submitted an application. Proposition 209, which banned the use of racial preferences in admissions, went into effect in 1998. Hence, we have three years of data before Proposition 209 and nine years after.

We begin by examining differences in graduation rates and SAT scores by school for both majority and minority students during the period where race-conscious admissions were legal. The first set of rows of Table 1 gives SAT scores by school and race. For majority students, there is clear sorting among the top three schools: Berkeley, UCLA, and San Diego, in that order. The next set of four schools (Davis, Irvine, Santa Barbara, and Santa Cruz) have somewhat similar average SAT scores, with Riverside just a bit lower than these five. For minority students, average SAT scores display the same patterns across schools, though the relationship is flatter here than for majority students, with the gap between Berkeley minority students and Riverside minority students at 178 points, as opposed to 234 points for majority students. SAT scores for minority students are substantially lower than their white counterparts at each school, with average minority SAT scores at each school all being lower than the average SAT score for a majority student at Santa Cruz.

Differences in academic preparation translate to differences in graduation rates, with the gaps being particularly large at the top schools. Majority students at Berkeley have five-year graduation rates that are almost 18 percentage points higher than minority students at Berkeley, while the gap at Riverside is less than 3 percentage points. Four year graduation rates are even starker, with almost 56% of majority students at Berkeley graduating in four years and the corresponding number for minorities being less than 35%. Gaps also exist across schools, with top schools having both students with stronger academic preparation and higher graduation rates.

Despite significant differences in SAT scores between majority and minority groups, there is a U-shaped pattern between average SAT scores and share minority. The three most diverse universities are Berkeley, UCLA, and Riverside. A similar U-shaped pattern was found in national data in Arcidiacono, Khan, and Vigdor (2011), suggesting diversity at the top schools comes at the expense of diversity of the middle tier institutions.

2.2 Persistence in the Sciences

Differences in the persistence rates in science majors and the characteristics of those who persist are also large. Table 2 shows average SAT scores and the share of individuals completing a science or non-science major in 5 years by race and initial major. Significant sorting occurs at each school, with those who finish in the sciences having higher average

Table 1: 1995-1997 Average SAT Scores and Graduation Rates by Majority-Minority Status

	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside	Overall
Majority SAT	1335	1279	1245	1182	1136	1156	1164	1100	1211
Minority SAT	1142	1119	1121	1071	1025	1023	1019	965	1074
Majority-Minority SAT	193	161	124	111	111	133	145	135	136
Majority 5 Year Grad. rate	85.9%	83.3%	80.4%	76.1%	68.3%	72.5%	67.7%	63.0%	76.1%
Minority 5 Year Grad. rate	68.4%	66.0%	66.4%	54.8%	63.2%	60.0%	60.9%	59.2%	63.0%
Majority-Minority 5 Year Grad. rate	17.6%	17.2%	14.0%	21.3%	5.1%	12.5%	6.7%	3.8%	13.1%
Majority 4 Year Grad. rate	56.1%	48.2%	49.5%	37.2%	32.7%	44.5%	45.9%	38.9%	44.5%
Minority 4 Year Grad. rate	32.5%	26.1%	32.2%	20.1%	24.9%	27.8%	38.4%	29.3%	28.4%
Majority-Minority 4 Year Grad. rate	23.5%	22.1%	17.3%	17.1%	7.9%	16.8%	7.5%	9.5%	16.0%
Minority Share	22.1%	25.3%	12.6%	14.8%	13.2%	18.2%	17.7%	25.3%	18.5%

SAT scores than those who do not, regardless of initial major. While within each school SAT scores for majority students who persist in the sciences are between 16 to 41 points higher than those who switch to a non-science major, the differences are much larger for minority students. Within each school, minority students who persist in the sciences have SAT scores between 51 and 105 points higher than those who switch to a non-science major.

The much larger differences in average SAT scores for minority students are indicative of substantial differences in the probability of persisting in the sciences. Majority students whose initial major is in the sciences finish in the sciences over 60% of the time at Berkeley. In contrast, minority students at Berkeley who initial major is in the sciences finish in the sciences only 30.5% of the time. The majority-minority gap in persistence rates shrinks as the university becomes less selective. Switching into the sciences is also much less likely among minority students, with gaps again largest at the top schools. While 14.2% of majority students in the non-sciences switch into the sciences, only 3% of minority students do so.

The low persistence rates in the sciences also translate into higher rates of not finishing for those who initial major is in the sciences. With the exception of Berkeley, majority students whose initial major is in the sciences are less likely to finish in any major than those who majors are not in the sciences, despite higher SAT scores for those who start out in the sciences. The gaps are again much larger for minority students, with those whose initial major is in the sciences being between 5 and 15 percentage points less likely to finish in any major in five years, again despite higher SAT scores.

Table 2 showed that persistence rates in the sciences were higher at the top schools but that these schools also had higher average SAT scores. Similarly, persistence rates were higher for majority students than minority students, but this too may be driven by differences in average SAT scores. We now take a first step towards separating out whether higher persistence rates at top schools are due to better students or due to something top schools are doing differently than the the less-selective schools by breaking out persistence rates by quartiles of the SAT score distribution.

We define the quartiles of the SAT score distribution based on all applicants to the UC system between 1995 and 1997 regardless of whether the applicant attended or even was admitted to a UC school. Table 3 shows the share of minority and majority students in each quartile at each institution. At each of the schools, minority students are disproportionately represented in the bottom quartile. Even at Berkeley, over 34% of minorities are in the bottom quartile of the applicant SAT score distribution. The share of minority students in the bottom quartile at Berkeley is actually higher than the share of majority students in the bottom quartile at all institutions except for UC Riverside. Less than 3% of majority

Table 2: 1995-1997 SAT Scores by School, Majority-Minority Status, Initial and Final (5 Year) Major

Group	Initial Major	Final Major		Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside
Majority	Science	Science	SAT	1359	1299	1266	1220	1171	1193	1172	1177
			share	55.3%	48.1%	50.1%	42.2%	34.1%	32.2%	27.8%	35.1%
		Non-Science	SAT	1331	1285	1241	1184	1136	1163	1164	1134
			share	30.7%	33.1%	27.8%	32.2%	32.1%	35.5%	36.4%	27.5%
		Did Not Finish	SAT	1334	1275	1224	1183	1125	1158	1138	1098
			share	14.0%	18.8%	22.1%	25.7%	33.9%	32.4%	35.8%	37.4%
	Non-Science	Science	SAT	1352	1295	1253	1193	1141	1163	1189	1125
			share	11.6%	9.4%	14.7%	12.8%	6.8%	4.2%	6.3%	9.8%
		Non-Science	SAT	1324	1274	1239	1170	1129	1153	1165	1072
			share	74.3%	75.5%	68.4%	64.8%	63.5%	70.4%	62.5%	53.4%
		Did Not Finish	SAT	1300	1240	1236	1150	1122	1141	1166	1069
			share	14.1%	15.1%	16.9%	22.4%	29.7%	25.5%	31.1%	36.8%
Minority	Science	Science	SAT	1266	1179	1177	1175	1109	1089	1064	1062
			share	24.9%	25.8%	30.7%	22.3%	22.7%	23.8%	18.8%	20.1%
		Non-Science	SAT	1151	1133	1108	1087	1036	1029	1037	991
			share	39.8%	35.1%	34.4%	29.4%	38.0%	33.7%	34.5%	34.6%
		Did Not Finish	SAT	1155	1108	1095	1077	1038	1022	1012	982
			share	35.4%	39.1%	34.9%	48.3%	39.3%	42.5%	46.7%	45.3%
	Non-Science	Science	SAT	1185	1179	1169	1122	1060	1137	1037	989
			share	3.2%	3.4%	5.4%	5.9%	3.5%	1.4%	3.8%	3.7%
		Non-Science	SAT	1129	1118	1127	1059	998	1025	1024	949
			share	66.8%	65.4%	62.4%	51.5%	61.8%	59.6%	59.9%	57.4%
		Did Not Finish	SAT	1112	1085	1090	1021	998	1001	998	945
			share	30.0%	31.2%	32.2%	42.6%	34.7%	39.0%	36.2%	38.9%

