Do Credential Gaps in College Reduce The Number of Minority Science Graduates?

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Who becomes a scientist in contemporary America has a lot to do with one's ethnicity. Foreign students from Asia dominate many graduate programs at American universities, and native-born Asians are significantly more likely than their peers to eventually become scientists. Hispanics and particularly blacks, in contrast, are notably underrepresented relative to their numbers in the U.S. population – a disparity sufficiently noticeable and acute that the federal government has programs specifically aimed at recruiting, aiding, and training minority scientists at the graduate level.

The disparities are captured in Table 1, which compares the likelihood that young adults (under the age of 35) in various racial groups had specific types of educational achievements in 2003, relative to a similar-size cohort of whites.[2] From this data, we can see that young Asian adults in the United States were 28% more likely than whites to have a bachelor's degree, but more than three times as likely to have a bachelor's degree in science, and seven times as likely to have a doctorate in science. Conversely, blacks are about one-third as likely as whites to secure a bachelor's degree in science, and less than one-sixth as likely to secure a science doctorate.

This paper does not seek to explain Asian overrepresentation in science; rather, it investigates one possible explanation of black and Hispanic underrepresentation. In the

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[2] The data is from the 2003 National Survey of College Graduates, conducted by the Bureau of the Census. The study conducted a follow-up survey in 2003 of a large sample persons who identified themselves as college graduates in the 2000 census. Table 1 selects those who are 35 and under from this sample.

mid-1990s, Dartmouth psychologist Rogers Elliott advanced the hypothesis that blacks and Hispanics might drop out of college science programs at disproportionate rates because affirmative action programs placed them in college settings where they often had much lower credentials than their classmates, and thus stood at a substantial competitive disadvantage in highly-competitive science curricula. Elliott's evidence was quite indirect and inconclusive, and his hypothesis has been largely ignored since then. In this paper, we use a variety of data – in particular, a vast, newly-released dataset on University of California undergraduates – to explore and test this "science mismatch" hypothesis.

Table 1. How Significant Is the Racial Gap in Science?

Freq Rel to Pop	White	Black	Hispanic	Asian
Gen Pop	100	100	100	100
BA	100	56	33	128
Ph.D.	100	43	21	130
BA Science	100	36	41	454
Ph.D. Science	100	15	26	703

Source: Census Survey of College Graduates (2003).

Earlier work

As an initial matter, one might suppose that the lower rates at which blacks and Hispanics achieve science degrees is entirely due to influences that operate before college begins. Both groups, of course, have substantially lower levels of average academic achievement through high school than either whites or Asians; the gap in SAT scores is on the order of a full standard deviation. This substantial disparity surely has an effect upon college entrance and completion, and presumably would affect both interest in, and ability to complete, college science curricula.

Yet two basic findings from the literature suggest that college plays an important causal role. First, black, Hispanic, and white high school seniors all appear to show equal levels of interest in pursuing science degrees in college (Elliott et al 1996). Second, a number of studies have shown that blacks and Hispanics are only about half to two-thirds as likely as whites to persist in college science programs (Astin & Astin 1993, NSF 1990), though these studies generally do a poor job of controlling for other factors.

Table 2. Evidence from various sources how interest in the sciences varies across racial groups

Data source	Proportion of students of each race intending as high school seniors to major in science or engineering			
	White	Black	Hispanic	Asian
University of California Average	34.7%	37.5%		52.6%
University of California 2004-2006	37.3%	40.5%		57.1%
HERI-CIRP data (Astin et. al.)	27.3%	34.2%	35.7%	52.6%
Roger Elliott data (4 elite institutions)	41.4%	44.2%	44.0%	55.0%

Elliott and his colleagues collected data on some 4700 students who matriculated at one of four very elite U.S. colleges in 1988. The matriculants had an average SAT of 1219, and the researchers collected data on their entering credentials, they science preparation in high school, their initial interest in science, and a variety of outcomes during their college careers. Their key findings from this data were these:

1) Blacks and Hispanics entered the selective schools with substantial disparities in credentials – test scores, high school grades, and even (to a lesser degree) the number of high school science courses taken. Controlling for other factors, blacks are more likely than other groups to be interested in pursuing a science degree.

2) Many of the matriculants interested initially interested in science quickly shifted fields after starting college, and many additional students dropped out of their science majors (or college itself) once they had begin. This attrition affected blacks at much higher rates than other groups, but it appears that ethnic effects per se were small; the attrition was mostly driven by low starting credentials.

