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Affirmative action and university fit: evidence from Proposition 209

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Abstract

Proposition 209 banned the use of racial preferences in admissions at public colleges in California. We analyze unique data for all applicants and enrollees within the University of California (UC) system before and after Prop 209. After Prop 209, minority graduation rates increased by 4.35 percentage points. We present evidence that certain institutions are better at graduating more-prepared students while other institutions are better at graduating less-prepared students and that these matching effects are particularly important for the bottom tail of the qualification distribution. We find that Prop 209 led to a more efficient sorting of minority students, explaining 18% of the graduation rate increase in our preferred specification. Further, there appears to have been behavioral responses to Prop 209, by universities and/or students, that explain between 23% and 64% of the graduation rate increase.

JEL codes: I28; J15

Keywords: Affirmative action; College enrollment; College graduation; Mismatch

1 Introduction

Over the past several years, the U.S. Supreme Court has taken up and decided several cases concerning the constitutionality of race-based preferences (affirmative action) in university admissions[1]. One of the arguments opponents of affirmative action have advanced is that affirmative action actually hurts the individuals it is supposed to help – the *mismatch hypothesis*. According to the mismatch hypothesis, affirmative action in admissions actually results in worse outcomes for minority students as students admitted under affirmative action are attending colleges where the curriculum is designed for students with significantly stronger credentials[2].

In this paper we examine the mismatch hypothesis in the context of college graduation rates. As documented in Turner (2004), Bound and Turner (2007, 2011), and Bound et al. (2010), while the number of students attending college has increased over the past three decades in the U.S., college graduation rates (i.e., the fraction of college enrollees that graduate) and college attainment rates (i.e., the fraction of the population with a college degree) have hardly changed since 1970 and the time it takes college students to complete a baccalaureate (BA) degree has increased (Bound et al. 2012). The disparities between the trends in college attendance and completion or time-to-completion of college degrees is all the more stark given that the earnings premium for a college degree relative to a high school degree nearly doubled over this same period (Goldin and Katz 2008).

We examine differences in graduation rates and the academic preparation of minority and non-minority students attending the various UC campuses between the years 1995–2000, using a unique source of student-level data that covers the universe of students who applied to one or more of the UC campuses. We obtained these data from the University of California Office of the President, the administrative offices of the entire UC system and refer to them as the "UCOP" data. The UCOP data cover a period where race-based preferences were banned in California. In 1996, the voters of California approved Proposition 209 – Prop 209 hereafter – which stipulates that: "The state shall not discriminate against, or grant preferential treatment to, any individual or group on the basis of race, sex, color, ethnicity, or national origin in the operation of public employment, public education, or public contracting". The Proposition took effect in 1998.

Using these student-level data, we find evidence that the graduation rates of minorities increased after Prop 209 was implemented. Indeed, the data reveal that under-represented minorities were 4.4 percentage points more likely to graduate in the period after Prop 209 that the period before[3]. We also find that the distribution of minorities entering the UC system shifted from its more selective campuses (e.g., UC Berkeley and UCLA) towards its less selective ones. Moreover, while there was an overall improvement in the academic preparation of minorities enrolling at UC campuses after Prop 209 went into effect, the greatest improvements occurred at the less-selective campuses. Taken together, this evidence may be consistent with the mismatch hypothesis noted above.

As we argue below, the scope for the mismatch of students to campuses with affirmative action and its alleviation with bans on its use hinges on whether some campuses, presumably less-selective ones, are better-suited to produce positive outcomes, e.g., graduation rates, for less-prepared students while other universities, typically more-selective ones, are better-suited for more-prepared students. In contrast, if more-selective universities were able to produce better outcomes, such as graduation rates, for students of all levels of preparation than less-selective ones, then there is no scope for student-university mismatch. Bans on affirmative action would not be expected to improve the graduation rates of minority students, especially those with weaker backgrounds. We formalize these arguments below, characterizing and estimating graduation production functions for each of the UC campuses and examining whether and how they differ across campuses.

The student-level UCOP data we examine also reveal that after Prop 209 there was a decline in the number of under-represented minorities enrolled at one of the UC campuses. And, if the minority students who did not attend a UC campus after Prop 209 were the least prepared, then graduation rates would have likely risen, regardless of the campus they would have attended. That is, Prop 209 may have induced a significant *selection effect* on minority enrollments within the UC system that would provide an alternative explanation to mismatch for why minority graduation rates improved.

To separate mismatch and selection explanations for the post-Prop 209 minority graduation rate increases, we exploit the richness of the UCOP data on cohorts of students that entered the UC system before and after Prop 209. These data contain measures of high school GPAs and SAT scores and of parental income and education, which allow us to both control for these factors in evaluating the effects of Prop 209 and assess how they influence minority (and non-minority) graduation probabilities at the various UC campuses. The UCOP data provide information not only on which UC campus a student enrolled (as well as whether they graduated from that campus), but also on the other

UC campuses to which they applied and the ones to which they were admitted. We use the information on the UC campuses to which students were admitted, and the quality of those UC campuses, to implement a modified version of the method used in Dale and Krueger (2002) to control for student qualifications beyond those measured by high school GPA and test scores.

We decompose the post-Prop 209 change in minority graduation rates into three components: better matching, better students, and a third, residual, category of post-Prop 209 change in graduation rates not accounted for by the matching or selection. We refer to the latter (residual) component as other *behavioral responses* to the Prop 209 affirmative action ban. While we cannot directly characterize them, these behavioral responses could have been the results of universities investing more in their students and/or changes made by minority students that improved their college academic outcomes.

We find that better matching explains around 18% of the improvement in minority graduation rates within the UC system. However, this relatively small overall effect masks two notable phenomena related to the potential role of matching. First, we find that matching is much more important in accounting for the graduation gains of students in the bottom of the academic preparedness distribution. Second, as we discuss in Section 7, Arcidiacono et al. (2013) find that improved matching played a much more prominent role in improved graduation rates of minorities who initially enrolled at UC campuses in STEM (Science, Technology and Engineering) majors, especially in the higher rates that minorities who started in STEM majors actually graduated with a STEM degree.

We find that between 18% and 59% of the minority graduation rate increase is due to changes in student characteristics, both observed and unobserved, of those enrolled in the UC system after Prop 209. We note that the changes in the characteristics of minority enrollees post-209 are not all in the same direction. While some measures of preparation were higher in the post Prop 209 period (high school grades and SAT scores) other measures actually fell (parental income and parental education). Hence, the pool of minority enrollees actually became more diverse from a socioeconomic perspective[4].

Finally, somewhere between 23% and 64% of the minority graduation gains cannot be explained either by selection or matching. There is some evidence that this residual consist of behavioral responses to Prop 209. Below, we present anecdotal evidence that suggests that universities responded to Prop 209 by focusing more resources on the retention of their enrolled students, especially minorities and/or students from disadvantaged background, to increase their retention and graduation rates. And with respect to changes in the academic performance of minority students attending UC campuses, research by Antonovics and Sander (2013) on enrollments conditional on admittance suggests the possibility that minorities may have felt more comfortable at universities where professors and peers know that they were admitted on the basis of academic credentials and not their race or ethnicity.

The remainder of the paper is organized as follows. In Section 2 we describe the UCOP data and present the unadjusted levels and post-Prop 209 changes in minority and white student enrollments, measures of their academic preparation and their graduation rates. In Section 3 we examine how much of the increased graduation rates for the UC system as a whole remain after accounting for changes in observables. After showing that a substantial portion of the graduation gap is unexplained, in Section 4 we characterize the mismatch hypothesis and establish the conditions it requires in terms of the differences

across colleges in their capacity to produce graduates with disparate academic preparation. In Section 5 we develop and estimate a model of college graduation that embeds campus-specific graduation production functions that depend on student preparation using only data in the pre-Prop 209 period. The estimates in Section 5 serve as one of the inputs of the decomposition of the changes in graduation rates after Prop 209. Section 6 decomposes the increased graduation rates following Prop 209, focusing in particular on the roles of better matching, changes in the selection of students who enrolled in the UC system, and behavioral responses to Prop 209. Section 7 concludes.

2 Graduation patterns in the UC system before and after Prop 209

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 we were provided have the following limitations[5]:

1. The data are aggregated into three year intervals from 1992–2006.
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 two important pieces of information about the individuals who applied to and possibly enrolled at a UC campus. First, we have information on every individual who applied to any of the campuses in the UC system over the period, including to which campuses they applied and were admitted. As described below, we use the latter information to adapt a strategy used in Dale and Krueger (2002) in order to account for unmeasured student qualifications. Second, we were provided with access to an index of each student's preparation for college, given by the sum of a student's SAT I score, rescaled to be between 0 to 600, and his or her high school GPA, rescaled to be between 0 to 400. Below, we refer to this as a student's high school *Academic Index* (*AI*). We have data for the entering cohorts in the three years prior to the implementation of Prop 209 (1995, 1996, 1997), and for three years after its passage (1998, 1999, 2000).