Table 3: Share of Majority and Minority Students in each Quartile of the 1995-1997 Applicant SAT Score Distribution by Institution

		Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside
Majority	Q1	2.8%	5.0%	7.5%	19.1%	30.5%	24.4%	25.1%	44.1%
	Q2	11.4%	20.6%	32.0%	40.2%	43.9%	45.2%	39.5%	34.1%
	Q3	21.4%	35.7%	33.8%	26.4%	17.3%	20.6%	22.3%	11.9%
	Q4	64.3%	38.7%	26.8%	14.2%	8.4%	9.8%	13.2%	9.9%
Minority	Q1	34.5%	37.1%	35.7%	51.5%	65.2%	62.4%	62.5%	77.8%
	Q2	32.3%	40.4%	41.7%	31.1%	23.6%	28.2%	22.9%	18.3%
	Q3	20.6%	16.3%	15.0%	10.8%	7.9%	6.6%	9.8%	2.9%
	Q4	12.7%	6.2%	7.6%	6.6%	3.4%	2.8%	4.9%	1.0%

students at Berkeley were in the bottom quartile with over 64% in the top quartile. As we move down school selectivity, the share of both minority and majority students in the bottom quartile rises, topping out at 78% for minority students and 44% for majority students at UC Riverside.

Given the shares of majority and minority students in each SAT quartile, we now turn to persistence rates conditional on institution and SAT quartile. Table 4 gives the results for minority students with the corresponding results for majority students in the Appendix. Table 4 presents evidence that minority students with low SAT scores would be more likely to persist in the sciences if they attended a less-selective institution. Minority students in the bottom quartile of the SAT score distribution who attended Berkeley graduated in the sciences at a lower rate that similar students at Riverside, despite those in the bottom quartile at Berkeley likely being stronger in other dimensions (high school grades, parental education, etc.) than those in the bottom quartile at Riverside.[5] Note that the total graduation rate for initial science majors in the bottom quartile is actually higher at Berkeley and Riverside. The primary difference is that at Berkeley many of the students switch to non-science majors. Indeed, initial science majors in the bottom quartile at Berkeley are close to four times as likely to graduate in the non-sciences than in the sciences.

The results are different for minorities in the top quartiles, with those attending Berkeley graduate at a higher rate in the sciences than those at Riverside. This is suggestive that

[5]One may be concerned that the bottom quartile of the total SAT score distribution would not be well represented at Berkeley. However, minority students at Berkeley are spread fairly evenly across the SAT quartiles.

matching may be important–at least in the sciences–, with top schools being particularly advantageous for those at the top of preparation distribution and less selective schools being more advantageous for those further down the preparation distribution. But beyond differences across schools, the reality is that those in the bottom quartiles of the SAT score distribution have very low persistence rates in the sciences.

Table 4 also reenforces the point that an initial major in the sciences makes graduation in any field in five years less likely, particularly for minorities in the bottom quartile of the SAT score distribution. Overall, minorities in the bottom quartile with an initial major in science have graduation probabilities that are over eight percentage points lower than their non-science counterparts. The similar gap for those in the top quartile is five and a half percentage points.

As shown in the Appendix, the results for majority students are very different. Namely, at all quartiles of the SAT score distribution majority students are on average more likely to graduate in the sciences at Berkeley than at Riverside, and are significantly more likely to graduate overall at Berkeley than at Riverside. While there are no controls for selection and Berkeley students are likely to be stronger than Riverside students along a number of dimensions, the results for majority and minority students as a whole suggest mismatch is likely to be a much bigger issue for the latter, precisely because of affirmative action policies.

The patterns of persistence in the science and probabilities of graduating in any field are even more striking if we instead examine four year graduation rates. Table 5 repeats the analysis of Table 4, but this time examines four year graduation rates. The probability that a minority in the bottom quartile of the SAT score distribution who is initially interested in the sciences graduates in the sciences in four years at Berkeley is astonishingly low at 3.1%– less than a third of the similar four-year rate for Riverside. This again occurs despite those Berkeley having stronger academic preparation on other dimensions. In general, those at the bottom of the SAT score distribution see significantly higher four-year graduation rates in the sciences at lower tier institutions while there is little relationship between four-year graduation rates and the selectivity of the institution for those at the top of the SAT score distribution.

3 Model and Estimation

We now turn to the modeling of college graduation in particular fields, treating finishing in a particular time period in a particular major as a choice. The individual can choose to major and graduate in a science field, m, or in a non-science field j. The individual can also

Table 4: Minority 5 Year Graduation Rates by School, SAT Quartile, and Initial Major

Initial Major	SAT Quartile	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside	Overall
		Probability of Graduation in Science								
Science	Q1	10.3%	15.5%	19.7%	13.1%	17.3%	18.3%	16.7%	15.6%	15.9%
	Q2	14.6%	27.4%	32.1%	21.9%	26.6%	27.4%	21.7%	28.9%	25.2%
	Q3	37.6%	34.8%	36.6%	39.8%	28.8%	41.3%	17.9%	27.8%	35.4%
	Q4	45.5%	40.0%	57.4%	42.4%	50.0%	40.0%	29.4%	50.0%	44.9%
Non-Science	Q1	2.6%	2.0%	3.0%	3.9%	3.3%	0.6%	4.0%	3.5%	2.6%
	Q2	2.3%	3.5%	6.6%	5.9%	2.4%	2.0%	1.9%	4.7%	3.4%
	Q3	3.5%	4.8%	5.0%	13.7%	8.1%	5.3%	6.0%	6.3%	5.4%
	Q4	7.6%	9.0%	11.4%	15.0%	10.0%	5.4%	6.7%	0.0%	8.7%
		Probability of Graduation in Non-Science								
Science	Q1	47.1%	35.3%	37.2%	30.8%	42.8%	35.3%	32.7%	35.7%	36.9%
	Q2	49.8%	35.4%	34.4%	32.9%	33.6%	34.1%	40.0%	32.5%	36.7%
	Q3	31.8%	34.8%	34.1%	21.6%	28.8%	21.7%	32.1%	33.3%	30.7%
	Q4	23.1%	33.3%	23.4%	20.3%	25.0%	33.3%	35.3%	25.0%	25.8%
Non-Science	Q1	65.5%	60.5%	55.1%	47.9%	62.1%	58.0%	58.2%	58.0%	58.6%
	Q2	66.3%	68.3%	65.2%	57.6%	58.5%	62.4%	63.0%	53.9%	64.2%
	Q3	70.0%	69.6%	73.8%	56.2%	67.6%	60.0%	58.2%	56.3%	67.1%
	Q4	67.5%	67.0%	60.0%	50.0%	70.0%	70.3%	73.3%	75.0%	65.9%
		Probability of Graduation Total								
Science	Q1	57.5%	50.8%	56.9%	43.9%	60.1%	53.6%	49.4%	51.2%	52.8%
	Q2	64.4%	62.8%	66.5%	54.8%	60.1%	61.6%	61.7%	61.4%	61.9%
	Q3	69.4%	69.5%	70.7%	61.4%	57.7%	63.0%	50.0%	61.1%	66.1%
	Q4	68.7%	73.3%	80.9%	62.7%	75.0%	73.3%	64.7%	75.0%	70.8%
Non-Science	Q1	49.7%	37.2%	40.3%	34.7%	46.1%	35.8%	36.7%	39.2%	39.5%
	Q2	52.1%	38.9%	41.0%	38.8%	36.0%	36.1%	41.9%	37.2%	40.1%
	Q3	35.4%	39.6%	39.1%	35.3%	37.0%	27.1%	38.1%	39.6%	36.1%
	Q4	30.8%	42.3%	34.8%	35.3%	35.0%	38.7%	42.0%	25.0%	34.6%

Table 5: Minority 4 Year Graduation Rates by School, SAT Quartile, and Initial Major