All of this, while interesting, does little to explain whether low minority persistence in college science is due to a mismatch effect or to the initial disadvantages many of the minority students bring from their pre-college lives. Elliott's data, examining only highly elite schools, does not enable us to compare students receiving large racial preferences with otherwise similar students who do not receive large preferences, and Elliott's analytical methods did not do much to exploit what relevant comparisons he could have made. If anything, the fact that Hispanic students in his sample have nearly as much success as whites in securing science degrees (28% for Hispanics versus 30% for whites) argues against a mismatch effect, since the Hispanic students interested in science start college at a significant credentials disadvantage to whites (the Hispanic-white credentials gap, in the Elliott sample, is roughly half the black-white gap).[3]

Elliott presents two other sorts of evidence to buttress his case for mismatch effects. First, he notes that historically black colleges and universities (HCBUs) produce a large number of science graduates: "of the top twenty-one undergraduate produces of black Ph.D.s during the period 1986-93, seventeen were HCBUs and none were among the thirty or so most selective institutions that so successfully recruit the most talented black secondary school graduates." This is suggestive, of course, but hardly dispositive, since it is a measure of collective volume, not individual success rates (the HCBUs, and some of the major state universities, have a much larger number of black graduates than any Ivy League school and this alone may account for the finding). Second, Elliott presents data on from eleven colleges of varying eliteness, showing at each college the distribution of earned degrees in the natural sciences as a function of terciles of student performance on the mathematics portion of the SAT (SATM). This table is reproduced in Table 2. The table shows that, on average, students in the top tercile of their college's SATM distribution account for somewhat more than half of all natural science degrees awarded by the college, while students in the bottom tercile account for, on average, only about 15% of such degrees. The relative percentages are fairly constant across a wide range of institutions (the median SATM score of each school is roughly approximated by the SATM of Tercile 2, and one can see that the schools vary dramatically in the academic strength of their students). At first blush, the data would seem to confirm that a student with, say, an SATM of 570 would be much more likely to complete a science

[3] In this connection, it is worth noting that, according to Table 1, Hispanics who secure college degrees appear to be more likely than whites to have a science degree.

degree at Institution K, where the student is in the top tercile, than at the elite Institution A, where the student is in the bottom tercile. But we cannot firmly draw that conclusion from this data, because Elliott provides no information on the overall *rate* of science degrees from these schools. If Institution A produces four times as many science graduates per 1000 matriculants as Institution K, then the student with a 570 SATM would be more likely to get the science degree at Institution A.

Elliott's findings are thus consistent with a science mismatch effect, but the analysis is maddeningly elusive on the critical points.

TABLE 3. Percentage of Earned Degrees in the Natural Sciences as **a Function of Terciles of the SATM Distribution in 11 Institutions**

	Tercile 1		Tercile 2		Tercile 3	
Institution	% Degrees	SATM	% Degrees	SATM	% Degrees	SATM
Institution A	53.4	753	31.2	674	15.4	581
Institution B	57.3	729	29.8	656	12.9	546
Institution C	45.6	697	34.7	631	19.7	547
Institution D	53.6	697	31.4	626	15.0	534
Institution E	51.0	696	34.7	624	14.4	534
Institution F	57.3	688	24.0	601	18.8	494
Institution G	62.1	678	22.6	583	15.4	485
Institution H	49.0	663	32.4	573	18.6	492
Institution I	51.8	633	27.3	551	20.8	479
Institution J	54.9	591	33.9	514	11.2	431
Institution K	55.0	569	27.1	472	17.8	407
Medians	53.6		31.4		15.4	

From Elliott (1996)

Credentials versus institutions

One important point that cannot be gainsaid from Elliott's analysis is that credentials matter to success within particular institutions. There has been a tendency for influential scholars in higher education to assert (or at least imply) that credentials matter in getting students into elite schools, but that once one has arrived at such a place, success is largely assured or, at least, not influenced much by one's starting position. For example, Bowen & Bok argue at some length in *The Shape of the River* that SAT scores are almost irrelevant in predicting outcomes in the elite schools they study. If this were true, it would be hard to take mismatch effects very seriously.

Every original data source that we have examined, however, contradicts the Bowen & Bok claim. To give just one example, consider the data from the University of Michigan in Figure 1 and Table 4.[4] Whether one considers concentration in the sciences and engineering, or graduation rates, entering credentials have a dramatic effect upon outcomes, particularly for minority students. It is worth noting that for both science concentration and graduation, black students whose credentials are at or below the campus average at Michigan have better outcomes than comparable white students.

Table 4. Outcomes for Michigan Undergraduates in the 1999 Cohort

Outcome	Race	Index Range of Students		
		Less than 660	660-819	820 or above
Graduation in four years	Black	21%	50%	73%
	White	35%	52%	70%
Final major is in science or engineering	Black	5%	23%	43%
	White	4%	16%	33%

[4] The data analyzed here was disclosed by the University of Michigan as part of the discovery process in *Coalition to Defend Affirmative Action et al v. Cantrell*, a suit brought to enjoin the implementation of Proposition 2 (a ban on the use of racial preferences in Michigan modeled on California's Prop 209). The data covers undergraduates who matriculated at the University of Michigan's College of Arts and Sciences in 1999, and includes graduation outcomes through 2006. The index is a weighted combination of SAT I scores and HSGPA; the index can take values from 0 to 1000.