In Table 1, we present summary statistics for the individual-level UCOP data and its measures of student qualifications by race and for applicants, admits, enrollees and graduates for campuses in the UC system, pre- and post-Prop 209[6]. The first panel gives the descriptive statistics for under-represented minorities (URMs). As a fraction of the number of minority graduates from California's public high schools[7], enrollment rates fell from 4.6% to 3.6%. Conditional on enrolling, minority graduation rates increased by 4.4 percentage points[8] off a base rate of 62.4% post-Prop 209[9]. While the share of white high school graduates who applied, attended, and graduated in the UC system all did not significantly change post-Prop 209 (second panel), graduation rates conditional on enrolling also showed a significant increase at 2.5 percentage points.

With respect to applications at UC campuses before and after Prop 209, while applications by URMs increased, as a share of California public high school graduates they declined 1.1%. The latter decline suggests the possibility of a chilling effect of Prop 209,

Table 1 Characteristics of UC applicants, admits, and enrollees by race, pre-Prop 209 and change post Prop 209[†]

	Applied		Admitted		Enrolled		Graduated	
	Pre-Prop 209	Change	Pre-Prop 209	Change	Pre-Prop 209	Change	Pre-Prop 209	Change
Under-represented Minorities:								
No. of Minorities	31,002	2,493	24,352	-472	13,291	-714	8,205	91
High School Acad. Index	619.7	14.7***	645.7	17.2***	641.5	15.6***	653.7	12.4***
Parents have BA	0.369	0.004	0.381	-0.014***	0.385	-0.039***	0.417	-0.046***
Parents' Income $\leq$ \$30K	0.379	-0.019***	0.364	-0.008*	0.364	0.008	0.334	0.012
Parents' Income $\geq$ \$80K	0.195	0.015***	0.203	0.009**	0.211	-0.010*	0.238	-0.018***
Graduation Rate[‡]							0.624	0.044***
Share of Calif. Public HS Grads	0.107	-0.011***	0.084	-0.016***	0.046	-0.010***	0.028	-0.005*
Whites:								
No. of Whites	67,986	8,217	54,571	4,398	27,652	1,937	20,791	2,210
High School Acad. Index	710.4	11.1***	729.8	8.8***	722.6	13.3***	730.7	12.4***
Parents have BA	0.801	-0.002	0.813	-0.010***	0.805	-0.008**	0.822	-0.008**
Parents' Income $\leq$ \$30K	0.103	-0.008***	0.101	-0.006***	0.109	-0.006***	0.100	-0.006*
Parents' Income $\geq$ \$80K	0.528	0.019***	0.533	0.013***	0.525	0.015***	0.540	0.016***
Graduation Rate[‡]							0.769	0.025***
Share of Calif. Public HS Grads	0.187	0.003	0.150	-0.003	0.076	-0.002	0.057	0.000

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Data Source: UCOP individual data, Pre-Prop 209 (1995–97); Post-Prop 209 (1998–2000).

Variables: *No. of Observations* is the total number of students who engaged in activity indicated in column heading; *No. of Obs./No. of HS Grads* is ratio of a column's No. of Observations to the number of public high school graduates per year in California; *Graduation Rate* is share of enrolled students that graduated in 5 years or less; *High School Acad. Index* is sum of re-scaled student's SAT I score (0 to 600 scale) plus re-scaled student's UC-adjusted high school GPA (0 to 400 scale); *Parents have BA* is indicator variable of whether student has at least one parent with Bachelor Degree or more; *Parents' Income* $\leq$ *\$30K* is indicator variable for whether parents' annual income is $\leq$ \$30,000, where Pre-Prop 209 income are inflation-adjusted to Post-Prop 209 levels; *Parents' Income* $\geq$ *\$80K* is corresponding variable whether parents' annual income is $\geq$ \$80,000; and where *Graduated* denotes those who graduated in 5 years or less.

[†]Descriptive statistics for Asian Americans and Others (including Unknowns) are omitted from table, but are available in the Additional file 1.

[‡]Totals in each category include occasional cases with missing data; when calculating average sample characteristics, individuals missing that data are dropped. This includes enrollees with missing graduation information, so Graduation Rate is not identical to graduates/enrollees.

where minorities are less likely to apply under the new admissions rules. However, other evidence suggests otherwise. For example, using the same UCOP data as used in this paper, Antonovics and Sander (2013) argue that Prop 209 resulted in a warming, rather than a chilling, effect, in that minorities, as a group, were more likely to enroll in the UC campus conditional on being admitted and Antonovics and Backes (2013a) show that the sending of SAT scores by minority applicants to UC campuses did not change post-Prop 209.

With respect to academic preparation as measured by the student's academic index, minorities had much lower scores at each stage of the college process than whites both prior to and after Prop 209 was implemented (Table 1). This difference in academic preparation accounts, in part, for the lower proportion of minority high school students being admitted to a UC campus ("Share of Calif. HS Grads") compared to whites. However, after Prop 209 is implemented, the academic preparation of minority applicants, admits, enrollees, and graduates improved, both absolutely and relative to whites. This improvement in academic preparation of the minority students that enrolled at a UC campus after Prop 209 suggests that changes in minority student *selectivity* with respect to academic preparation noted in the Introduction may have accounted for some, if not all, of the improved graduation rates of minorities after the implementation of Prop 209.

But, the change in the selectivity of enrolled minority students with Prop 209 may not have improved uniformly. As shown in Table 1, there was a significant and sizable decline in the proportion of minority enrollees and graduates from more "advantaged" family backgrounds after Prop 209 went into effect. Among admitted minorities who actually enrolled at a UC campus, there was an 0.039 reduction (a 10% decline) in the proportion with parents who had a BA degree and a corresponding 0.046 reduction (an 11% decline) among those minorities that graduated from a UC campus after Prop 209 was implemented. Similarly, post-Prop 209 a greater share of applicants and admits had parents with incomes above $80,000. Yet, the share of enrollees whose parental income was greater that $80,000 fell. That is, while minorities from more advantaged family backgrounds continued to apply and be admitted to UC campuses after Prop 209 (though the set of UC campuses where they were admitted may have changed), they were less likely to enroll at one of the campuses and less likely to graduate from one of them[10]. This decline in minority students from more advantaged backgrounds that enrolled at UC campuses after Prop 209 would seem to work against improved graduation rates, given previous findings that students from wealthier and better educated parents do better in college[11].

We next consider how graduation rates and academic preparation varied across UC campuses before and after Prop 209. Table 2 gives the distribution of both for minorities and whites, respectively. The campuses are listed in order of their overall academic index which roughly corresponds to their *U.S. News & World Report* ranking as of the fall of 1997[12]. We use this ranking throughout our study as our measure of the selectivity and/or quality of the UC campuses. Focusing initially on the pre-Prop 209 tabulations, one sees that the academic index and graduation rates are systematically related to the rankings of UC campuses, with more-selective campuses having students that are better prepared and more likely to graduate. This is true for minorities and for whites. And, consistent with the tabulations in Table 1, whites have higher academic indices and graduation rates than do minorities, a pattern that holds campus-by-campus.

Table 2 High school academic index (*AI*) and college graduation rates by UC campus for minorities & whites, pre- & post-Prop 209

	Under-represented Minorities					Whites				
	Academic Index			Grad. Rate		Academic Index			Grad. Rate	
	Pre-Prop 209					Pre-Prop 209				
Campus[‡]	Mean	S.D.	Change	Pre Prop 209	Change	Mean	S.D.	Change	Pre Prop 209	Change
UC Berkeley	679	91	15	0.675	0.030	794	82	5	0.847	0.026
UCLA	674	78	29	0.656	0.057	766	76	19	0.839	0.036
UC San Diego	681	69	40	0.661	0.061	760	55	13	0.826	-0.005
UC Davis	637	88	12	0.540	0.091	721	69	3	0.776	0.009
UC Irvine	621	78	34	0.626	0.039	693	83	8	0.685	0.047
UC Santa Barbara	605	78	44	0.599	0.104	682	67	34	0.743	0.054
UC Santa Cruz	590	101	29	0.598	0.044	683	73	5	0.688	0.033
UC Riverside	582	87	15	0.583	0.005	669	86	0	0.636	-0.014

Data Source: UCOP. [‡]Campuses are listed in order of their ranking in the 1997 *U.S. News & World Report* Top 50 National Universities.

The changes in student preparedness and graduation rates post-Prop 209 are not ordered according to the selectivity of the various campuses (Table 2). For example, UC Santa Barbara had the largest post-Prop 209 improvements in student academic preparedness and graduation rates, even though it ranked sixth out of the eight UC campuses in the *U.S. News & World Report* rankings. Furthermore, UC Berkeley and UC Riverside, which were the top and bottom ranked UC campuses, were both in the bottom third of post-Prop 209 gains in minority academic preparedness and graduation rates.

Taken together, the across-campus changes that occur in minority graduation rates and the academic preparation of those minorities that do enroll is potentially consistent with the view that the Prop 209 ban of affirmative action resulted in minority students being *better matched* to campuses based on their academic preparation. But as noted earlier, this improvement also may be consistent with greater selectivity in UC minority enrollments post-Prop 209.

3 Adjusting graduation gains for changes in observables

In the period after Prop 209 graduation rates increased for under-represented minorities by 4.4 percentage points and increased for whites by 2.5 percentage points. But characteristics of the entering students changed as well, with both under-represented minorities and whites coming in with higher academic indexes but lower parental education. Here we examine how much of the increase in graduation rates can be accounted for after controlling for changes in observables. We also investigate how the changes in graduation rates differ across different levels of the academic index.