Initial Major	SAT Quartile	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside	Overall
		Probability of Graduation in Science								
Science	Q1	0.6%	2.2%	5.9%	1.4%	4.9%	6.1%	7.7%	8.2%	4.5%
	Q2	5.5%	6.5%	14.7%	5.3%	8.4%	12.8%	11.7%	16.9%	9.0%
	Q3	19.7%	12.3%	18.3%	19.3%	15.4%	21.7%	14.3%	22.2%	17.0%
	Q4	23.1%	20.0%	23.4%	25.4%	28.6%	26.7%	29.4%	50.0%	24.3%
Non-Science	Q1	0.2%	0.3%	1.5%	0.6%	0.0%	0.0%	2.2%	1.7%	0.7%
	Q2	0.8%	0.5%	2.2%	1.7%	0.8%	0.6%	0.6%	1.6%	0.9%
	Q3	1.6%	1.5%	2.5%	2.7%	5.4%	1.3%	1.5%	0.0%	1.8%
	Q4	4.5%	4.0%	11.4%	12.5%	10.0%	5.4%	6.7%	0.0%	6.1%
		Probability of Graduation in Non-Science								
Science	Q1	14.4%	6.5%	13.8%	7.6%	11.8%	12.2%	16.7%	12.7%	11.3%
	Q2	22.4%	11.6%	16.1%	13.2%	9.1%	14.0%	16.7%	16.9%	14.6%
	Q3	12.7%	13.4%	17.1%	10.2%	9.6%	13.0%	10.7%	22.2%	13.1%
	Q4	9.7%	17.3%	12.8%	6.8%	7.1%	26.7%	23.5%	25.0%	12.5%
Non-Science	Q1	27.2%	22.6%	21.7%	16.6%	28.1%	27.2%	36.9%	28.5%	26.3%
	Q2	34.1%	33.2%	38.8%	25.6%	30.9%	32.3%	46.3%	30.5%	33.6%
	Q3	43.5%	35.9%	46.3%	28.8%	37.8%	34.7%	43.3%	37.5%	39.3%
	Q4	41.4%	38.0%	40.0%	30.0%	50.0%	29.7%	56.7%	25.0%	39.5%
		Probability of Graduation Total								
Science	Q1	14.9%	8.7%	19.7%	9.0%	16.7%	18.3%	24.4%	20.9%	15.7%
	Q2	27.9%	18.1%	30.8%	18.4%	17.5%	26.8%	28.3%	33.7%	23.6%
	Q3	32.5%	25.7%	35.4%	29.5%	25.0%	34.8%	25.0%	44.4%	30.1%
	Q4	32.8%	37.3%	36.2%	32.2%	35.7%	53.3%	52.9%	75.0%	36.8%
Non-Science	Q1	14.5%	6.8%	15.3%	8.2%	11.8%	12.2%	18.9%	14.4%	12.0%
	Q2	23.1%	12.2%	18.3%	14.8%	9.9%	14.6%	17.3%	18.4%	15.5%
	Q3	14.3%	14.9%	19.6%	13.0%	15.0%	14.4%	12.2%	22.2%	14.9%
	Q4	14.2%	21.3%	24.2%	19.3%	17.1%	32.1%	30.2%	25.0%	18.6%

choose to drop out, n. The individual's decision is given by d_i, $d_i \in \{m, h, n\}$.

We assume that the various abilities of the student can be characterized by a set of characteristics X_i. These characteristics are then rewarded in majors differently. The academic index for major $j \in \{m.h\}$, AI_j, is then given by:

$$AI_{ij} = X_i \beta_j \tag{1}$$

where β_j allows for the weights on the various abilities to vary by major.

The payoff an individual receives from majoring in j at school k is a function of the academic indexes as well as whether the student was initially interested in the major. We specify the utility function for the school choices as:

$$\begin{aligned} U_{ijk} &= u_{ijk} + \epsilon_{ijk} \\ &= \alpha_{0jk} + AI_{ij}\alpha_{1jk} + C_{ijk} + \epsilon_{ijk} \end{aligned} \tag{2}$$

where α_{0jk} represents the baseline payoff majoring in k at school j, α_{1jk} gives how the returns to the academic index in major j vary by school, C_{ijk} represents a switching cost that individuals pay if they are making a major choice that is not the same as the major they entered with, and ϵ_{ijk} is an unobserved preference term.

We specify the cost of switching majors to depend on the major, the individual's academic index, a set of characteristics designed to measure, for example, parental support, Z_i, and allow switching costs to differ by school. C_{ijk} is then specified as:

$$C_{ijk} = \begin{cases} AI_{ij}\alpha_{2j} + Z_i\alpha_3 + \alpha_{4k} & \text{if initial major} \neq j \\ 0 & \text{if initial major} = j \end{cases} \tag{3}$$

Normalizing the utility of not finishing, $d_i = n$, to zero, an individual attending school k then makes his schooling choice according to:

$$d_i = \arg\max_{m,j,n} \{U_{imk}, U_{ihk}, 0\}$$

3.1 Construction of the Academic Index

Selection is a key issue in estimating the effects of college quality on outcomes. We take a Dale and Krueger (2002) approach and construct the academic index to not only depend on observables such as SAT math and verbal scores, but also on where the student applied and where the student was admitted. The full set of characteristics X_i is then a function

of observed academic background variables, B_i, which includes high school GPA, and SAT math and verbal scores, parental background, Z_i, which includes family income and parental education, dummy variables for each of the schools in the UC system where the individual submitted an application where $s_{ij} = 1$ if the individual submitted an application to school j and zero otherwise, and whether the individual was admitted to school j, a_{ij}:

$$X_i = \left[\begin{array}{cccc} B_i & Z_i & S_i & A_i \end{array} \right]$$

where:

$$\begin{aligned} S_i &= \left[\begin{array}{ccc} s_{i1} & \cdots & s_{iJ} \end{array} \right] \\ A_i &= \left[\begin{array}{ccc} a_{i1} & \cdots & a_{iJ} \end{array} \right] \end{aligned}$$

The academic index for individual i in major j, AI_{ij}, is then given by a major-specific weighted average of the characteristics in X_i as in equation (1). In this way, we allow the possibility that characteristics such as SAT math may be more important for science majors than non-science majors.

3.2 Estimation

We specify the error structure such that it has a nested logic form, allowing the errors to be correlated among the two schooling options. The probability of choosing one of the schooling options when X and Z are observed but not ϵ then follows:

$$p_{ijk} = \frac{\left(\sum_{j'} \exp\left(\frac{u_{ij'k}}{\rho}\right)\right)^{\rho-1} \exp\left(\frac{u_{ijk}}{\rho}\right)}{\left(\sum_{j'} \exp\left(\frac{u_{ij'k}}{\rho}\right)\right)^{\rho} + 1} \tag{4}$$

with the corresponding probability of choosing not to graduate given by:

$$p_{i0k} = \frac{1}{\left(\sum_{j'} \exp\left(\frac{u_{ij'k}}{\rho}\right)\right)^{\rho} + 1} \tag{5}$$

We then estimate separate nested logit models for minority and majority students, as well as separate models for four and five year graduation rates.

4 Results

Estimates of the key parameters for 5 year graduation rates are given in Table 6. The first set of rows give some of the parameters governing the academic index for science and non-science majors. There are significant asymmetries across the two majors. SAT math is much more important to the science index, while SAT verbal is more important for the non-sciences. High school gpa is important to both indexes but the coefficient in the science index is close to double that of the coefficient in the non-science index for both majority and minority students.

The next set of columns show the importance of institutional fit. Top schools such as Berkeley and UCLA have lower intercepts and steeper slopes relative to other schools. Hence, they have a comparative advantage in graduating those who have high academic indexes. While the general patterns seem to indicate that the coefficients are the same for minority and majority students, that the production functions are the same for majority and minority students fails a likelihood ratio test.