Conceptualizing the science mismatch hypothesis

Our theoretical analysis and modeling of the mismatch effect generally follows the discussion in Williams (2009). The central idea is that classroom instruction is pitched to the median student. Students who are far above the median in their credentials ("positively mismatched") may not learn at an optimal rate because they are not sufficiently challenged. Students who are far below the median ("negatively mismatched") may not learn at an optimal rate because they are challenged too much, falling behind and not mastering key building-block concepts that will need to build upon later.

On the other hand, it is plausible that, mismatch effects aside, more elite universities provide better educations. They tend to spend more per student, may have more personalized instruction, more gifted teachers, and provide more stimulating peers with whom each student can interact. Some of these things may not in fact hold true in specific comparisons between a less elite and more elite college or university, but there is a strong conventional wisdom that eliteness does confer some educational advantages independent of its credentialing benefits.[5] We would thus like our analysis to take account of both individual levels of mismatch, and the possible offsetting, independent advantages of school eliteness.

Most of the recent literature on mismatch issues has focused on legal education (e.g., Sander 2004, Rothstein & Yoon 2006). A key reason for this focus is the requirement that law graduates pass a bar exam to become certified as a lawyer. Since

[5] Of course, Dale & Krueger's comparison (2004) of more- and less-elite colleges in the College & Beyond dataset suggests that for most students, graduates from less elite schools have equal or higher earnings than do comparable graduates from more elite schools.

over ninety percent of law graduates take bar exams within a few months after graduation, and since bar exams are heavily based on law school curricula,[6] one can use bar exams as a measure of how effectively individual students learn in law school. By comparison, it is far more difficult to measure the effectiveness of undergraduate education. The attainment of a bachelor's degree is not a certification that the graduate has achieved a specific degree of competence in a set of subjects or even on one particular subject. Elite private colleges, in particular, often go to exceptional lengths to minimize rates of attrition.

Within the undergraduate realm, however, science majors do pose an interesting analogy to the law school context and thus are perhaps well-suited subjects for the study of mismatch in the undergraduate environment. In most science disciplines, there is a fairly standard body of material students are expected to master. Courses are often sequenced, and satisfactory performance in early parts of the sequences is necessary to enroll in later parts. Grading tends to be curved and is generally more rigorous than in other parts of the undergraduate curriculum. And instructors generally like to move classes at a "rigorous" pace, presumably meaning a pace they believe most students can handle.

Given these conditions, a science-inclined student's success in actually achieving a bachelor's degree in science is a plausible measure of an educationally successful outcome, and the process of obtaining a science degree is an intriguing and plausible measure of mismatch effects. The essential empirical approach taken in this paper is to compare students who are as similar as possible in their pre-college academic characteristics, who come to college planning to study science, but who attend colleges in

[6] The correlation of law school grades and bar exam scores is generally .7 or higher.

which their academic distance from the median student in sciences can be measured as an independent variable.

Available data and its limitations

To study and measure the possible existence of a science mismatch effect, one needs to have a certain type of dataset. The data should track the credentials and college experiences of a large number of students who are measurably similar in important ways but are different in the degree of potential "mismatch" they face in college. For example, a useful dataset might track the high school experiences and college outcomes of several thousand students who have similar high school achievements and pre-college credentials, but who are evenly split between one group that attends elite schools (where the subject students have credentials well below those of their average classmate) and a second group that attends significantly lower-tiered schools.

Almost any study of such data faces at the outset a significant problem of selection bias. Suppose we are comparing two students – one at Harvard and one at Ohio State University – who have similar SAT scores and high school grades, and went to high schools of apparently similar quality. Since students are not randomly assigned to colleges, there is some (unmeasured) reason why one of these students, but not the other, is at Harvard: the Harvard matriculant may have substantially higher SES, have successfully completed several AP classes, or won the Westinghouse Science competition. These unmeasured characteristics should logically favor the Harvard matriculant over the Ohio State matriculant, and thus would seem to make it more likely that if both students are interested in pursuing a science degree, the Harvard matriculants is more likely to succeed. Comparisons of students across schools will thus face a selection bias that militates against finding a science mismatch effect, with the strength of the bias depending on the quality and number of relevant student characteristics captured by the data.[7]

One strategy for dealing with this bias is to focus on underrepresented minorities, particularly blacks. A white student at an elite school, whose credentials are far below those of his average classmates, is very likely to have important unobservables (whether these be unobserved academic achievements or very important parents) that make selection bias particularly hazardous. In contrast, the elite schools are known to use aggressive preferences in recruiting racial minorities, making it plausible that the lower credentials of a black student at an elite school fairly summarize the student's actual academic preparation. Since it is also plausible that many minority students will attend less elite institutions (say, for geographic reasons) despite their ability to get admissions offers from more elite schools, studying minority cohorts can be at least somewhat successful in limiting selection bias.