Letting G_{it} denote whether individual i who entered college in period t graduated within five years, we first specify G_{it} as depending on whether the individual was in the period post-Prop 209, $POST_{it}$, a flexible function of observable characteristics X_{it}, and an error term, ϵ_{it}:

$$G_{it} = \alpha_0 POST_{it} + f(X_{it}) + \epsilon_{it} \tag{1}$$

We estimate several versions of (1) where we control for academic index, add controls for parental education, income, and initial major, and then add interactions between the academic index and the other variables. We estimate (1) separately for under-represented minorities and whites.

To assess how the graduation gains vary with a student's academic index, we interact whether the individual was in the post-Prop 209 period with their quartile in the academic index distribution. We specify the academic index quartiles separately for minorities and whites, using the pre-Prop 209 distribution of the academic index for enrollees. Denoting Q_{it} as the quartile of the academic index distribution for student i at time t, $Q_{it} \in \{1, 2, 3, 4\}$, we specify G_{it} as:

$$G_{it} = \alpha_0 POST_{it} + \sum_{q=1}^{3} \alpha_q I(Q_{it} = q) POST_{it} + f(X_{it}) + \epsilon_{it}, \tag{2}$$

where the graduation gains are then relative to those in the top quartile.

Results are presented in Table 3. Estimates of (1) show that controlling for the academic index reduces the overall graduation gains for under-represented minorities and whites

Table 3 pre- to post-Prop 209 changes in graduation rates: without & with controls

		Regression coefficient on:		
Regression Specification:	***POST***	***POST* × *Q*1(*AI*)[§]**	***POST* × *Q*2(*AI*)**	***POST* × *Q*3(*AI*)**
Under-represented Minorities				
No Controls	0.044***			
Control for *AI*	0.030***			
Extended Controls 1[†]	0.031***			
Extended Controls 2[‡]	0.030***			
Control for *AI*	0.005	0.041***	0.035***	0.028**
Extended Controls 1[†]	0.008	0.037**	0.031**	0.028**
Extended Controls 2[‡]	0.005	0.035**	0.037***	0.035***
Whites				
No Controls	0.025***			
Control for *AI*	0.013***			
Extended Controls 1[†]	0.014***			
Extended Controls 2[‡]	0.014***			
Control for *AI*	0.013**	-0.006	0.008	0.000
Extended Controls 1[†]	0.012**	-0.003	0.009	0.001
Extended Controls 2[‡]	0.011*	-0.002	0.011	0.002

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.
[§]Academic index quartiles are based on pre-Prop 209 enrollees and are group specific: breakpoints for the quartiles vary by minority/white status.
[†]Extended controls 1 include parents' education & income, initial major and *AI*.
[‡]Extended controls 2 include parents' education & income, initial major, alone and crossed with *AI* (and *AI* alone).

by 1.4 and 1.2 percentage points, respectively[13]. These reductions correspond to 29% of the graduation gains for under-represented minorities and 48% of the graduation gains for whites. Adding additional controls–parental education, income, and initial major–has little effect on these baseline results, if anything slightly raising the estimated graduation gains.

Table 3 also shows how the graduation gains vary across the academic index distribution. For under-represented minorities, the gains are concentrated in the bottom quartiles, with all specifications showing significantly higher gains for those in the bottom three quartiles relative to the top quartile. This is consistent with mismatch in that removing affirmative action means students in the lower quartiles are attending campuses that better match their levels of preparation. In contrast, the gains for whites are fairly uniform across the quartiles of the academic index distribution. The results for whites suggests the possibility of campuses responding to Prop 209, particularly since Prop 209 had little to no effect on the share of white students at each of the campuses, implying matching effects for whites are likely to be small.

The differences in the graduation gains between under-represented minorities and whites then motivates the possibility that the match between the campus and the student is important in determining graduation outcomes. But the evidence for whites also suggests something happened with the implementation of Prop 209 such that graduation rates improved for all levels of academic preparation. In the next section we develop a model that is flexible enough to capture these matching effects and return to the possibility of campuses responding to the passage of Prop 209 in Section 6.

4 The mismatch hypothesis and campus graduation production functions

In this section, we characterize the mismatch hypothesis as it applies to minority graduation rates. To fix ideas, consider the following characterization of the *graduation production function* for one of the UC campuses. Let $Pr(g = 1|AI, j)$ denote the graduation rate that campus j can produce for a minority student with an academic preparation index of AI. We shall maintain the assumption throughout that these campus-specific functions take the following linear form,

$$Pr(g = 1|AI, j) = \phi_{0j} + \phi_{1j} AI \tag{3}$$

for UC campus $j \in \{1, \ldots, J\}$. In the remainder of this section, we also shall assume that $Pr(g = 1|AI, j)$ is increasing in AI, i.e., $\phi_{1j} > 0$. (We do not restrict $\phi_{1j} > 0$ when estimating these campus-specific production functions below).

One could proceed by specifying the admission criteria of campuses in the presence and absence of affirmative action, characterizing the criteria students have for the campuses to which they apply and to which they enroll if admitted and that campuses use in its admission decisions and, thus, the matching of students to colleges (or alternative activities)[14]. For the purposes of assessing the mismatch hypothesis, it is sufficient to assume that relative to an affirmative action regime, a college under an affirmative action ban will place less (or no) weight on the diversity of an incoming student body and more weight on selecting students based on their academic preparation or AI. The mismatch hypothesis asserts that, under affirmative action, minority students are more likely to be matched to higher quality colleges for which they are less well-prepared than their non-minority counterparts. By banning affirmative action, this form of mismatch of minority students will be reduced, i.e., minority students will be "better matched" to colleges on the basis of their academic preparation (AI), and the outcomes of minorities, such as their graduation rates, will improve[15].

The validity of this mismatch explanation hinges on whether colleges differ in their graduation production functions and how they differ between high-quality (more selective) and lower quality (less selective) colleges. To see this, consider Figure 1, which illustrates two possibilities for the relationship between the production functions of a more-selective college, *Campus A*, and a less-selective one, *Campus B*. Panel (a) illustrates the case where Campus A has an *absolute advantage* over Campus B in producing higher graduation rates for students of *all* levels of academic preparation (AI). At the same time, the way Panel (a) is drawn, the higher quality campus, A, has a comparative advantage at producing higher graduation rates among better prepared students than Campus B. This latter assumption provides a motivation for why better prepared students tend to attend higher quality colleges.

For the predictions of the mismatch hypothesis to hold, one requires a stronger set of differences between the production functions of higher- and lower-quality campuses. To see this, consider Panel (b) of Figure 1. As before, Campus A has a comparative advantage in graduating better prepared students. Now, however, Campus A only has an absolute advantage in the production of graduations for better prepared students, i.e., only for $AI > \overline{AI}$. And, Campus B now has an absolute advantage in the production of graduations for less-prepared students ($AI < \overline{AI}$). Now consider what happens to a minority student

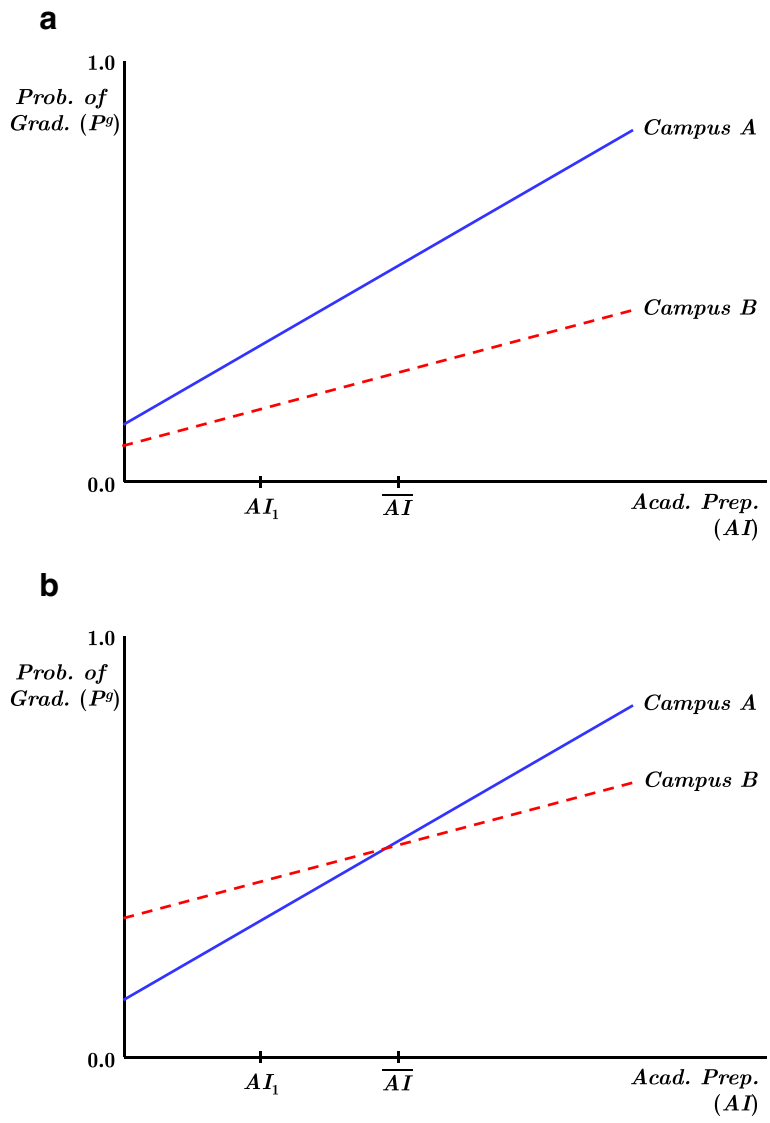

Figure 1 Alternative relationships between graduation production functions of higher and lower quality campuses. In **(a)**, Campus A has a comparative advantage for better-prepared students and an absolute advantage for all students; in **(b)**, Campus A has a comparative advantage for better-prepared students, but Campus B has an absolute advantage for all students with an AI below $\overline{AI}$.

with academic preparation AI_1 who was admitted and attended Campus A under affirmative action but is no longer able to get into Campus A once affirmative action is banned[16]. Because Campus B has an absolute advantage in graduating less prepared students, this student's likelihood of graduating from college increases by enrolling in Campus B, as the mismatch hypothesis predicts[17].