To understand how the productions vary by institution, we use the model estimates to obtain predicted graduation rates for all those who attended a UC school, obtaining both predicted probabilities at the school they attended as well as at all counterfactual UC schools. Table 7 gives predicted graduation probabilities by initial major and SAT quartile for minorities, effectively allowing us to purge the results of Table 4 of selection effects. Since these are averages of all individuals in each of the SAT quartiles, the other observed characteristics will be representative of those found within the SAT quartile.

Lower SAT scores are associated with switching out of the sciences or not finishing at all schools. However, there is a lot of heterogeneity across schools in persistence rates, particularly for the bottom quartile. Students in the bottom quartile see an average persistence rate in the sciences of 11.1% at Berkeley. The corresponding numbers for the bottom three UC schools are all above 20%. The relationship substantially flattens out at higher SAT quartiles, with Riverside being a bit of an outlier in having very high science graduation rates.

Students in the bottom quartile who are interested in the sciences have much higher probabilities of graduating in the non-sciences at top schools than at the bottom schools. Hence, the overall graduation probability is fairly flat across schools for students whose initial major is science. To sum up, for those interested in the sciences, the school attended has small effects on graduation probabilities but larger effects on what major the student will graduate with.

Table 6: Nested Logit Coefficients for Choice of Final Major (5 year) for 1995-1997 period

	Majority		Minority		Majority		Minority	
	Science	Non-Science	Science	Non-Science	Science	Non-Science	Science	Non-Science
	Intercept Coefficients (relative to Berkeley)				Slope Coefficients (Berkeley norm. to 1)			
UCLA	-0.174	-1.657***	0.818	-1.440**	0.591***	0.833***	0.561***	0.807***
	(0.728)	(0.361)	(1.672)	(0.685)	(0.044)	(0.067)	(0.081)	(0.105)
San Diego	2.369***	-0.299	3.958***	-0.492	0.466***	0.626***	0.434***	0.687***
	(0.595)	(0.327)	(1.641)	(0.742)	(0.033)	(0.055)	(0.074)	(0.124)
Davis	2.006***	-0.506*	2.193*	-0.422	0.461***	0.611***	0.506***	0.610***
	(0.587)	(0.305)	(1.616)	(0.630)	(0.032)	(0.052)	(0.075)	(0.103)
Irvine	1.902***	-0.313	4.129***	0.412	0.476***	0.615***	0.410***	0.560***
	(0.607)	(0.311)	(1.870)	(0.669)	(0.034)	(0.056)	(0.079)	(0.111)
Santa Barbara	3.517***	0.188	4.632***	0.557	0.384***	0.576***	0.404***	0.535***
	(0.609)	(0.317)	(1.603)	(0.559)	(0.032)	(0.052)	(0.069)	(0.086)
Santa Cruz	5.079***	1.047***	7.257***	1.453**	0.280***	0.419***	0.289***	0.476***
	(0.671)	(0.380)	(1.741)	(0.768)	(0.034)	(0.053)	(0.062)	(0.096)
Riverside	3.584***	0.139	5.143***	0.830*	0.398***	0.576***	0.400***	0.525***
	(0.627)	(0.340)	(1.772)	(0.626)	(0.034)	(0.061)	(0.073)	(0.102)
	Index Coefficients							
	Majority				Minority			
	Science		Non-Science		Science		Non-Science	
HS GPA	1.317***		0.618***		1.406***		0.647***	
	(0.104)		(0.082)		(0.305)		(0.193)	
SAT Math	5.475***		-0.765***		7.405***		-0.466*	
	(0.371)		(0.158)		(1.040)		(0.329)	
SAT Verbal	-0.151		1.405***		1.663**		1.895***	
	(0.224)		(0.186)		(0.973)		(0.598)	
	Nesting parameter							
ρ	0.593***				0.612***			
	(0.052)				(0.160)			

For non-science majors, overall graduation rates are higher, particularly for those in the bottom quartile. Initial non-science majors in the bottom quartile have graduation probabilities that are seven percentage points higher than their science counterparts with little variation across college selectivity. The similar gap for the top quartile is around four percentage points.

As with the descriptive statistics, results are starker for four year graduation rates which are displayed in Table 8. Bottom quartile students interested in the sciences would only have a 2.1% chance of graduating in four years at Berkeley, with the corresponding number at Riverside at 13.3%. The non-science four year graduation rates for those who begin in the sciences are fairly stable across institutions. This is in contrast to five year graduation rates where the top schools were particularly good at graduating initial science students in non-science fields. The overall impact on graduation rates results in much higher four year graduation rates at lower tier schools for those who begin in the sciences. Four year graduation rates are also lower at the top schools in the non-sciences as well, though the results are not as strong as for sciences.

The message of the two tables is then that the school attended affects one's probability of finishing in the sciences as well as finishing in four years, particularly for those with lower SAT scores. Weighed against this are benefits not measured in this paper, such as that a degree from a top school may be more valuable than a degree from a school lower down.

5 Counterfactual Assignments

With the parameter estimates in hand, we now consider how graduation probabilities would change if students at Berkeley were given, for example, the production function at Riverside.We consider three cases:

1. the probability of graduating in the sciences conditional on an initial major in the sciences,

2. the probability of graduating in any field conditional on an initial major in the sciences,

3. the probability of graduating in any field conditional on an initial major not in the sciences.

The last case is almost equivalent to graduating in the non-sciences conditional on not beginning in the sciences as we have seen that switch rates from non-science majors to science majors are rare.

Table 7: Predicted Minority 5 Year Graduation Rates by School, SAT Quartile, and Initial Major

		Berkeley	UCLA	San Diego	Davis	Irvine	UCSB	Santa Cruz	Riverside
		Probability of Graduation in Science							
Science	Q1	9.3%	13.5%	17.6%	13.8%	15.3%	19.8%	19.0%	18.4%
	Q2	19.6%	24.6%	28.5%	25.3%	26.8%	32.9%	27.5%	30.7%
	Q3	28.9%	33.6%	36.5%	34.6%	35.7%	42.2%	33.6%	39.6%
	Q4	40.3%	43.9%	45.5%	45.2%	45.8%	52.2%	40.4%	49.3%
Non-Science	Q1	1.1%	1.6%	3.0%	3.3%	2.5%	1.2%	3.7%	3.7%
	Q2	2.7%	3.2%	5.4%	6.7%	4.9%	2.4%	5.4%	7.2%
	Q3	4.6%	4.9%	7.7%	10.4%	7.4%	3.9%	6.9%	11.0%
	Q4	7.2%	7.1%	10.5%	15.0%	10.5%	5.7%	8.5%	15.4%
		Probability of Graduation in Non-Science							
Science	Q1	45.0%	38.0%	35.0%	35.4%	40.6%	33.0%	37.4%	36.8%
	Q2	43.0%	35.8%	31.4%	32.6%	36.8%	27.6%	35.4%	31.1%
	Q3	38.9%	32.5%	28.0%	28.9%	32.7%	23.2%	33.4%	26.5%
	Q4	32.4%	27.5%	23.5%	23.7%	27.1%	18.0%	30.4%	20.9%
Non-Science	Q1	60.0%	56.4%	56.6%	51.6%	60.0%	60.2%	59.7%	58.5%
	Q2	66.8%	63.9%	61.4%	57.2%	65.2%	66.0%	64.4%	61.3%
	Q3	69.9%	67.8%	63.6%	59.2%	67.3%	69.0%	67.0%	61.5%
	Q4	70.4%	69.1%	63.6%	58.2%	67.0%	69.9%	67.8%	59.7%
		Probability of Graduation Total							
Science	Q1	54.4%	51.4%	52.6%	49.2%	55.9%	52.8%	56.4%	55.1%
	Q2	62.6%	60.4%	59.9%	57.9%	63.6%	60.5%	62.9%	61.8%
	Q3	67.8%	66.0%	64.5%	63.5%	68.4%	65.4%	67.0%	66.1%
	Q4	72.7%	71.4%	69.0%	68.9%	72.9%	70.1%	70.8%	70.2%
Non-Science	Q1	46.2%	39.6%	38.1%	38.7%	43.2%	34.2%	41.2%	40.4%
	Q2	45.6%	39.0%	36.8%	39.3%	41.7%	30.0%	40.8%	38.3%
	Q3	43.5%	37.4%	35.7%	39.3%	40.1%	27.1%	40.2%	37.4%
	Q4	39.7%	34.6%	34.1%	38.7%	37.6%	23.7%	38.9%	36.3%