Databases capable of carrying out such a research design are very rare. The federally-sponsored longitudinal education databases (e.g., High School and Beyond and the National Educational Longitudinal Study) contain on the order of six thousand participants who attend four-year colleges; the number of blacks and Hispanics attending elite colleges is so small as to make robust analysis difficult. The same is largely true of other longitudinal databases, such as the National Longitudinal Survey of Youth, while

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[7] A countervailing bias is the Roy effect, under which students select themselves into less elite schools when they know they have particular characteristics that will mesh particularly well with that school (other than credential matches) and will thus produce better outcomes at the less elite school. We are not aware of any research showing Roy effects to be meaningful in the types of comparisons made here.

the College and Beyond dataset developed by the Mellon Foundation, which focus on the top of the education heirarchy, includes only a narrow range from the most prestigious schools in the country to those that are merely "elite".

Last year, we obtained a new data source that we believe permits a robust examination of the science mismatch hypothesis. The University of California is one of the largest university systems in the country, with nearly two hundred thousand undergraduates spread across nine campuses. Although individual campuses have substantial autonomy, the university's Office of the President ("UCOP") has gathered comprehensive data on all students in the system going back to at least 1992. University policy has long limited the use of this data to the reporting of aggregate statistics and "administrative" studies, but in 2007 a research project based at UCLA (of which Sander is the principal investigator) submitted public records requests to the UC schools and a number of other universities around the country. Lengthy negotiations about public records law and the privacy protections of FERPA led to the university's agreement in the summer of 2008 to produce a comprehensive release of microdata covering undergraduate applicants and matriculants in the UC system from 1992 through 2006.

Because the UCOP data is a public-release dataset, a number of fine-grain categories in the original data have been combined to protect individual privacy.[8] Thus, ten racial categories in the original data have been collapsed into four: whites, Asians, underrepresented minorities, and others. A few dozen fields of study have been collapsed into three: science & engineering, social science, and humanities. Individual year

[8] We believe UC's suppression of characteristics in the released dataset far exceeded what was required to protect student privacy and comply with federal law, but that is another story.

cohorts have been combined into three-year groupings based on year of intended enrollment or matriculation: 1992-94, 1995-97, 1998-2000, 2001-03, and 2004-06.

Nonetheless, we believe this is an extraordinarily rich dataset for studying a range of significant issues in higher education, including the science mismatch hypothesis. The dataset is very large, including data on nearly one million UC applicants and nearly half-a-million matriculants. The data includes about a dozen measures of student credentials at the time of application, including not just high school grades and SAT scores but a UC rating of the quality of the student's high school and a UC-adjusted HSGPA that is far more predictive of college performance than standard, unadjusted high school grades. Other reported variables include the student's intended major as of the time of application (crucial for the present study), eventual major, college grades, whether the student graduated and the time to graduation. Usefully, we also know which of the eight[9] UC campuses each student applied to, which ones admitted the student, and where the student ultimately enrolled.

The eight UC schools cover a wide range of school eliteness; the median SAT score of Berkeley students is more than two hundred points higher than the median at the least-elite UC campuses. Since these schools are all public, all in California, and subject to many of the same institutional constraints, it is easier to make comparisons across them. And since California's Proposition 209 restricted the use of racial preferences (beginning, at the undergraduate UC level, with the class admitted in 1998), the data includes many blacks and Hispanics (henceforth "URMs") who received a preference and

[9] There are a total of ten UC campuses; one, UC San Francisco, has graduate programs only (all related to medicine) and one, UC Merced, opened in the last few years and is thus not included in the dataset.

attended an elite campus before 1998, along with similar students in later cohorts who did not receive a racial preference and thus attended a less elite campus.

Testing Science Mismatch

To test for science mismatch effects, we took two alternative approaches, which we call the "distance" method and the "first choice/second choice" method. Let us explain each of these approaches.

Distance method. The distance method compares students who attended different campuses of the University of California at the same time (e.g., all students who enrolled as freshmen during the years 1998 through 2000). Included in the sample is any student who indicated in their application that they intended to major in science or engineering. The outcome of interest is whether the student eventually graduates with a bachelor's degree in science or engineering. This means that there are two different types of "unsuccessful" outcome – students who do not graduate at all, and students who graduate but end up with a major in the humanities or social sciences. Overall, about 36% of the students we are examining have "successful" outcomes, as here defined.

