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The case of computer science education, employment, gender, and race/ethnicity in Silicon Valley, 1980–2015

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ABSTRACT

We analyse race and gender trends in the Silicon Valley technology industry from 1980 to 2015, with a focus on education, employment and wages in computer science. Racial gaps in representation are more salient among programmers than in the overall technology labour force; in addition, we document a stable or increasing gender gap across all races in computer science. However, these demographic shifts are not always consistent with either a pipeline argument that there are insufficient supplies of potential underrepresented programmers or a wage explanation. Hispanic males, for example, have had increasing rates of computer science degree completions yet decreasing representation in the programmer labour force. On the other hand, White females have had decreasing representation among both degrees and the labour force despite comparatively high wages in the technology sector. The persistent and increasing race and gender gaps suggest that policies to attract underrepresented groups need to be differentiated by the group and may require significant changes in industry culture to increase the representation of these groups.

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Race; gender; higher education; computer science; technology

1. Introduction

Science, Technology, Engineering and Maths (STEM) higher education is central to the debate on whether training more women and disadvantaged minorities in STEM majors can help close gaps in job opportunities and income.[1] Given the rapidly growing technology sector, graduating more women and underrepresented minority STEM from universities could be viewed as a way to equalise gender wage differences and increase minority social mobility. Certain fields, such as software development, seem to offer especially great possibilities for higher wages and the resulting social mobility (Xue and Larson 2015).

However, such a scenario implicitly assumes that regardless of gender or race/ethnicity, STEM graduates have equal access to higher-paying high tech jobs and are therefore similarly motivated to take university education leading to STEM professions. Our paper explores this assumption by examining race-ethnic/gender differences in degree attainment and the employment and wages of college graduates over the past 35 years in one prototypical example of high tech industry: Silicon Valley, California. Although Silicon Valley has its own peculiarities (Saxenian 1994), its labour market practices are representative of practices in the high tech industry globally (Benner 2008). Our analysis has important implications across economies for relying primarily on STEM higher education policies to equalise opportunity through employment in high tech occupations.

The six counties in the Bay Area surrounding San Francisco employ over 400,000 (330,000 manager and professional) workers in the technology industry. There have been dramatic changes

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in the racial and gender composition of this sector's workforce since 1980, and significant increases in the percent with advanced degrees. In the 1980s, technology companies seemed to have shifted to hiring White females in professional and management jobs (Carnoy and Gong 1996). But after 1990, this was superseded by large relative increases in Asian male and (less so) Asian female employment, mainly non-US citizens. Hispanics (the largest minority group in California) and Blacks have made little or no inroads into the industry despite, in the case of Hispanics males, significant increases in the number achieving computer science degrees.

A growing body of research suggests that while gender and race disparities have been widely documented in STEM (Beede et al. 2011; Landivar 2013; U.S. Equal Employment Opportunity Commission 2016), these gaps may be particularly severe in computer science, one of the major disciplines in STEM. Although the proportion of females earning degrees in STEM has risen in most STEM fields, computer science remains one of the STEM disciplines with the lowest proportion of women (National Science Foundation 2017). Furthermore, the gender wage gap is smaller in STEM compared to non-STEM jobs, but the computer and mathematics job category have the highest gender wage gap among the STEM fields (Beede et al. 2011). In addition, while there has been increasing representation of Blacks and Hispanics in STEM degrees (National Science Foundation 2017), these minorities have relatively lower representation in computer occupations than in other STEM occupations, specifically the largest of the STEM occupations, software developer ('programmers') (Landivar 2013).

This paper provides a broad overview of race and gender employment patterns in the technology industry from 1980 to 2015. We cannot provide a causal analysis of race/gender gaps in the technology industry, but we can explore two common explanations for such differences – the supply of potential programmers (higher education computer science graduates) and trends in the wages of employed programmers. To analyse the supply of potential programmers, we examine the programmer pipeline as a possible factor for demographic differences in the programmer workforce. Many papers have used or critiqued a 'leaky pipeline' metaphor for STEM workers (Metcalf 2010, for a review). Whether or not the pipeline is the most appropriate metaphor, gender and racial disparities have been observed in the supply of STEM labour, 'explained' by factors such as attitudes and exposure to technology in junior high and high school (Google Inc. and Gallup Inc 2016; Riegle-Crumb, Moore, and Ramos-Wada 2011; Quinn and Cooc 2015) and enrolment and persistence in STEM courses in higher education (Katz et al. 2003; Griffith 2010). Higher education is the most common transition into the professional workforce and thus a critical juncture for understanding its demographics. Keeping this in mind, we examine race and gender trends in students who major in computer science, which we use as a proxy for the numbers of potential programmers by race and gender.