Table 8: Predicted Minority 4 Year Graduation Rates by School, SAT Quartile, and Initial Major

		Berkeley	UCLA	San Diego	Davis	Irvine	UCSB	Santa Cruz	Riverside
		Probability of Graduation in Science							
Science	Q1	1.3%	1.6%	4.9%	2.8%	3.9%	6.5%	11.2%	8.9%
	Q2	5.5%	5.6%	11.9%	8.4%	9.5%	14.8%	19.2%	19.2%
	Q3	12.3%	11.4%	19.5%	15.7%	15.8%	23.2%	25.9%	29.1%
	Q4	24.6%	21.4%	29.9%	27.0%	24.9%	34.2%	33.9%	41.2%
Non-Science	Q1	0.1%	0.1%	0.7%	0.4%	0.3%	0.6%	1.5%	1.4%
	Q2	0.6%	0.5%	2.2%	1.7%	0.8%	1.7%	3.1%	4.0%
	Q3	1.6%	1.2%	4.2%	3.9%	1.6%	3.3%	4.7%	7.4%
	Q4	4.2%	2.6%	7.5%	8.1%	2.9%	5.9%	6.9%	12.6%
		Probability of Graduation in Non-Science							
Science	Q1	12.6%	8.0%	11.6%	9.5%	10.9%	10.7%	18.9%	15.7%
	Q2	15.7%	11.1%	14.3%	11.3%	12.9%	11.7%	20.5%	16.5%
	Q3	16.2%	12.4%	15.0%	11.5%	13.3%	11.3%	20.6%	15.5%
	Q4	14.7%	12.6%	14.6%	10.5%	12.9%	10.2%	19.9%	13.5%
Non-Science	Q1	24.9%	18.4%	22.9%	17.8%	27.5%	27.6%	39.8%	31.5%
	Q2	34.1%	28.6%	32.2%	24.9%	36.3%	35.7%	47.6%	39.0%
	Q3	40.0%	36.1%	38.2%	29.3%	42.1%	40.6%	51.9%	42.6%
	Q4	43.2%	41.3%	41.3%	31.1%	45.7%	43.1%	54.1%	43.1%
		Probability of Graduation Total							
Science	Q1	14.0%	9.6%	16.6%	12.2%	14.8%	17.2%	30.1%	24.6%
	Q2	21.2%	16.7%	26.2%	19.7%	22.4%	26.4%	39.7%	35.7%
	Q3	28.5%	23.8%	34.5%	27.2%	29.1%	34.5%	46.5%	44.6%
	Q4	39.2%	34.0%	44.6%	37.5%	37.7%	44.4%	53.7%	54.6%
Non-Science	Q1	12.7%	8.1%	12.4%	9.9%	11.2%	11.2%	20.4%	17.2%
	Q2	16.3%	11.5%	16.5%	13.0%	13.7%	13.3%	23.6%	20.5%
	Q3	17.8%	13.5%	19.2%	15.4%	14.9%	14.6%	25.3%	23.0%
	Q4	18.9%	15.2%	22.1%	18.7%	15.7%	16.1%	26.7%	26.1%

Table 9 gives the share of majority students at school A who would see higher probabilities of graduating at school B. A number of patterns stand out. First, UC San Diego and UC Davis are particularly good at graduating students in the sciences. Among the top five schools, virtually everyone would have the higher probability of graduating at UC San Diego than their own school, with UC Davis seeing the next highest probabilities. However the results change as we move to the bottom three schools where a substantial fraction of majority students at these schools see higher probabilities of graduating in the sciences. This is due to the production technology being different at these bottom schools as these schools are particularly beneficial to those with lower levels of academic preparation.

Particularly interesting are the cross-school comparisons: how UC Berkeley students would do at UC Riverside and how UC Riverside students would do at Berkeley. While there is overlap in the academic preparation distribution between UC Berkeley and UC Riverside, students at UC Riverside are generally less prepared. While 34% of majority students at Berkeley would have a higher probability of graduating in the sciences at Riverside, only 12% of majority students would have a higher probability of graduating in the sciences at Berkeley. This suggests that the differing production technologies at the different schools serve their current students well: on average, majority students at Riverside are well-placed at Riverside and majority students at Berkeley are well-placed at Berkeley.

Lower-ranked schools look less attractive wen we move to overall graduation probabilities, particularly for majority students who begin in the non-sciences. While matching issues are still present here as not everyone would be best placed at the top schools, the bottom panel suggests that non-science majors often would see higher probabilities of graduating at the top schools. Berkeley in particular is outstanding at graduating students outside of science.

The overall message of Table 9 is that matching is particularly important in the sciences, but in the non-sciences going to a more-selective school may increase graduation probabilities. As shown in Table 10, the results for minority students are very different due to the combination of differences in academic preparation and affirmative action.

Table 10 shows that almost all minorities would have higher probabilities of graduating in the sciences if they moved to a less selective institution: the numbers on the lower diagonal are generally very small with large numbers on the upper diagonal. This suggests affirmative action may come at the expense of having a strong minority representation in science fields. The one exception is again UC San Diego where relatively strong minority students would have a higher probability of graduating in the sciences.

Total graduation rates tell a different story. While a significant fraction minority students at the top schools would see higher graduation probabilities at the bottom schools, some

Table 9: Share of majority students who would increase their graduation probability by changing schools

	Counterfactual School							
Initial School	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside
	Science conditional on initial major science							
Berkeley	–	45%	100%	98%	32%	42%	9%	34%
UCLA	46%	–	100%	99%	52%	66%	14%	56%
San Diego	0%	0%	–	0%	0%	4%	2%	9%
Davis	0%	0%	100%	–	1%	45%	17%	46%
Irvine	10%	18%	100%	99%	–	99%	48%	91%
Santa Barbara	3%	2%	63%	22%	0%	–	27%	83%
Santa Cruz	11%	14%	55%	36%	26%	59%	–	84%
Riverside	12%	14%	55%	33%	11%	35%	18%	–
	Total conditional on initial major science							
Berkeley	–	0%	9%	11%	1%	3%	1%	1%
UCLA	100%	–	61%	59%	11%	15%	5%	5%
San Diego	84%	27%	–	66%	0%	5%	3%	1%
Davis	59%	13%	24%	–	0%	7%	4%	2%
Irvine	83%	31%	98%	100%	–	93%	35%	27%
Santa Barbara	60%	29%	56%	76%	11%	–	12%	0%
Santa Cruz	57%	32%	56%	72%	42%	80%	–	20%
Riverside	65%	41%	70%	83%	60%	99%	62%	–
	Total conditional on initial major non-science							
Berkeley	–	0%	0%	0%	0%	2%	0%	0%
UCLA	100%	–	15%	19%	11%	19%	6%	3%
San Diego	100%	84%	–	82%	5%	44%	3%	1%
Davis	99%	53%	6%	–	2%	67%	5%	1%
Irvine	100%	38%	54%	92%	–	100%	20%	2%
Santa Barbara	84%	35%	13%	16%	0%	–	0%	0%
Santa Cruz	97%	57%	75%	87%	86%	100%	–	0%
Riverside	95%	48%	78%	91%	93%	100%	100%	–

students at the bottom schools would have a higher probability of graduating at the top schools. Hence, the issue of mismatch is much more important for representation in the sciences (and also time to graduation) than for overall graduation rates. UC San Diego and UC Davis do particularly poorly for total minority graduation rates: moving these students to either more selective or less selective schools may increase their overall probability of graduating but may do so at the expense of lowering their probability of graduating in the sciences.