For every student in the UCOP database, we have a variable that measures the student's "academic index" on a scale of 0 to 1000. The index rescales each student's SAT I score to a 0 to 600 scale, and rescales each student's UC-adjusted high school GPA to a 0 to 400 scale. The academic index is thus a simple shorthand for the academic credentials of entering freshmen. It correlates well with nearly every academic outcome measure in our data.

In implementing the distance method, we calculate for each student the difference between that student's academic index and the median academic index of all science-interested students at that student's campus in that student's cohort. Thus, for example, if a student has an academic index of 700 and matriculates at the University of California at San Diego in 1999, we determine the median academic index of all UCSD students who matriculated in 1998, 1999, or 2000 and who indicated in their application that they wanted to major in a science or engineering field (this median is 780). This student then has a "distance" value of -80 (700-780). This measure of distance is a simple measure of mismatch – it captures the basic idea that we want to know the extent to which students are in environments in which their credentials are higher than, similar to, or lower than those of their classmates.

The basic idea behind the distance method is to compare students at different UC campuses who are similar in their academic characteristics, but differ in their level of "mismatch". A student with an index of 700 would have a distance value of -120 at UC Berkeley, but a positive distance value at several of the less elite campuses. A student with an index of 600 would have a negative distance value at every campus, but the size of the distance would be very small at UC Riverside or UC Santa Cruz and quite large at UCLA or Berkeley.

There are a couple of basic analytical challenges raised by the distance method. First are problems of collinearity. The equation estimating mismatch effects includes both the credentials of each student and the student's "distance" from his peers. Ideally, one would also like to estimate the effect of a school's eliteness. But the distance measure is itself a function of school eliteness and individual student credentials. It is thus possible for the entire analysis to be over-determined and not computable in a regression. We solved this problem in three ways. First, we treated all students with a positive distance variable as having a "zero" value for mismatch – that is, we did not attempt with this method to examine the effect of being "positively" matched with one's peers. Second, we did not use the academic index, per se, as a control variable for general academic ability. Instead, we used several individual measures of student's academic credentials, including SAT I math score, SAT I verbal score, SAT II scores, adjusted and raw HSGPA, the number of AP classes taken by the student…. Third, we used a single "dummy" to compare the independent effect of school eliteness (treating Berkeley, UCLA, and UCSD as the elite schools).

A second analytic challenge is the likelihood that mismatch effects, if they exist, are non-linear. There is no a priori reason to believe that mismatch effects, if they exist, operate in a linear way – i.e., that being mismatched by 50 points on our 1000-point scale is twice as bad as being mismatched by 25 points. Consequently, we decided to use a categorical variable to characterize different levels of mismatch. Specifically, after identifying all students with negative mismatch at all UC campuses, we divided them into ten equal groups, with Group 1 having the smallest mismatch levels and Group 10 having the largest. We also excluded from the analysis all students who were mismatched by more than 200 points (about 1% of the sample), because our experience in other research showed that students with extremely low credentials relative to their peers were often simple cases of measurement error – e.g., situations where the student had a missing test score for some reason, or a particularly misleading high school GPA.

Table 5
Distance Analysis of UC Students, 1998-2000

1998-2000			
Effect	**Odds-ratio**	**Eff. Size**	**p_value**
Intercept		-4.3035	0.0000
Normed SES	1.0013	0.0013	0.0075
Adj HSGPA	1.7808	0.5771	0.0000
SAT Verbal	0.9985	-0.0015	0.0000
SAT Math	1.0051	0.0051	0.0000
SAT Writ	0.9993	-0.0007	0.0004
Under-Represent. Minority (1=Yes)	0.8385	-0.1761	0.0000
Mismatch: 1st Decile	0.8231	-0.1947	0.0008
Mismatch: 2nd Decile	0.8256	-0.1917	0.0012
Mismatch: 3rd Decile	0.7938	-0.2309	0.0001
Mismatch: 4th Decile	0.8397	-0.1747	0.0039
Mismatch: 5th Decile	0.7958	-0.2284	0.0003
Mismatch: 6th Decile	0.7284	-0.3169	0.0000
Mismatch: 7th Decile	0.6860	-0.3769	0.0000
Mismatch: 8th Decile	0.5999	-0.5111	0.0000
Mismatch: 9th Decile	0.6010	-0.5091	0.0000
Mismatch: 10th Decile	0.4938	-0.7055	0.0000
Tier (1=Upper)	1.1189	0.1124	0.0023
Model Fit	**Chi-Square**	**df**	**Change**
	2574	17	9/1/p<.0027

Sample=All students enrolling at the college in science; students with a mismatch of > 200 points have been dropped from the analysis (a total of 180 students)

Tier: UCLA, Berkely and UCSD have been placed in the upper tier. All other schools are in the lower tier