As the above discussion makes clear, the mismatch hypothesis requires lower-quality (less selective) universities to have an absolute advantage, and not just a comparative advantage, in graduating less academically prepared minority students. In the next section, we estimate campus-specific graduation production functions for each of the UC campuses and assess whether this condition holds across the UC system's higher and lower ranked campuses.

5 Estimating matching effects prior to Prop 209

The previous section outlined the flexibility needed in the graduation production function in order to operationalize the mismatch hypothesis. In this section, we present the basic model we estimate to gauge the importance of the match between the campus and the student to graduation outcomes. The specification relies only on data before Prop 209, essentially comparing graduation outcomes of students from different campuses but who had otherwise similar observed characteristics.

While Section 3 could be criticized for failing to account for post-Prop 209 minority enrollees being stronger in unobservable dimensions than pre-Prop 209 minority enrollees – and hence biasing the estimated effects of Prop 209 on minority graduation rates upward – the concern is the opposite when examining match effects using only the pre-Prop 209 data. Namely, minority students at highly ranked UC campuses are likely stronger on unobserved dimensions than minority students at lower ranked campuses. To address this issue, we take the approach used by Dale and Krueger (2002) and add to the baseline specification characteristics of the UC campuses where minority students submitted applications as well as characteristics of the campuses where minority students were admitted.

As we will show, results from both the baseline specification and from the Dale and Krueger approach show that the more highly ranked UC campuses have a comparative advantage in graduating more prepared students. Further, lower ranked UC campuses appear to have an absolute advantage in graduating students at the bottom of the distribution, suggesting the possibility that one of the reasons for the increased in graduation rates after Prop 209 was due to minority students being better matched.

5.1 Baseline model

Our baseline model simply extends the model from the previous section also to allow the probability of graduating to depend on her family background characteristics, X_{it}, to capture the influence of financial constraints and preferences and allowing the production function parameters to vary with the time period – pre-Prop 209 vs. post-Prop 209 – to allow for behavioral responses to these regime changes. Let G_{ijt} denote an indicator of whether minority student i who enrolled at UC campus j in Prop 209 regime t, $t = PRE, POST$, graduated. We then specify G_{ijt} as[18]:

$$G_{ijt} = \phi_{0jt} + \phi_{1jt} AI_{it} + X_{it}\phi_{2t} + \zeta_{it}, \tag{4}$$

where ϕ_{0jt} and ϕ_{1jt} are the parameters of the campus-specific production function in (3) and where ζ_{it} is an error term that captures unobserved (to the econometrician) student preferences and characteristics. Our baseline estimates are found by simply regressing the graduation outcomes of the students on their observed characteristics, allowing the intercept and slope to vary by the UC campus attended.

5.2 Dale and Kruger controls

Ideally, a student's unobserved preferences and characteristics captured by ζ_{it} would be independent from which campus they attended, their AI_{it} and their family background, X_{it}. If so, the parameters in Linear Probability Model in (4) would be consistently

estimated using standard regression methods. But some of a student's unobserved characteristics are likely to correlated with the quality/selectivity of the campus they attend. As has been noted in the literature[19], failure to control for the full set of factors will likely to result in biased estimates of the effects of attending more-selective colleges on the outcomes of interest.

To help mitigate this source of selection bias, we implement an approach similar to Dale and Krueger (2002) in which we estimate an extension of (4) in which we also control for the UC campuses to which students applied and were admitted as well as measures of the quality/selectivity of these campuses. We use alternative sets of measures to implement our version of Dale-Krueger. Let $DK_i^{(k)}$ the the kth set of campus quality/selectivity measures. Then the associated Dale-Krueger selection-adjustment for campus-specific minority graduation probabilities is given by:

$$G_{ijt} = \phi_{0jt}^{(k)} + \phi_{1jt}^{(k)} AI_{it} + X_i \phi_{2t}^{(k)} + DK_{it}^{(k)} \psi_t^{(k)} + \zeta_{it}^{(k)}, \tag{5}$$

where $\phi_{0jt}^{(k)}$ and $\phi_{1jt}^{(k)}$ again denote the campus-specific graduation production function parameters in (3), now adjusted not only for student background characteristics (X_{it}) but also for Dale-Krueger controls, $DK_i^{(k)}$. To assess the robustness of our estimates of ϕ_{0jt} and ϕ_{1jt}, we employ for four alternative specifications of $DK_i^{(k)}$. They are:

- **Specification 1:** Adds a set of indicator variables for whether the individual applied and was admitted to each of the eight UC campuses (sixteen indicator variables in all) to the baseline specification.
- **Specification 2:** Adds the number of UC campuses where the individual submitted applications and was admitted in each of the three tiers of UC campuses to Specification 1.
- **Specification 3:** Adds indicator variables for the highest ranked campus where the individual was admitted to the baseline specification.
- **Specification 4:** Adds the average academic index of the UC campuses where the individual submitted applications and was admitted to Specification 2.

For the Dale and Krueger strategy employed in (5) to be successful in accounting for selection in the estimation of these graduation production function parameters, it must be the case that students do not always attend the best UC campus to which they were admitted. In Table 4 we look at students who were admitted to different pairs of campuses and examine the probability of attending each campus in the pair, based on minority students who were admitted during the pre-Prop 209 period. Conditional on attending one of the campuses in the pair, the entries above the diagonal give the share that attend the campus along the row while the entries below the diagonal give the number of students that were admitted to the pair and attended one of the two campuses. Hence, 1,763 minority students were admitted to both UC Berkeley and UCLA in the pre-Prop 209 period and chose to attend one of these two campuses. Of the 1763, 53.3% chose to attend Berkeley. With only a few exceptions, the numbers above the diagonal in Table 4 are above fifty percent. This suggests that our ordering of colleges is reasonable as, conditional on being admitted to both campuses and enrolling in one of them, students are more likely

Table 4 Attendance decisions of minority students admitted to different pairs of UC campuses for pre-Prop 209 period

	UC Berkeley	UCLA	UC San Diego	UC Davis	UC Irvine	UC Santa Barbara	UC Santa Cruz	UC Riverside
Under-represented minorities:								
					Pre-Prop 209			
UC Berkeley	–	53.3%	76.6%	81.1%	81.7%	85.9%	87.9%	83.1%
UCLA	1,763	–	75.3%	80.5%	81.5%	87.3%	88.5%	83.0%
UC San Diego	834	1,194	–	53.9%	66.0%	62.8%	70.6%	66.8%
UC Davis	958	713	473	–	54.1%	55.6%	65.6%	64.3%
UC Irvine	416	1,160	438	364	–	49.9%	57.9%	64.3%
UC Santa Barbara	737	1,073	637	666	577	–	63.8%	62.0%
UC Santa Cruz	602	400	296	489	214	776	–	43.7%
UC Riverside	237	587	250	252	563	471	247	–
					Post-Prop 209			
UC Berkeley	–	53.1%	77.6%	89.6%	88.5%	91.4%	93.6%	90.4%
UCLA	855	–	80.8%	87.9%	91.9%	92.3%	93.2%	91.5%
UC San Diego	491	854	–	71.9%	73.5%	70.2%	82.3%	74.7%
UC Davis	548	488	385	–	53.1%	48.1%	77.0%	66.8%
UC Irvine	269	692	438	390	–	45.8%	65.4%	67.3%
UC Santa Barbara	451	755	541	572	592	–	75.5%	72.1%
UC Santa Cruz	264	265	192	473	272	691	–	45.2%
UC Riverside	208	492	253	374	756	628	504	–
Whites:								
					Pre-Prop 209			
UC Berkeley	–	65.7%	77.9%	79.9%	81.8%	84.3%	85.2%	83.3%
UCLA	1,923	–	72.9%	77.5%	85.0%	83.8%	84.9%	79.5%
UC San Diego	1,606	2,275	–	63.6%	79.1%	69.1%	73.4%	79.2%
UC Davis	1,337	1,170	2,274	–	72.7%	55.9%	64.1%	80.3%
UC Irvine	373	919	1,105	802	–	35.3%	51.7%	68.5%
UC Santa Barbara	924	1,411	2,410	2,833	1,517	–	61.7%	81.3%
UC Santa Cruz	710	392	997	1,568	412	2,947	–	66.6%
UC Riverside	108	273	437	351	537	672	308	–
					Post-Prop 209			
UC Berkeley	–	59.5%	79.5%	82.4%	90.8%	88.8%	88.9%	88.9%
UCLA	2,270	–	78.0%	84.2%	90.2%	88.2%	91.8%	84.5%
UC San Diego	1,867	2,722	–	69.8%	82.7%	67.3%	79.6%	81.2%
UC Davis	1,411	1,304	2,051	–	71.0%	44.9%	71.5%	83.2%
UC Irvine	414	1,006	1,073	910	–	26.6%	55.0%	73.6%
UC Santa Barbara	1,211	2,014	2,617	2,682	1,374	–	76.7%	85.4%
UC Santa Cruz	606	464	805	1669	567	2,335	–	69.1%
UC Riverside	135	343	436	601	762	809	637	–