To get a better sense of which students would see higher graduation rates from moving schools, Table 11 shows how five-year graduation outcomes would change if students at the three most selective schools (Berkeley, UCLA, and UC San Diego) were reallocated to the two least selective schools (UC Santa Cruz and UC Riverside). Results are reported by quartiles of the applicant SAT score distribution and focus on the same outcomes as in Tables 9 and 10.

The first three panels of Table 11 give the results for majority students. Majority students in the bottom quartile at UC Berkeley or UCLA would see a higher probability of graduating the sciences had they instead attended UC Santa Cruz or UC Riverside. Note that very majority students are in the bottom quartile of the total SAT score distribution at these schools. As we move to higher SAT scores, the results flip or diminish: the gains to moving down are either reversed or smaller for those with higher SAT scores. Majority students at UC San Diego have higher average graduation probabilities in the sciences in each quartile by staying at UC San Diego than switching to UC Santa Cruz or Riverside, again reflective of UC San Diego's emphasis on the sciences. Regardless of initial major, the total probability of graduating for majority students is higher at the three most selective schools, possibly reflecting school quality effects dominating matching effects in the non-sciences.

As shown in the second panel of Table 11, the results are strikingly different for minority students. Note that within an institution minority students are likely to be weaker in terms of academic preparation even conditional on SAT quartile due to affirmative action. With the exception of switching students from UC San Diego to UC Santa Cruz, minority students in the bottom two quartiles who attended one of the top three schools have significantly higher probabilities of graduating in the sciences had they instead attended UC Santa Cruz or UC Riverside. Recall from Table 3 that the share of minority students in these bottom two quartiles range from a low of 67.1% at Berkeley to a high of 77.5% at UCLA for the top three schools. UC Riverside seems especially good at graduating minority students in the sciences as across all quartiles minority students at top three schools would see a higher probability of graduating in the sciences at UC Riverside. In contrast, UC Santa Cruz tends

Table 10: Share of minority students who would increase their graduation probability by changing schools

	Counterfactual School							
Initial School	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside
Science conditional on initial major science								
Berkeley	–	94%	97%	100%	100%	100%	77%	100%
UCLA	3%	–	95%	70%	100%	100%	73%	100%
San Diego	1%	3%	–	10%	13%	98%	34%	86%
Davis	0%	52%	92%	–	96%	100%	78%	100%
Irvine	0%	0%	92%	2%	–	100%	71%	97%
Santa Barbara	0%	0%	20%	0%	0%	–	51%	1%
Santa Cruz	3%	7%	20%	9%	12%	36%	–	28%
Riverside	0%	1%	44%	0%	2%	98%	63%	–
Total conditional on initial major science								
Berkeley	–	0%	8%	0%	68%	8%	39%	28%
UCLA	100%	–	32%	0%	95%	40%	65%	53%
San Diego	96%	73%	–	33%	100%	93%	100%	100%
Davis	100%	100%	86%	–	100%	96%	95%	94%
Irvine	14%	3%	0%	0%	–	0%	43%	22%
Santa Barbara	80%	32%	36%	4%	100%	–	97%	93%
Santa Cruz	19%	9%	0%	2%	31%	3%	–	0%
Riverside	44%	21%	0%	3%	65%	6%	100%	–
Total conditional on initial major non-science								
Berkeley	–	0%	9%	0%	65%	26%	50%	32%
UCLA	100%	–	36%	0%	90%	60%	68%	54%
San Diego	98%	75%	–	19%	100%	100%	100%	91%
Davis	100%	100%	93%	–	100%	99%	99%	94%
Irvine	18%	2%	0%	0%	–	0%	58%	33%
Santa Barbara	48%	18%	0%	0%	98%	–	97%	68%
Santa Cruz	23%	11%	0%	0%	32%	3%	–	0%
Riverside	36%	14%	0%	1%	48%	24%	100%	–

to be better at graduating students overall. However, mismatch effects are much smaller for total five-year graduation rates than graduation rates in the sciences.

6 Conclusion

Our evidence suggests significant heterogeneity in how schools produce college graduates in science and non-science fields. The most-selective UC schools have a comparative advantage in graduating the most academically-prepared students while less selective schools have a comparative advantage in graduating the least academically-prepared students. Further, some schools, such as UC San Diego and UC Davis, are particularly good at graduating students in sciences but perform poorly when looking at overall graduation rates.

We find evidence that the match between the school and the student is particularly important in the sciences. Our evidence suggests that, in a period when racial preferences in admissions were strong, minority students were in general over-matched, resulting in low graduation rates in the sciences and a decreased probability of graduating in four years. In contrast, majority students are generally well-placed for graduating in the sciences. Policies which lead to a better match between the student and school–at least when the student is interested in the sciences–have the potential to mitigate some of the under-representation of minorities in the sciences.

Table 11: 5 year Graduation Gains or Losses from Moving to Least Selective Colleges from the Most Selective Colleges

	Berkeley Base Rate	Gain from Santa Cruz	Gain from Riverside	UCLA Base Rate	Gain from Santa Cruz	Gain from Riverside	UCSD Base Rate	Gain from Santa Cruz	Gain from Riverside
	Majority Probability of Graduating in Science Conditional on Initial Major Science								
Q1	28.2%	3.2%	9.3%	27.7%	2.0%	7.8%	36.1%	-6.9%	-1.6%
Q2	47.0%	-7.1%	1.9%	42.2%	-5.4%	3.4%	46.7%	-12.3%	-4.4%
Q3	53.9%	-11.9%	-1.0%	48.7%	-9.2%	1.3%	52.0%	-15.1%	-5.9%
Q4	56.5%	-14.0%	-2.0%	52.2%	-11.3%	0.1%	57.3%	-18.0%	-7.4%
	Majority Probability of Graduating Conditional on Initial Major Science								
Q1	72.6%	-4.2%	-4.3%	69.4%	-1.0%	-1.2%	70.5%	-3.2%	-3.5%
Q2	79.9%	-6.8%	-5.9%	77.7%	-4.7%	-3.9%	77.0%	-5.4%	-5.0%
Q3	84.4%	-8.1%	-6.8%	81.8%	-6.3%	-5.2%	79.8%	-6.2%	-5.5%
Q4	86.1%	-8.5%	-7.1%	83.9%	-7.0%	-5.7%	82.4%	-6.8%	-5.7%
	Majority Probability of Graduating Conditional on Initial Major Non-science								
Q1	75.4%	-5.1%	-6.8%	71.9%	-1.1%	-2.9%	76.8%	-2.6%	-4.1%
Q2	82.1%	-6.3%	-7.4%	81.3%	-4.1%	-5.3%	81.6%	-3.6%	-4.8%
Q3	86.6%	-6.8%	-7.5%	86.0%	-5.4%	-6.2%	82.5%	-3.8%	-4.9%
Q4	88.8%	-7.0%	-7.5%	87.6%	-5.8%	-6.4%	83.1%	-3.9%	-4.8%
	Minority Probability of Graduating in Science Conditional on Initial Major Science								
Q1	11.0%	9.3%	10.1%	16.1%	4.9%	5.6%	22.2%	-0.2%	2.0%
Q2	20.8%	7.5%	11.2%	26.8%	2.2%	6.7%	29.6%	-2.2%	3.2%
Q3	33.6%	2.4%	10.6%	35.2%	-0.6%	6.6%	37.3%	-3.3%	3.3%
Q4	42.9%	-0.8%	8.3%	44.5%	-3.9%	5.8%	45.5%	-5.7%	4.4%
	Minority Probability of Graduating Conditional on Initial Major Science								
Q1	58.1%	1.2%	-0.1%	55.3%	3.9%	2.6%	59.4%	3.2%	1.9%
Q2	63.6%	0.1%	-1.0%	63.3%	1.7%	0.6%	63.6%	2.6%	1.6%
Q3	71.1%	-1.6%	-2.3%	68.7%	0.1%	-0.7%	65.4%	2.3%	1.5%
Q4	73.2%	-2.0%	-2.5%	72.7%	-0.9%	-1.5%	70.5%	1.6%	1.1%
	Minority Probability of Graduating Conditional on Initial Major Non-science								
Q1	63.8%	1.7%	0.3%	62.5%	4.1%	2.7%	66.1%	3.1%	1.7%
Q2	70.5%	0.1%	-1.2%	69.4%	2.0%	0.6%	71.2%	2.5%	1.1%
Q3	74.9%	-0.8%	-2.2%	74.9%	0.4%	-1.0%	73.5%	2.2%	0.9%
Q4	77.6%	-1.3%	-2.6%	77.4%	-0.2%	-1.5%	74.1%	2.1%	0.8%