Mismatch=Student Index - School Median. Positive "mismatch" scores have been set to 0's;
Mismatch Decile=Deciles based on the relative rank WITHIN schools, i.e., each school contributes an proportionate share of their students to each decile; higher decile equals greater mismatch

Table 5 reports the results of the distance model for UC students in the 1998-2000 cohort – a total of 30,323 students with science aspirations from all eight UC campuses. Model 1 estimates graduation-in-science for all matriculants interested in science, using standard academic predictors. This model includes ten categorical mismatch variables, with the first category containing the ten percent of "negatively mismatched" students with the smallest credential gaps from their within-school science peers, and the tenth category containing students with the largest mismatch. The model also contains controls

Table 6
Distance analysis of UC students, adding interaction terms of mismatch * eliteness

1998-2000			
	Model 6: Crdntls/Race + Mismatch+Tier+Interaction		
Effect	**Odds-ratio**	**Eff. Size**	**p_value**
Intercept		-4.5905	0.0000
Normed SES	1.0012	0.0012	0.0103
Adj HSGPA	1.8298	0.6042	0.0000
SAT Verbal	0.9985	-0.0015	0.0000
SAT Math	1.0053	0.0053	0.0000
SAT Writ	0.9993	-0.0007	0.0002
Under-Represent. Minority (1=Yes)	0.8437	-0.1699	0.0000
Mismatch: 1st Decile	0.9337	-0.0686	0.3794
Mismatch: 2nd Decile	0.8747	-0.1338	0.0914
Mismatch: 3rd Decile	0.8623	-0.1482	0.0664
Mismatch: 4th Decile	0.9995	-0.0005	0.9954
Mismatch: 5th Decile	0.8899	-0.1166	0.1621
Mismatch: 6th Decile	0.7695	-0.2621	0.0025
Mismatch: 7th Decile	0.7739	-0.2563	0.0042
Mismatch: 8th Decile	0.7331	-0.3105	0.0009
Mismatch: 9th Decile	0.7169	-0.3328	0.0010
Mismatch: 10th Decile	0.6049	-0.5027	0.0000
Tier (1=Upper)	1.2173	0.1966	0.0000
Tier x Mismatch: 1st Decile	0.7776	-0.2515	0.0239
Tier x Mismatch: 2nd Decile	0.9037	-0.1013	0.3710
Tier x Mismatch: 3rd Decile	0.8608	-0.1499	0.1816
Tier x Mismatch: 4th Decile	0.7101	-0.3424	0.0021
Tier x Mismatch: 5th Decile	0.8171	-0.2020	0.0741
Tier x Mismatch: 6th Decile	0.9259	-0.0770	0.5038
Tier x Mismatch: 7th Decile	0.8146	-0.2050	0.0765
Tier x Mismatch: 8th Decile	0.6974	-0.3603	0.0025
Tier x Mismatch: 9th Decile	0.7453	-0.2939	0.0166
Tier x Mismatch: 10th Decile	0.7278	-0.3177	0.0180
Model Fit	**Chi-Square**	**df**	**Change**
	2602	27	28/10/p<.0018

Sample=All students enrolling at the college in science; students with a mismatch of > 200 points have been dropped from the analysis (180 students)

Tier=UCLA, Berkely and UCSD have been placed in upper tier. Other schools in lower tier

Mismatch=Student Index - School Median. Positive "mismatch" scores have been set to 0's;
Mismatch Decile=Deciles based on the relative rank WITHIN schools, i.e., each school contributes an proportionate share of their students to each decile; higher decile equals greater mismatch

Mismatch x Tier is a series of interaction terms formed by the product of these variables.

for individual academic credentials and an institutional dummy variable for whether the student attended one of the three most elite schools (UC San Diego, UCLA, and Berkeley).

Table 6, above, adds a set of interaction terms in which each category of mismatch interacts with the eliteness variable. This model tests for whether mismatch effects are limited to (or more severe or less severe at) more elite schools, holding other factors constant.

The patterns in these results are remarkably clean and coherent. There do seem to be large and significant mismatch effects. Students who have the largest credential gap with their classmates are much less likelyl to graduate with a science degree, compared with academically similar students facing no credential gap. While the logistic results (including the "effect" size) can be difficult to interpret, point estimates suggest that a large mismatch reduces a student's likelihood of achieving a bachelor's in science by roughly half. The effects appear to be nonlinear – that is, the negative effect of mismatch increases at an increasing rate across the categories with greatest mismatch. The eliteness variable has an independent, positive effect, which seems to roughly cancel out the negative effect of mismatch for students with mild mismatch levels. In other words, a student at a slight academic disadvantage relative to his peers may suffer some from that disadvantage, but receives compensating advantages from attending a more elite school.