For Row *A*, Column *B*, value of cell is: *Above diagonal:* If admitted to Campus *A* and *B*, Pr(Attends *A*|Attends *A* or *B*); *Below diagonal:* Number in race-period group admitted to Campus *A* and *B* and attended Campus *A* or *B*. (A student admitted to more than two campuses will appear in this count multiple times).

to attend the higher-ranked campus. However, Table 4 also reveals that a non-trivial share of students attend the lower ranked campus. This is particularly true for minorities in the pre-Prop 209 period where in all cases at least 10 percent of students chose the lower ranked campus, conditional on being admitted to both campuses and attending one of them.

5.3 Results

Estimates of the campus-specific parameters, ϕ_{0jt} and ϕ_{1jt}, for the Baseline Model in (4) and for four Dale-Krueger control model specifications in (5) using pre-Prop 209 ($t = PRE$) data on minorities are presented in Table 5. The models are estimated so that the academic index (AI) is normalized to have a zero mean and a standard deviation of one for minority enrollees in the pre-Prop 209 period. Both the campus-specific intercepts and slopes are measured relative to the intercept and slope for UC Riverside[20]. The campus-specific intercepts then reflect the difference in graduation rates for a minority enrollee at the average AI score, and the slopes are now normalized to be the percentage point gain in expected graduation resulting from a one standard deviation increase in the academic index.

The general pattern across the specifications suggests that the more highly-ranked campuses reward (penalize) students with high (low) academic indexes. Exceptions are UC

Table 5 Intercepts and slopes for UC campus-specific minority graduation rates for pre-Prop-209 period

		Model Specification:			
	Baseline	**(1)**	**(2)**	**(3)**	**(4)**
Campus-Specific Intercepts:					
UC Berkeley	0.018	-0.016	-0.020	-0.074***	-0.025
UCLA	-0.007	-0.037	-0.042	-0.078***	-0.046*
UC San Diego	0.010	-0.029	-0.035	-0.058**	-0.038
UC Davis	-0.069***	-0.068***	-0.065**	-0.135***	-0.069**
UC Irvine	0.036*	0.009	0.010	-0.023	0.006
UC Santa Barbara	0.006	-0.005	-0.004	-0.014	-0.005
Santa Cruz	0.001	0.006	0.002	-0.016	0.003
Campus-Specific Slopes:					
AI	0.053***	0.034**	0.036**	0.034**	0.031**
UC Berkeley	0.023	0.030*	0.025	0.042**	0.033*
UCLA	0.063***	0.068***	0.064***	0.078***	0.071***
UC San Diego	0.047**	0.059**	0.054**	0.063**	0.060**
UC Davis	0.055 ***	0.060***	0.056***	0.071***	0.063***
UC Irvine	0.022	0.027	0.024	0.035	0.029
UC Santa Barbara	0.021	0.024	0.020	0.019	0.024
UC Santa Cruz	-0.008	-0.007	-0.007	-0.004	-0.005

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Campus-specific intercepts are evaluated at mean academic index for pre-209 Minority students and are measured relative to UC Riverside.

Campus-specific slope coefficients on standardized academic index variable, $AI_{std,r,t}$ for $r = Minority$ and $t = Pre - 209$. Each coefficient measures the effect of a one S.D. increase in academic index on probability of graduation and these effects are measured relative of that for UC Riverside.

All specifications include the following control variables: parents' income and education and initial major.

Specification 1 adds a full set of dummy variables indicating whether the student applied to and/or admitted to each of the eight UC campuses.

Specification 2 adds to Specification 1 the number of campuses applied to and admitted to for each of three tiers of UC campuses, with Tier 1 which includes UC Berkeley, UCLA and UC San Diego, Tier 2 which includes UC Davis, UC Irvine and UC Santa Barbara, and Tier 3 which includes UC Santa Cruz and UC Riverside, and also dummy variables that indicate whether a student applied to campuses in the Tier above or in the Tier below the Tier to which they were admitted.

Specification 3 includes the base specification plus a set of dummies for the highest ranked campus a student was admitted to.

Specification 4 includes the controls in Specification 2, plus a student's total number of applications and admissions, respectively, as well as an average of average academic index of the applicants/admits for campuses the student applied/was admitted.

Davis' slope coefficient, which is higher than its rank, and UC Berkeley's slope coefficient, which is lower than its rank. With the exception of the baseline specification, the average minority enrollee would see a higher probability of graduating from any of the four bottom-ranked campuses than at any of the four top-ranked campuses, between 2 and 6.5 percentage points higher for Specification 4 depending on the campuses. With 60% of minority enrollees at the top four campuses in the pre-Prop 209 period, there would appear to be scope for increasing graduation rates through less aggressive affirmative action policies. While the differences in intercepts are often not statistically different, the point estimates are large. For example, Specification 4 shows that the average minority enrollee would be 4.6 percentage points less likely to graduate at UCLA than at UC Riverside. Highlighting the importance of match effects, if the student was one-standard deviation below the minority mean, the difference would increase to 11.7 percentage points. But if the student was one-standard deviation above the minority mean, her graduation probability would be 2.5 percentage points higher at UCLA than at UC Riverside.

To get a sense of the potential importance of match effects, we predict graduation probabilities at each campus for different percentiles of the minority academic index using Specification 4[21]. Table 6 ranks the campuses from highest to lowest predicted graduation probabilities for different percentiles of the academic index holding fixed the remaining characteristics (family income, the Dale and Krueger measures, etc.) at the minority sample average[22]. The rankings vary substantially across the academic index distribution. UC Santa Cruz and UC Riverside are the top two campuses for those at the 10th percentile or the 25th percentile of the academic index distribution yet are the bottom two campuses at the 90th percentile. At the other extreme, UCLA ranks second to last for the 10th and 25th percentiles yet is the top campus for those at the 90th percentile.

Table 6 also makes clear that the heterogeneity in graduation rates across universities is particularly large for those at the bottom of the distribution. The gap between the highest and lowest graduation rates across campuses for students at the 10th percentile of the academic index was 15.8 percentage points. For students at the 75th percentile of the academic index, the gap between the highest and lowest graduation rates was a third of the size at 5.2 percentage points.

6 Decomposition of post-Prop 209 graduation gains

The previous section illustrated that the match between the student and the university is important for graduation rates. Relatively less-prepared minority students see higher graduation rates at lower-ranked campuses while the reverse is true for the more-prepared students. Coupled with the gains in graduation rates post-Prop 209, this suggests the possibility Prop 209 improved graduation rates in part due to improving the match between the student and the campus.

But there are at least two other reasons Prop 209 may have improved graduation rates. The first is selection, as affirmative action bans may result in students who had the lowest probability of graduating no longer being admitted to any campus in the UC system. While Section 3 accounted for selection on observables, minority students in the post-Prop 209 period also may have been stronger on unobservables.

The second is that universities responded to affirmative action bans by changing how they mentored students and the students that attended these universities behaved and

Table 6 Rankings of UC campuses by predicted graduation rates at various percentiles of the high school academic index percentiles based on minority coefficients estimates†

Percentile of the Minority Academic Index									
10th		**25th**		**50th**		**75th**		**90th**	
UC Santa Cruz	0.611	UC Santa Cruz	0.627	UC Irvine	0.648	UC Irvine	0.689	UCLA	0.726
UC Riverside	0.602	UC Riverside	0.621	UC Santa Cruz	0.645	UC Santa Barbara	0.674	UC Irvine	0.725
UC Irvine	0.571	UC Irvine	0.607	UC Riverside	0.642	UC San Diego	0.666	UC San Diego	0.721
UC Santa Barbara	0.567	UC Santa Barbara	0.600	UC Santa Barbara	0.637	UCLA	0.664	UC Santa Barbara	0.707
UC Berkeley	0.535	UC Berkeley	0.574	UC Berkeley	0.617	UC Riverside	0.663	UC Berkeley	0.699
UC San Diego	0.488	UC San Diego	0.543	UC San Diego	0.604	UC Santa Cruz	0.663	UC Davis	0.694
UCLA	0.465	UCLA	0.527	UCLA	0.596	UC Berkeley	0.661	UC Riverside	0.682
UC Davis	0.453	UC Davis	0.510	UC Davis	0.573	UC Davis	0.637	UC Santa Cruz	0.679