7 Bibliography

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8 Appendix

Table 12: Majority 5 Year Graduation Rates by School, SAT Quartile, and Initial Major

Initial Major	SAT Quartile	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside	Overall
		Probability of Graduation in Science								
Science	Q1	25.0%	28.0%	33.7%	31.2%	25.1%	23.8%	22.3%	23.8%	26.4%
	Q2	42.4%	44.2%	45.9%	40.2%	35.5%	32.2%	28.7%	38.8%	38.7%
	Q3	51.0%	49.4%	51.0%	45.0%	39.6%	36.8%	30.0%	44.8%	46.2%
	Q4	59.1%	50.3%	57.7%	51.8%	43.8%	38.0%	33.3%	44.0%	53.5%
Non-Science	Q1	5.1%	5.3%	13.2%	10.8%	5.5%	3.5%	5.2%	7.7%	6.5%
	Q2	5.0%	6.5%	12.1%	11.2%	7.6%	3.8%	6.4%	10.0%	7.6%
	Q3	12.2%	9.9%	15.2%	14.8%	6.8%	5.0%	5.7%	17.3%	10.5%
	Q4	13.2%	11.3%	18.2%	17.7%	8.2%	5.9%	9.3%	14.2%	12.8%
		Probability of Graduation in Non-Science								
Science	Q1	34.6%	36.4%	31.4%	36.2%	34.3%	37.9%	35.5%	30.3%	34.5%
	Q2	41.6%	33.6%	30.3%	34.5%	32.7%	37.2%	34.4%	23.0%	33.4%
	Q3	36.3%	33.6%	27.4%	32.9%	28.2%	33.3%	39.5%	23.6%	31.9%
	Q4	27.3%	32.2%	24.7%	22.4%	29.7%	29.5%	39.2%	33.9%	28.1%
Non-Science	Q1	63.4%	63.9%	63.2%	59.1%	62.7%	68.2%	60.6%	53.6%	61.8%
	Q2	79.0%	75.9%	72.0%	69.5%	63.8%	71.3%	65.5%	54.6%	69.0%
	Q3	74.6%	77.4%	69.3%	64.3%	62.4%	71.1%	62.5%	49.0%	69.4%
	Q4	73.9%	75.4%	63.5%	59.9%	67.6%	69.9%	56.9%	51.7%	69.9%
		Probability of Graduation Total								
Science	Q1	59.6%	64.5%	65.0%	67.4%	59.4%	61.7%	57.8%	54.1%	60.9%
	Q2	83.9%	77.8%	76.2%	74.8%	68.2%	69.4%	63.1%	61.8%	72.1%
	Q3	87.3%	83.0%	78.4%	77.9%	67.8%	70.1%	69.6%	68.5%	78.0%
	Q4	86.4%	82.5%	82.4%	74.2%	73.4%	67.5%	72.5%	78.0%	81.6%
Non-Science	Q1	39.8%	41.7%	44.5%	47.0%	39.9%	41.4%	40.7%	38.0%	41.1%
	Q2	46.6%	40.1%	42.3%	45.8%	40.3%	41.0%	40.8%	33.0%	41.0%
	Q3	48.5%	43.5%	42.6%	47.7%	35.0%	38.3%	45.3%	41.0%	42.4%
	Q4	40.5%	43.4%	42.9%	40.1%	37.9%	35.3%	48.5%	48.1%	40.9%

Table 13: Majority 4 Year Graduation Rates by School, SAT Quartile, and Initial Major

Initial Major	SAT Quartile	Berkeley	UCLA	San Diego	Davis	Irvine	Santa Barbara	Santa Cruz	Riverside	Overall
		Probability of Graduation in Science								
Science	Q1	9.6%	14.0%	14.5%	9.2%	10.2%	10.3%	10.7%	11.6%	10.8%
	Q2	26.3%	17.9%	26.1%	16.6%	16.2%	16.9%	17.3%	24.6%	19.3%
	Q3	34.4%	24.4%	29.9%	20.5%	21.0%	21.5%	18.6%	30.0%	25.6%
	Q4	42.4%	28.2%	38.9%	27.6%	31.3%	23.7%	22.9%	35.8%	35.3%
Non-Science	Q1	0.6%	0.0%	4.3%	3.6%	2.3%	1.1%	2.6%	2.6%	2.2%
	Q2	2.2%	2.5%	5.7%	4.4%	2.2%	1.5%	3.1%	5.6%	3.1%
	Q3	7.0%	4.9%	8.6%	6.1%	2.7%	2.0%	2.9%	12.4%	5.3%
	Q4	8.2%	6.4%	10.5%	7.8%	4.1%	2.9%	5.2%	12.5%	7.4%
		Probability of Graduation in Non-Science								
Science	Q1	9.6%	11.2%	12.9%	11.6%	14.0%	15.8%	22.0%	16.3%	14.7%
	Q2	21.8%	13.9%	16.9%	15.8%	11.7%	19.5%	19.4%	11.6%	15.7%
	Q3	19.6%	17.2%	15.1%	14.9%	10.2%	18.8%	27.7%	14.3%	16.5%
	Q4	15.0%	16.5%	14.0%	11.5%	16.1%	17.9%	25.5%	28.9%	15.7%
Non-Science	Q1	34.3%	30.1%	38.0%	25.9%	30.8%	44.7%	41.7%	32.2%	35.3%
	Q2	44.1%	44.0%	48.7%	39.3%	34.6%	46.7%	47.8%	36.5%	42.9%
	Q3	49.7%	52.4%	48.5%	38.2%	33.8%	48.0%	45.5%	29.2%	45.8%
	Q4	52.5%	53.6%	41.7%	38.6%	36.1%	47.5%	41.3%	35.8%	48.4%
		Probability of Graduation Total								
Science	Q1	19.2%	25.2%	27.4%	20.7%	24.2%	26.1%	32.7%	27.8%	25.4%
	Q2	48.2%	31.8%	43.0%	32.4%	27.9%	36.4%	36.7%	36.2%	35.0%
	Q3	54.0%	41.6%	45.0%	35.4%	31.2%	40.2%	46.2%	44.3%	42.1%
	Q4	57.4%	44.7%	52.9%	39.1%	47.4%	41.6%	48.4%	64.7%	50.9%
Non-Science	Q1	10.2%	11.2%	17.1%	15.2%	16.3%	16.9%	24.6%	18.8%	16.9%
	Q2	24.1%	16.5%	22.6%	20.1%	13.9%	21.0%	22.5%	17.3%	18.9%
	Q3	26.6%	22.2%	23.8%	21.0%	12.9%	20.8%	30.6%	26.7%	21.8%
	Q4	23.2%	22.9%	24.5%	19.4%	20.2%	20.9%	30.7%	41.4%	23.0%

Table 14: Predicted Majority 5 Year Graduation Rates by School, SAT Quartile, and Initial Major