The interaction terms suggest that the mismatch effects are significantly greater at the more elite than the less elite schools, though we are inclined to view this result as very provisional, since we are only comparing two tiers of schools. However, other evidence suggests that at more elite schools, most students in the sciences have fairly homogenous training and skills, so that the price of having lower-than-average credentials or preparation could be especially debilitating at the most elite schools.

First-choice/Second-choice. To explore the robustness of these findings, we sought out other empirical tests for mismatch that would come at the question in distinct ways. Several tests are in the works, but one of them is in good enough shape to present here in preliminary form. This approach is the "first-choice/second-choice" model. It is loosely based on a method used by Dale and Krueger (2004) to study the market benefit of attending an elite college, and by Ayres and Brooks (2005) and Sander (2005) to study mismatch in law school. Using the College & Beyond dataset, Dale and Kruger identified pairs of students who were admitted to symmetrical pairs of colleges – one elite, and one less elite. In each pair, one student attended the more elite school, and the other attended the less elite school. Dale and Kruger then compared the outcomes of each pair. This method should reduce the selection bias from unobservables, since the student attending the less elite school is academically strong enough to be admitted to the more elite school of the pairing.

We can do something similar with the UCOP dataset, because for each matriculant in the dataset, we know what other UC schools the student applied to, and to which ones he was accepted. Thus, we can compare students who attended UC Santa Barbara (but were accepted to UCLA) with students who actually attended UCLA during the same time period. By controlling for other academic characteristics, we can compare very similar students for whom a key difference is their level of mismatch at each school.

What are the weaknesses of this approach? One significant drawback is the relatively small number of "second choice" subjects, since students tend to attend the most elite school that admits them. Among students who were admitted to both UCLA and UC Santa Barbara from 1998 to 2000 (and who ended up at one of those two schools), 91.9% chose UCLA. Among students admitted to both Berkeley and UC Irvine from 1998 through 2000, 92.1% decide to attend Berkeley. The proportion of "second choice" students is thus relatively small, but since the dataset itself is so large we still have hundreds of second-choice cases. A more serious concern is that the relatively small group of students who turn down a more elite school may be systematically different in some respect. To the extent we can tell from the available data, the second-choice students have slightly lower SES, but are very similar scholastically to their first-choice peers. Though there may be some unobserved, systematic differences, it is plausible that these differences tend to favor the first-choice students[10], and thus biases the analysis against a finding of mismatch.

To implement this test, we compared two groups of UC campuses: Berkeley and UCLA in the "elite" group, and UC Irvine, UC Riverside, UC Santa Barbara, and UC Santa Cruz in the non-elite group. We excluded two intermediate campuses, UC San Diego and UC Davis, on the theory that a stronger contrast between "elite" and "non-elite" schools would provide a stronger contrast and better test. For 1998-2000, the average index of matriculating freshmen at UCLA and Berkeley was 810; at the four "non-elite" schools, it was 675. The term "non-elite" is used advisedly, because even students with a 675 index rank at about the 90th percentile of all high school seniors. But

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[10] Specifically, those going to the more elite school are likely to have higher SES, more friends going to elite schools, and a more ambitious streak.

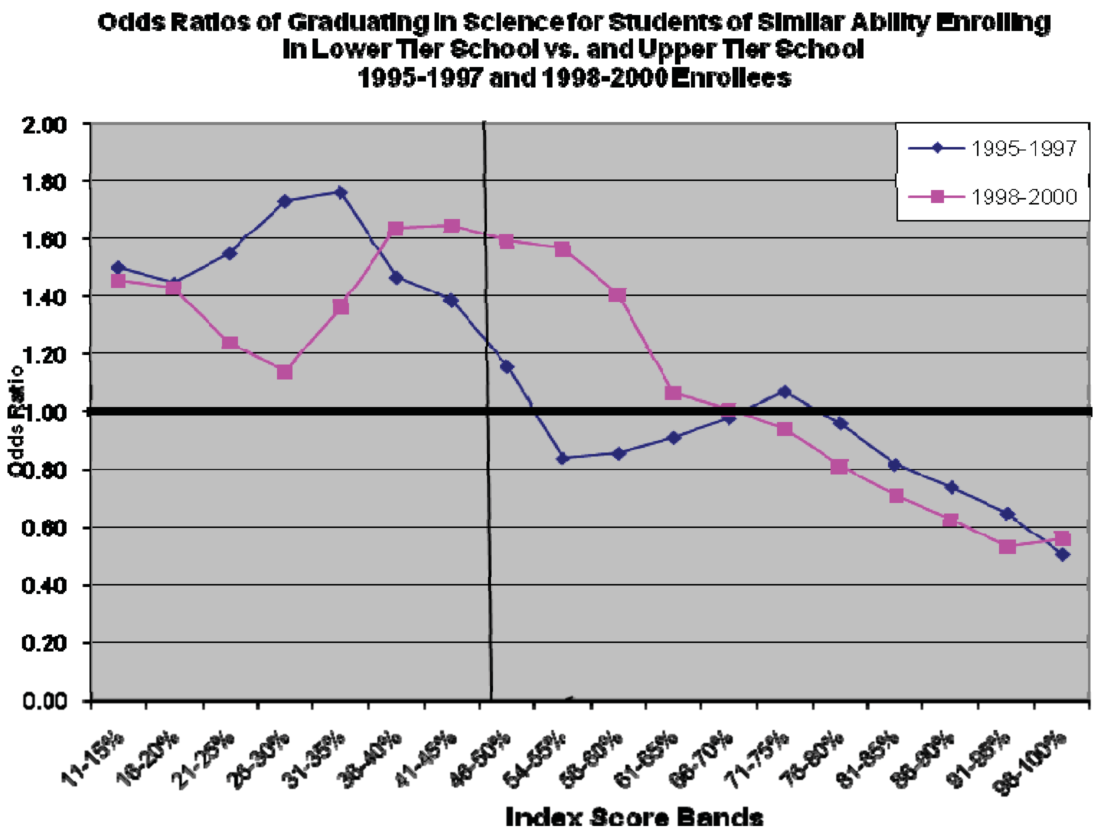
the important point for our purposes is that a student who at Berkeley or UCLA would have credentials a standard deviation below the mean would be at or above the mean index at the four non-elite campuses.