Data Source: UCOP.
†Average predicted graduation probabilities in parentheses. The predicted probabilities were formed using the estimated coefficients for Specification 4 of (5) for minorities and were predicted using the characteristics of minority students that enrolled at one of the UC campuses in the years 1995–1997.

performed differently with the bans. With respect to universities, it is possible that they respond by instituting programs and activities that try to improve the graduation prospects of those minority students and those from disadvantaged backgrounds that did enroll after the ban. These might include instituting or improving tutoring and counseling programs, especially for freshman, in order to help them get through their first year of collegiate studies, reduce drop-out rates and, thereby, improve graduation rates. There is anecdotal evidence that UC campuses did take actions after Prop 209 to improve student retention rates. For example, UCLA changed the way its introductory courses for first year students were organized in the wake of Prop 209 in an attempt to improve the retention of "disadvantaged students"[23]. While some of these efforts were direct responses to the passage of Prop 209, others appear to have been in response to the rising (and continuing) attention to retaining college enrollees, especially those from disadvantaged groups[24]. We note that the efforts by UC campuses to improve outreach and retention of minority students after Prop 209[25] could not directly target racial and ethnic groups, which was deemed a violation of ban on the use of race and ethnicity "in the operation of ... public education" (Text of Proposition 209)[26]. This led to a restructuring of official campus programs to target disadvantaged, rather than only minority, students based on "academic profiles, personal backgrounds and social and environmental barriers that may affect [a student's] university experience, retention and graduation[27]." As a result, some of these retention efforts in response to, or coincident with, Prop 209 may have affected the graduation rates of both minority and non-minority students.

With respect to students, the imposition of affirmative action bans like Prop 209 also may have changed the stereotypes about the capabilities of minorities admitted to college that may result in either increased effort levels of minority students or greater returns to minority student effort. In a study using the same data sources as this paper, Antonovics and Sander (2013) find that the passage of Prop 209 did not find much evidence of what they refer to as a "chilling effect," of Prop 209 among minorities i.e., a decrease in the probability of enrolling at a UC campus among minorities who were accepted. As a possible explanation for the lack of this chilling effect, they speculate that the the elimination of affirmative action in admissions could have made minorities more comfortable, and as a result were more successful, because they were now attending schools were their professors and fellow students no longer perceived that minorities were admitted to their campuses based primarily on race or ethnicity but, rather, were admitted based on their academic preparation.

In this section we seek to separate out the gains in graduation rates after Prop 209 was implemented into three components: matching, selection, and a residual component. We refer to this residual component as behavioral response, which could have been the types of responses by universities and/or students noted above. We begin by showing our decomposition strategy and then discuss how Prop 209 affected the allocation of minorities across campuses. Next, we discuss how to separate out the behavioral response from selection. Finally, we show the decomposition results.

6.1 Overview

We begin with an overview of how our decomposition is conducted. Denote the policy regime as $r \in \{PRE, POST\}$ and x as the set of observed characteristics of students that affect the probability of graduating from a particular UC campus j as well as the

probability of being *assigned* to campus j'. Here, assignment refers to which particular UC campus j a student that enrolled in the UC system attended. Using Bayes' rule, we can express the *unconditional* probability of a minority student in regime r graduating from college as:

$$Pr(g=1|r)=\sum_x\sum_j Pr(g=1|j,x,r)Pr(j|x,r)Pr(x|r), \tag{6}$$

where $Pr(g=1|j,x,r)$ is characterized by the graduation production function for campus j in regime r, given characteristics, x; $Pr(j|x,r)$ is the probability of attending campus j given characteristics x and regime r, and $Pr(x|r)$ denotes the distribution of observed characteristics x under regime r. The inner sum in (6) is over the possible campuses and the outer sum is over the possible observed characteristics. The difference in graduation rates across the two periods can be expressed as:

$$\begin{aligned}\Delta_T &= Pr(g=1|POST)-Pr(g=1|PRE)\\ &=\sum_x\sum_j Pr(g=1|j,x,POST)Pr(j|x,POST)Pr(x|POST)\\ &\quad-\sum_x\sum_j Pr(g=1|j,x,PRE)Pr(j|x,PRE)Pr(x|PRE)\end{aligned} \tag{7}$$

The expression in (7) represents a natural way of characterizing the three channels through which Prop 209 affected graduation rates: (i) through campus assignment, $Pr(j|x,r)$, which, in turn, characterizes matching; (ii) through the graduation production function, $Pr(g=1|j,x,r)$; and (iii) through the distribution of the observed characteristics of minority enrollment in the UC system under regime r, $Pr(x|r)$[28].

To isolate how Prop 209 affected graduation rates through matching, we use the parameter estimates from the graduation production functions and the distribution of observed characteristics from the pre-Prop 209 period to characterize the differences in graduation rates due to changes in how minorities were allocated across campuses:

$$\begin{aligned}\Delta_M &=\sum_x\sum_j Pr(g=1|j,x,PRE)Pr(j|x,POST)Pr(x|PRE)\\ &\quad-\sum_x\sum_j Pr(g=1|j,x,PRE)Pr(j|x,PRE)Pr(x|PRE)\end{aligned} \tag{8}$$

Given the post-Prop 209 assignment rules, we can examine how changes in campus-specific graduation production functions (*BR*) – which is what we mean by *behavioral response* – affected graduation rates using:

$$\begin{aligned}\Delta_{BR} &=\sum_x\sum_j Pr(g=1|j,x,POST)Pr(j|x,POST)Pr(x|PRE)\\ &\quad-\sum_x\sum_j Pr(g=1|j,x,PRE)Pr(j|x,POST)Pr(x|PRE)\end{aligned} \tag{9}$$

Finally, we examine changes in *selection* of minority students enrolled in the UC system across regimes, using how the distribution of observed characteristics of minority students changed from pre- to post-Prop 209.

$$\begin{aligned}\Delta_S = &\sum_x \sum_j Pr(g=1|j,x,POST)Pr(j|x,POST)Pr(x|POST) \\ &- \sum_x \sum_j Pr(g=1|j,x,POST)Pr(j|x,POST)Pr(x|PRE)\end{aligned} \tag{10}$$

The sum of the three changes then gives the total change in graduation rates pre- and post-Prop 209.

$$\Delta_T = \Delta_M + \Delta_{BR} + \Delta_S. \tag{11}$$

In Section 5, we presented a Baseline specification for the campus-specific minority graduation production functions, $Pr(g = 1|j,x,r)$, displayed in (4) and specifications with Dale-Krueger controls in (5). Parameter estimates for the pre-Prop 209 versions ($r = PRE$) of these specifications were presented in Table 5 and Additional file 1: Table S3. To perform the above decompositions, we also need parameter estimates of these same production functions for the post-Prop 209 regime, i.e., for $Pr(g = 1|j,x,POST)$. The parameter estimates derived from post-Prop 209 data are found in Additional file 1: Table S5 and Table S6, respectively. The estimates for ϕ_{0jr} and ϕ_{1jr} differ across the pre- and post-Prop 209 regimes (Table 5 vs. Additional file 1: Table S5), suggesting there were behavioral responses to the Prop 209 in the graduation rates of minority students depending on their academic preparation (AI). But, we also find differences in the influences of the various Dale-Krueger controls (Additional file 1: Table S3 vs. Additional file 1: Table S6), suggesting that some care will need to be taken in order to truly separate behavioral responses from selection. Below, in Section 6.3, we outline ways to bound the relative importance of these two components in our decomposition of the Prop 209 graduation gains for minorities.

The rest of this section outlines how the remaining components of the decomposition are calculated as well as how we perform the decomposition.

6.2 Graduation gains due to matching

We first consider how Prop 209 affected the allocation of minority students across the different UC campuses. We use the same regressors for x that were included in our Baseline specification of the campus-specific graduation production functions in (4). We estimate the probability of being *assigned* to campus j, conditional on having enrolled in one of the UC campuses and as a function of x with a multinomial logit specification and allow the coefficients to differ across the two regimes[29]. The probability of being assigned to campus j in regime r given characteristics x is then:

$$Pr(j|x,r) = \frac{\exp(x\alpha_{jr})}{\sum_j \exp(x\alpha_{jr})} \tag{12}$$

Note that we do not include the Dale and Krueger controls when examining the assignment of students to campuses. Clearly these controls have different interpretations in the two regimes and implicitly include the dependent variable: if the student did not apply to a particular campus or was not admitted then that student could not be assigned to the campus. Estimates of our allocation mechanism will under-predict unobserved ability

at the top campuses and over-predict unobserved ability at campuses with lower rankings. However, this will not affect the results of our decomposition because we have specified unobserved ability to have the same effect on graduation probabilities at all campuses. Indeed, if matching on unobservables is important, the strategy we use is likely to underestimate the importance of match effects.

Estimates of the minority assignment rules for the two regimes are given in Additional file 1: Table S4. Table 7 gives the predicted probability of pre-Prop 209 students being assigned to each of the campuses using both the pre- and post-Prop 209 campus assignment rules for minorities. Assigning pre-Prop 209 students to UC campuses according to the post-Prop 209 rules shifts minority students out of the top three campuses and into the bottom five, with particularly large shifts to UC Riverside. As noted above, some of the students assigned to UC Riverside likely would not have been admitted to any campus in the UC system. It remains an outstanding question whether these students would then be better matched at institutions ranked below the UC campuses, such as those in the California State system, and therefore would graduate at an even higher rate or whether these institutions produce lower graduation rates than UC Riverside at all levels of academic preparation.