		Berkeley	UCLA	San Diego	Davis	Irvine	UCSB	Santa Cruz	Riverside
		Probability of Graduation in Science							
Science	Q1	18.0%	20.3%	29.7%	26.3%	24.4%	28.8%	26.7%	30.0%
	Q2	30.6%	32.5%	42.1%	38.5%	35.3%	38.9%	33.0%	39.1%
	Q3	41.1%	42.0%	51.3%	47.6%	43.5%	46.1%	37.1%	45.6%
	Q4	50.9%	50.8%	59.3%	55.8%	50.8%	52.4%	40.5%	51.3%
Non-Science	Q1	2.2%	2.8%	6.5%	6.7%	4.5%	4.1%	7.0%	8.9%
	Q2	3.8%	4.5%	9.7%	10.1%	6.7%	5.7%	8.4%	11.8%
	Q3	6.3%	6.9%	14.1%	14.8%	9.6%	7.8%	10.3%	15.5%
	Q4	10.5%	10.8%	20.6%	21.8%	14.1%	11.0%	12.8%	20.8%
		Probability of Graduation in Non-Science							
Science	Q1	45.5%	38.8%	33.8%	38.2%	37.6%	35.1%	35.7%	31.6%
	Q2	41.1%	36.1%	29.4%	33.6%	34.0%	31.6%	34.7%	28.6%
	Q3	37.2%	34.0%	26.4%	30.3%	31.7%	29.6%	35.1%	27.1%
	Q4	32.5%	31.0%	23.3%	26.8%	29.1%	27.5%	35.2%	25.5%
Non-Science	Q1	70.3%	64.6%	62.3%	62.8%	64.5%	67.5%	61.0%	57.1%
	Q2	74.1%	69.6%	64.8%	64.9%	67.5%	70.4%	63.9%	58.9%
	Q3	76.0%	72.6%	65.1%	64.7%	68.8%	72.0%	65.8%	59.3%
	Q4	75.6%	73.5%	62.9%	61.9%	68.3%	72.2%	66.7%	58.0%
		Probability of Graduation Total							
Science	Q1	63.5%	59.1%	63.5%	64.5%	62.1%	63.9%	62.4%	61.5%
	Q2	71.7%	68.6%	71.6%	72.0%	69.4%	70.5%	67.7%	67.8%
	Q3	78.2%	76.0%	77.7%	77.9%	75.2%	75.7%	72.1%	72.8%
	Q4	83.4%	81.8%	82.6%	82.6%	79.9%	79.9%	75.7%	76.9%
Non-Science	Q1	47.7%	41.5%	40.3%	44.9%	42.1%	39.2%	42.7%	40.4%
	Q2	44.9%	40.6%	39.1%	43.6%	40.7%	37.3%	43.1%	40.4%
	Q3	43.5%	40.9%	40.5%	45.1%	41.4%	37.5%	45.3%	42.7%
	Q4	43.0%	41.9%	43.9%	48.6%	43.2%	38.5%	48.0%	46.3%

Table 15: Predicted majority 4 year graduation rates by school, SAT quartile, and initial major

		Berkeley	UCLA	San Diego	Davis	Irvine	UCSB	Santa Cruz	Riverside
		Probability of Graduation in Science							
Science	Q1	5.8%	5.7%	13.2%	8.8%	9.7%	13.8%	14.4%	15.8%
	Q2	13.3%	12.3%	22.7%	15.9%	17.6%	21.6%	20.4%	24.7%
	Q3	22.3%	20.1%	31.8%	23.3%	25.8%	28.7%	25.4%	32.7%
	Q4	34.1%	30.2%	42.2%	32.2%	35.6%	36.8%	30.9%	41.4%
Non-Science	Q1	0.6%	0.7%	2.6%	1.9%	1.4%	1.6%	3.3%	4.3%
	Q2	1.4%	1.5%	4.5%	3.4%	2.5%	2.5%	4.4%	6.6%
	Q3	3.0%	2.9%	7.5%	5.8%	4.4%	3.8%	6.0%	9.9%
	Q4	6.6%	5.7%	12.9%	10.3%	8.0%	6.0%	8.6%	15.5%
		Probability of Graduation in Non-Science							
Science	Q1	18.2%	12.1%	14.7%	13.6%	13.8%	14.9%	20.4%	18.5%
	Q2	18.9%	14.2%	14.9%	14.4%	14.4%	15.4%	20.6%	18.7%
	Q3	18.8%	15.8%	14.8%	15.0%	14.6%	15.9%	21.1%	18.7%
	Q4	17.1%	16.3%	13.9%	14.8%	14.1%	15.8%	21.3%	18.1%
Non-Science	Q1	38.7%	28.5%	34.4%	28.9%	33.7%	40.5%	41.9%	37.7%
	Q2	44.9%	36.3%	40.0%	34.2%	39.6%	46.4%	45.9%	42.6%
	Q3	49.4%	42.7%	43.7%	38.1%	44.0%	51.0%	48.7%	45.5%
	Q4	52.6%	48.7%	45.7%	40.9%	47.4%	54.9%	51.0%	46.8%
		Probability of Graduation Total							
Science	Q1	24.0%	17.9%	27.9%	22.4%	23.5%	28.7%	34.8%	34.4%
	Q2	32.3%	26.6%	37.5%	30.3%	32.0%	37.0%	41.0%	43.4%
	Q3	41.1%	35.8%	46.6%	38.2%	40.4%	44.6%	46.5%	51.4%
	Q4	51.2%	46.5%	56.1%	47.0%	49.7%	52.6%	52.1%	59.5%
Non-Science	Q1	18.8%	12.9%	17.3%	15.6%	15.2%	16.5%	23.6%	22.8%
	Q2	20.4%	15.7%	19.4%	17.8%	16.9%	17.9%	25.1%	25.3%
	Q3	21.8%	18.6%	22.2%	20.8%	19.0%	19.7%	27.2%	28.6%
	Q4	23.7%	22.0%	26.8%	25.1%	22.1%	21.8%	29.9%	33.6%

Table 16: Nested Logit Coefficients for Choice of Final Major (5 year) for 1995-1997 period

	Majority		Minority		Majority		Minority	
	Science	Non-Science	Science	Non-Science	Science	Non-Science	Science	Non-Science
	Intercept Coefficients (relative to Berkeley)				Slope Coefficients (Berkeley norm. to 1)			
UCLA	0.676	-0.480*	1.197	-2.418**	0.438***	0.514***	0.447***	0.776***
	(0.597)	(0.333)	(1.923)	(1.109)	(0.028)	(0.034)	(0.097)	(0.110)
San Diego	2.341***	0.862***	1.760	-0.013	0.363***	0.370***	0.454***	0.528***
	(0.547)	(0.341)	(1.719)	(0.865)	(0.023)	(0.029)	(0.083)	(0.098)
Davis	2.810***	0.483*	2.662*	-0.588	0.336***	0.398***	0.397***	0.567***
	(0.520)	(0.312)	(1.697)	(0.768)	(0.021)	(0.028)	(0.088)	(0.095)
Irvine	2.534***	0.876***	3.170**	0.454	0.349***	0.357***	0.392***	0.472***
	(0.545)	(0.342)	(1.652)	(0.784)	(0.023)	(0.030)	(0.077)	(0.087)
Santa Barbara	2.805***	0.351	3.332**	1.125*	0.352***	0.459***	0.396***	0.420***
	(0.559)	(0.345)	(1.679)	(0.816)	(0.025)	(0.034)	(0.076)	(0.070)
Santa Cruz	5.345***	2.078***	6.806***	2.789**	0.217***	0.275***	0.213***	0.256***
	(0.647)	(0.453)	(2.124)	(1.304)	(0.022)	(0.030)	(0.058)	(0.064)
Riverside	2.493***	0.653**	3.343**	1.672**	0.365***	0.381***	0.394***	0.332***
	(0.568)	(0.347)	(1.714)	(0.882)	(0.026)	(0.033	(0.070)	(0.066)
	Index Coefficients							
	Majority				Minority			
	Science		Non-Science		Science		Non-Science	
HS GPA	1.302***		0.827***		1.147***		0.742***	
	(0.126)		(0.111)		(0.326)		(0.312)	
SAT Math	4.924***		-0.604***		4.884***		-0.566**	
	(0.309)		(0.168)		(0.856)		(0.344)	
SAT Verbal	0.442**		1.565***		2.141**		2.110***	
	(0.229)		(0.208)		(1.034)		(0.861)	
	Nesting parameter							
ρ	0.480***				0.518***			
	(0.051)				(0.195)			