Our sample consisted of all students who applied to both an elite and a non-elite campus, was admitted to a campus in both categories, and enrolled in one of the schools that admitted them. We divided these students into twenty equal groups ("duodeciles"), ranked by their academic index. We then ran an identical logistic regression with the students from each duodecile. The dependent variable was whether the student graduated with a degree in science or engineering. The independent variables included a variety of controls for each student's high school credentials, test scores, race, and socioeconomic background. The critical independent variable was whether the student attended one of the four schools in the "non-elite" cluster.

Figure 1 plots out the key results, separately analyzing duodeciles for the 1995-97 cohort and the 1998-2000 cohort. For each of twenty regressions (for each cohort) we obtained an odds-ratio coefficient on the "non-elite" variable; we averaged these across five duodeciles and plotted the results. Although the results are less stable in this analysis than in the distance analysis, this is unsurprising given the relatively small number of "non-elite" students in each duodecile (generally about fifty to one hundred). The overall pattern is very similar: large relative benefits to students attending non-elite schools for students with relatively lower credentials, with these benefits disappearing (and reversing) for students with relatively high credentials.

Because the first-choice/second-choice approach avoids the problem of collinearity, it is easier to examine effects of mismatch for both low- and high-index students, and thus to consider both "positive mismatch" as well as "negative mismatch" effects. We have not thought carefully about why "positive mismatch" results should occur in the completion of science degrees, but Figure 2 certainly suggests that such effects deserve careful investigation.

Figure 2



<u>Conclusions</u>

Minority attrition in science is a very real problem, and the evidence in this paper suggests that "negative mismatch" probably plays a role in it. In addition to the two models presented here, we have used "propensity score matching" with both the UCOP data and the national longitudinal databases (NELS and HS&B), and the results are quite consistent: students with credentials more than one standard deviation below their science peers at college are as much as half as likely to end up with science bachelor degrees, compared with similar students attending schools where their credentials are much closer to, or above, the mean credentials of their peers. Since most of these tests suffer from selection bias, and since this generally biases the tests *against* a finding of mismatch, the evidence for this core conclusion seems strong to us.

That said, this research is still at an early stage and there is a great deal we do not know. We need to make more precise our comparisons across schools, to better define exactly what levels of "mismatch" matter and how much these are offset at the less elite comparison schools. Better calibration will also help us compare our results across different analyses.

More broadly, we need to explore the consequences of "success" or "failure" as we have defined it. Do students who get science degrees from less elite schools have successful careers, compared with their peers at more elite schools who drop out or switch to other fields? What grades are these students getting, and how much does that matter? It's worth noting that in the "distance" analysis, students were more likely to "fail" – that is, switch to a non-science major – if they had a higher Verbal SAT score. It is plausible that at Berkeley or UCLA, versatile students are finding a broader variety of challenges and opportunities outside the sciences than they might at a less elite school. These are important issues to ponder and explore.

But the evidence for a mismatch effect is strong, and the neglect of Elliot's early and very suggestive work in this field is disappointing. Those studying science higher education, administrators of programs aimed at fostering the development of minority scientists, and the custodians of data helpful in studying these issues more carefully, need to be willing to consider mismatch effects seriously, and foster further work in this area.

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