We then predict graduation probabilities using the two different assignment rules to calculate minority graduation gains from Prop 209 due to matching. Table 8 gives the results for each of our five specifications, both overall and for each quartile of the academic index[30]. Absent the Dale and Krueger controls (baseline specification), the gains from matching are positive but very small. Including the Dale and Krueger controls increases the overall minority graduation rate between 0.64 percentage points and 1.2 percentage points.

These estimated gains in minority graduation rates may seem small, given the substantial heterogeneity in graduation rates shown in Table 6. But the size of these gains is more indicative of the limited scope for reallocating students. For example, students at the very bottom of the distribution will be allocated to UC Riverside regardless of whether we use the pre- or post-Prop 209 campus assignment rules for minorities. And those at the top of the distribution may be hurt by shifting to the new rules. The last four rows of Table 8 illustrate the distributional effects by showing the graduation gains from matching for different quartiles of the academic index. Here we see that the gains are largest for those in the bottom quartile followed by those in the next-lowest quartile. These students

Table 7 Predicted distribution of pre-Prop 209 minority enrollees across UC campuses, using using pre- and post-Prop 209 assignment rules†

	Assignment Rule		
	Pre-Prop 209 Predicted	Post-Prop 209 Predicted	Difference
UC Berkeley	0.178	0.100	-0.078
UCLA	0.217	0.140	-0.077
UC San Diego	0.084	0.072	-0.012
UC Davis	0.118	0.127	0.009
UC Irvine	0.087	0.113	0.026
UC Santa Barbara	0.144	0.152	0.008
UC Santa Cruz	0.077	0.107	0.030
UC Riverside	0.095	0.190	0.095

Data Source: UCOP.

Table 8 Estimated gains in minority graduation rates from Prop 209 due to matching

	Model Specification:				
	Baseline	**(1)**	**(2)**	**(3)**	**(4)**
Average Gain	0.13%	0.64%	0.69%	1.20%	0.77%
AI Quartile 1	0.81%	1.51%	1.45%	2.20%	1.66%
AI Quartile 2	0.18%	0.80%	0.85%	1.45%	0.96%
AI Quartile 3	-0.22%	0.26%	0.36%	0.80%	0.40%
AI Quartile 4	-0.26%	-0.01%	0.09%	0.36%	0.06%

See Table 5 for descriptions of Specifications 1-4 in this table.
Final four rows of the table give estimated matching effects for only those in each quartile of the pre-209 Minority *AI* distribution.

benefit from being shifted down to campuses where they are more competitive. Smaller, or negative, gains are seen for those in the top two quartiles, both because these students are better matches for higher-ranked campuses and because there is less across-campus heterogeneity in graduation rates for better-prepared students.

6.3 Bounding behavioral responses to Prop 209 and selection effects

We now turn to how to isolate the behavioral response to Prop 209, i.e., Δ_{BR} in (8), using the pre-Prop 209 and post-Prop 209 production function parameter estimates found in Table 5 and Additional file 1: Tables S3, S5 and S6, respectively[31]. As noted above, the issue is how to adjust the Dale and Krueger effects across the two regimes. We can obtain the predicted effects from the Dale and Krueger measures under specification k for a student i in regime r using:

$$PDK_{ir}^{(k)} = DK_{ir}^{(k)}\hat{\psi}_r^{(k)} \tag{13}$$

from equation (5). However, we need to be able to map the pre-Prop 209 effects of the Dale and Krueger controls, $PDK_{ir}^{(k)}$, into their post-Prop 209 counterparts. We do this in two ways, one of which we believe provides an upper bound on the increase in graduation rates due to the behavioral response, with the other providing a lower bound.

We first assume that the distribution of unobservables is the same both in the pre- and post-Prop 209 periods among minority students admitted to any UC campus, regardless of whether or not the student ultimately enrolled in the UC system. For those admitted to at least one campus, the nth percentile $PDK_{PRE}^{(k)}$ is matched to the nth percentile of $PDK_{POST}^{(k)}$. Recall that the change in graduation rates due to the behavioral response is given by:

$$\begin{aligned}\Delta_{BR} = &\sum_x \sum_j Pr(g=1|j,x,POST)Pr(j|x,POST)Pr(x|PRE) \\ &- \sum_x \sum_j Pr(g=1|j,x,PRE)Pr(j|x,POST)Pr(x|PRE)\end{aligned} \tag{14}$$

Hence when we calculate the change in behavioral response, we replace the contribution of $PDK_{POST}^{(k)}$ to our estimate of $Pr(g=1|j,x,POST)$ for each student with the value of $PDK_{PRE}^{(k)}$ at the same percentile of the distribution for admitted students.

The behavioral response as estimated above is likely an upper bound on the behavioral response because our matching procedure assumes the unobservable quality of minority students accepted to at least one UC campus is the same in the pre and post-Prop 209 periods. However, due to more students being rejected from all of the UC campuses, minority

students who enrolled post-Prop 209 are likely stronger in the unobservable dimensions captured by our Dale and Krueger controls than their pre-Prop 209 counterparts. The share of minority applicants who are rejected from all UC campuses where they submitted applications rose by 9.2% from the pre-period to the post-period.

In our second method, we drop the bottom 9.2% of pre-Prop 209 admits. We then repeat the matching for the remaining pre-Prop 209 students' Dale and Krueger effects to their post-Prop 209 counterparts by matching percentiles of their distributions. Since we assume in this version of the matching procedure that the excess UC rejections in the post-Prop 209 regime represent the least prepared minority students, in contrast to the previous assumption that the distribution did not change, we consider this method a lower bound on behavioral response, and therefore also an upper bound on the effect of selection.

To implement the procedure, we now have the issue of calculating $PDK^{(k)}_{i,POST}$ for the bottom 9.2% of minority admits in the pre-Prop 209 period that we just dropped from the matching. We assume that, had we observed the values of $PDK^{(k)}_{i,POST}$ for those rejected from all of the UC campuses in the post-Prop 209 period but who would have been accepted to at least one of the campuses in the pre-Prop 209 period, the distribution of $PDK^{(k)}_{i,POST}$ would be normal, implying what we actually observe is a truncated distribution. Given the truncated distribution, we can calculate the variance for the full distribution and forecast $PDK^{(k)}_{i,POST}$ for those in the left tail.

6.4 Decomposition results

The results for the decomposition for our five specifications are given in Table 9, showing both the level changes in graduation rates due to each of the three factors (matching, behavioral response, and selection) as well as the share of the total post-Prop 209 gain. The first row gives the matching effects from the first row of Table 8, but now adding the share of the total graduation gain. The share of the total is very small absent the Dale and Krueger controls, with the Dale and Krueger controls the share ranges from 14.7% to 27.7% of the total gain.

The next set of rows present our estimates of the upper and lower bounds for the behavioral response accompanied by the corresponding estimates of the selection component. With the Dale and Krueger controls, the upper bound on the behavioral response ranges from 2.2 percentage points to 2.9 percentage points, or between 50% and 67% of the total. The lower bound estimates range from 1.0 percentage points to 1.5 percentage points, or between 23% and 33% of the total. Interestingly, these gains, particularly those for the lower bound, line up well with the reduced-form gains for whites found in Table 3.

7 Conclusion

In this paper we have examined how the match between the student and the college she attends affects college graduation rates. We have found evidence that less-selective campuses in the UC system tend to be better at graduating less-prepared students, with more selective campuses better at graduating more-prepared students. These results are relevant to the debate over the merits of affirmative action in university admissions to the extent that affirmative action leads to inefficient sorting.

Using data before and after an affirmative action ban, we found evidence that Prop 209 did lead to a more efficient sorting of minority students within the UC system.

Table 9 Decomposing the effect of Prop 209 on minority graduation rates

	Model Specification:									
	Baseline		(1)		(2)		(3)		(4)	
	Level	Share of Total	Level	Share of Total	Level	Share of Total	Level	Share of Total	Level	Share of Total
(A) Improved Matching	0.13	3.0%	0.64	14.7%	0.69	15.8%	1.20	27.7%	0.77	17.8%
Upper Bound on Behavioral Response										
(B) Behavioral Response	3.06	70.5%	2.91	67.0%	2.92	67.1%	2.21	50.8%	2.80	64.4%
(C) Selection	1.15	26.6%	0.79	18.2%	0.74	17.1%	0.93	21.5%	0.77	17.8%
Lower Bound on Behavioral Response										
(B') Behavioral Response			1.44	33.2%	1.33	30.7%	0.43	9.8%	1.01	23.3%
(C') Selection			2.26	52.1%	2.33	53.5%	2.72	62.5%	2.56	58.9%

Specifications as listed in Table 5.
Selection effect calculated as *Total Increase* $-(A) - (B)$.
For results dropping bottom of PRE admit distribution, baseline not reported because there is no DK distribution from admission variables.

However, the effects were relatively small and we can say little about what happened to those that did not attend a UC campus as a result of Prop 209[32]. Given large differences in academic preparation due to differences in the family backgrounds of students and the quality of the primary and secondary schools they attended, there is little scope for dramatic shifts in graduation outcomes by re-sorting of students across campuses[33]. That being said, our results indicate that better matching of students to campuses based on academic preparation does produce improvements in graduation rates, especially for those students in the bottom part of the distribution of academic preparation. Further, while matching effects are small when comparing five-year graduation rates, a companion paper (Arcidiacono et al. 2013) shows that mismatch effects are much larger when looking at persistence in STEM fields and in time to graduation.

The size of the change in graduation rates not accounted for by matching or selection indicates that other responses to Prop 209 were important. The anecdotal evidence that we cite offers one possible response that is quite intriguing, namely that the imposition of an affirmative action ban may have induced universities to expand their efforts to keep students from dropping out and completing their studies. Previous studies of affirmative action have ignored the potential for such institutional responses. More attention should be focused on them and their role in accounting for the effects of affirmative action bans.

More generally, finding ways to improve the college graduation rates of minorities - regardless of the motivation - would appear to be of growing importance, given the evidence that attending but not graduating from college has sizable consequences. Acemoglu and Autor (2011) have shown that earnings and employment prospects of less educated workers have declined sharply since the late seventies. For example, the hourly wage of college graduates in the U.S. was approximately 1.5 times the hourly wage of the typical high-school graduate in 1979, but this ratio has increased to 1.95 by 2009. Hence, current inequalities across races may perpetuate or even exacerbate if graduation rates of minorities are not improved.

Endnotes

[1]In April 2014, the Court upheld, in *Schuette v. Coalition to Defend Affirmative Action*, the right of Michigan's citizens to amend that State's constitution to prohibit the State from engaging in affirmative action in public employment, higher education and contracting. This case follows the 2013 Supreme Court ruling in *Fisher v. University of Texas* which made clear that the use of race in college admissions is restricted in remitting the case back to the appellate court.

[2]See the debate over mismatch effects in law schools in Sander (2004, 2005a, 2005b), Ayres and Brooks (2005), Ho (2005), Chambers et al. (2005), Barnes (2007) and Rothstein and Yoon (2008).

[3]Based on five-year graduation rates. We use five-year gradation rates throughout our analysis.

[4]This may be a result of the UC system placing more weight on characteristics correlated with race after Prop 209 since they could not explicitly take race into account. See Antonovics and Backes (2013b) for a discussion.

[5]See Antonovics and Sander (2013) for a more detailed discussion of this data set.

[6]The corresponding data for Asian American and Other Races (including un-reported) are given in Additional file 1: Table S1.

[7]The number of California public high school graduates by race and year is given at http://www.cpec.ca.gov/StudentData/StudentSnapshot.ASP?DataReport=KGrads. The number of California applicants by race and year can be found at http://statfinder.ucop.edu. While not all of the minorities applying, enrolling, or graduating from UC campuses are from California's public high schools, a large fraction are and we use this benchmark to account for the trends in the numbers of minorities at risk to go to college.

[8]Given that totals in Table 1 in each category include occasional cases with missing data; when calculating average sample characteristics, individuals missing that data are dropped. This includes enrollees with missing graduation information, so Graduation Rate in Table 1 is not identical to graduates/enrollees.

[9]Graduation rates are measured as graduating in 5 years or less. There are a small number of individuals that are listed as graduating but do not have a graduation time. In the period we analyze, these individuals are almost exclusively listed as having a major classified as 'Other'. We drop these individuals from our sample though our qualitative results are unaffected by the treatment of these individuals.

[10]We are unable to determine whether, after Prop 209, these more advantaged minorities who applied and were accepted to a UC campus went to colleges not subject to Prop 209, i.e., private colleges in California or public or private colleges outside of the state. But we doubt that they disproportionately ended up at less-selective public colleges in the state, i.e., at CSU campuses or one of California's community colleges, or not attending college.

[11]For example, Turner (2004) finds that students of mothers with a college degree have a 14 percentage point higher probability of attaining a BA degree than do students whose mothers do not.

[12]The 1997 *U.S. News & World Report* rankings of National Universities are based on 1996–97 data, the academic year before Prop 209 went into effect. The rankings of the various campuses were: UC Berkeley (27); UCLA (31); UC San Diego (34); UC Irvine (37); UC Davis (40); UC Santa Barbara (47); UC Santa Cruz (NR); and UC Riverside (NR). The one exception is that we rank UC Davis ahead of UC Irvine. The academic index is significantly higher for UC Davis and students who are admitted to both campuses and attend one of them are more likely to choose UC Davis. See Table 4.

[13]Additional file 1: Table S2. presents the coefficient estimates for the extended sets of control variables.

[14]See Epple et al. (2008) for such an equilibrium model of college admissions under affirmative action and when it is banned.

[15]See Dillon and Smith (2009) for reasons why students end up over-matched or under-matched.

[16]If students know their academic preparation then they would presumably internalize the fact that their graduation rates are lower at the more selective campus. In this regard, students may be interested in a different outcome. For example, selective universities may provide amenities to minority students that more than compensate for the worse graduation probabilities. However, students may not be well informed about their success probabilities. For instance, Arcidiacono et al. (2011) show that affirmative action can lead minority students to be worse off if universities have private information about how well the student will perform at their school. In this regard, Bettinger et al. (2013) and Hoxby and Avery 2012 show that information may be a serious concern among low income students.

[17]Campus B having a comparative, but not absolute, advantage over A with respect to graduations among less prepared students, as in Panel (a) of Figure 1, is not enough to generate the implications of the mismatch hypothesis. To see this, note that if higher quality colleges have an absolute advantage in graduating all students as in Panel (a), then a less prepared minority student with AI_1 ($AI_1 < \overline{AI}$) that was admitted to Campus A under affirmative action will experience a *lower*, rather than *higher*, graduation rate after affirmative action is banned and she can no longer attend Campus A.

[18] We estimate (4) with the Linear Probability Model.

[19] See, for example, Black et al. (2001), Dale and Krueger (2002), Black and Smith (2004), and Hoxby (2009).

[20] Additional file 1: Table S3 presents estimates of the coefficients on the various sets of control variables that were included in the alternative selection-corrected specifications of the campus-specific graduation production functions in (4) and (5) but not presented in Table 5.

[21] Relative rankings of the campuses in terms of predicted graduation rates are fairly similar across the different specifications.

[22] Those with lower academic indexes are likely worse off on the other characteristics as well but since the estimated match effects vary only across the academic index, varying these other observed characteristics neither changes the ranking of the campuses nor does it change the differences in graduation probabilities across campuses conditional on the percentile of the academic index.

[23] See "Intercollegiate Forums at UCLA discuss Retention of Minorities," *Daily Bruin*, March 2, 1998.

[24] See "Scholars urge Early Help for Minorities," *UCLA Today*, March 16, 1998.

[25] A brief description of how outreach programs have been implemented can be found in "In California, Push for College Diversity Starts Earlier," *The New York Times*, May 7, 2013.

[26] See "Prop. 209 Mandates Changes on Campus," *UCLA Today*, October 10, 1997. As noted in Horn and Flores 2003, some of the post-Prop 209 efforts to improve the retention of minority enrollees at UC Berkeley were handled by student-run organizations who were not directly subject this provision of Prop 209.

[27] "Prop. 209 Mandates Changes on Campus," *UCLA Today*, October 10, 1997.

[28] Note that here we are effectively assuming that universities change their graduation production functions in response to the changes in the assignment rules as the primary effect of Prop 209 was to change how minorities were allocated to colleges.

[29] Here we ignore the fact that some of these students would not be admitted to any of the campuses post-Prop 209. This aspect of selection process is accounted for by changes in the distribution of the xs, $Pr(x|r)$, across regimes.

[30] As before, the quartiles are assigned based on the academic indexes for minority enrollees in the pre-Prop 209 period.

[31] It is possible, however, that universities may have implemented policies to improve graduation rates prior to Prop-209 that took awhile to come into effect. In this case, the behavioral response was not to Prop 209 itself.

[32] While estimates suggest selective campuses see a drop in minority enrollment following affirmative action bans (Long 2004; Hinrichs 2012), overall college enrollment rates remain relatively unaffected following a ban (Backes 2012; Hinrichs 2012).

[33] These results are consistent with Arcidiacono and Koedel (2014) who find that most of the black/white differences in college graduation rates stem from differences in student academic preparation.

Additional file

Additional file 1: Appendix. Table S1. Characteristics of UC applicants, admits, and enrollees by race, pre-Prop 209 and change post Prop 209. **Table S2.** Coefficient estimates on extended controls variables for UC graduation rate regressions in Equations (1) and (2). **Table S3.** Coefficient estimates for selection-corrected campus graduation production functions in (4) and (5) not reported in Table 5, using pre-Prop 209 data. **Table S4.** Coefficients from pre- and post-Prop 209 minority enrollee campus assignment rules. **Table S5.** Intercept and slope for UC campus-specific minority graduation rates for post-Prop 209 period. **Table S6.** Coefficient estimates for selection-corrected campus minority graduation production functions in (4) and (5) not reported in Table S5., using post-Prop 209 data.

Competing interests
The IZA Journal of Labor Economics is committed to the IZA Guiding Principles of Research Integrity. The authors declare that they have observed these principles.

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