We also examine wage differences as a possible factor in explaining the demographic employment trends we observe for different race-gender groups. We add to the broader literature on wage differences (see Altonji and Blank 1999) by including the intersectionality of sex and race (Browne and Misra 2003) in the analyses. In addition, we focus on wages in a particular occupation, programmers, which provides a more nuanced view on potential wage inequalities that goes beyond occupational segregation (see Petersen and Morgan 1995) or high/low skills gaps (Goldin and Katz 2007).

Our results show that the technology industry is becoming increasingly male (contrary to trends in the 1980s), highly educated (advanced degrees), Asian, and non-citizen, and is characterised by a pervasively low representation of Hispanics and Blacks. These trends are even more dramatic among programmers. Our analysis suggests that the masculinisation and the continued low representation of Hispanics and Blacks may have different explanations. Although there is some evidence of gender wage gaps, the computer science major in U.S. higher education is also becoming increasingly masculinised, suggesting that gender employment trends could reflect pipeline issues. To the contrary, the supply of Hispanic male computer science majors has increased significantly, but not their employment in the Valley's programmer labour force. This suggests that low employment of Hispanics may be due to employer preferences, not pipeline effects.

Section 2 describes the data used in the analyses. We then undertake a broad overview of the demographic trends in the Silicon Valley technology industry (Section 3). We go on to discuss demographic trends in computer science higher education graduates and in programmers employed in the Valley's labour force (Section 4). In Section 5, we analyse wage trends for White versus Asian male and female programmers – citizens and non-citizens – to better understand how higher education supply interacts with possible employer preferences. Section 6 discusses the significance of these findings.

2. Data

To construct the dataset of race and gender in computer science higher education, we combined data from the Integrated Postsecondary Education Data System (IPEDS) with data from the Open Doors[2] surveys (Open Doors). We use IPEDS completion data for computer science degrees, including race and gender data, from the earliest available data in 1985 to 2015 for California[3] and include national data for context. We combine these data with the country of origin data from the Open Doors surveys for non-resident alien students whose race is not identified. This combination creates degree completion numbers by race and gender for computer science undergraduate and graduate degrees.

The labour force analyses use microdata from the 5% sample in 1980, 1990 and 2000 U.S Censuses and the 1% samples of the 2010 and 2015 American Community Surveys.[4] We limit the sample population to the geographic region most salient in technology: Silicon Valley,[5] and further limit the sample to full-time full-year (FTFY) workers in the labour force, defined as individuals who usually work 35 h a week or more and worked at least 50 weeks in the previous year.[6] All analyses are weighted by individual weights.

We restrict our detailed analyses to one specific occupation, software developers[7] ('programmers'). Although there have been several re-classifications of technology occupations in the census over time, the definition of the programmer occupation has remained stable since the census began recording information on technology professions in 1970, and it is easily comparable across years (Beckhusan 2016). Programmers are part of the professional occupation category, and they span across industries.

Research suggests that gender wage gaps are due largely to differences between rather than within occupations or industries. Narrowing our focus to programmers minimises potential differences between occupations and produces a more conservative estimate of wage gaps (Petersen and Morgan 1995). Because of low numbers of observations in wage data for Hispanics and Blacks, our analysis of wage data is restricted to Whites and Asians. Hourly wages are restricted to positive wages (i.e. zero wages are dropped) of full-time, full-year workers and are constructed by dividing the annual income from work in that occupation by the number of weeks worked per year and number of hours worked per week.[8]

3. Silicon Valley context

In 2015, 2% of the national full-time, full-year labour force was in Silicon Valley, yet 7.5% of the technology labour force and 10% of programmers were employed there, which illustrates the importance of this region in the technology sector.[9] Several demographic trends characterise the Valley's technology industry[10]. First, the managerial and professional labour force has become more educated – 90% of all managers and professionals[11] in technology held at least a bachelor's degree, and almost half the managers and professionals had graduate degrees in 2015. Second, the technology labour force became more Asian and less White in the great expansion of the industry in 1980–2015. It also remained less female.[12] Although their absolute numbers increased from 1980–2015, Hispanics and Blacks had a consistently low presence as managers or professionals in technology.

In addition, the percentage of foreign (non-citizen) workers is particularly high in Silicon Valley. Nationally, the percentage of foreign workers has been increasing, from about 3% in 1980 to 8.5% in 2015, and is even higher in the technology industry (11%). Meanwhile, in Silicon Valley, the percentage of foreign workers was 7% in 1980 and increased to 18% in 2015. Foreign workers comprised nearly a quarter of the Valley's technology labour force and 39% of programmers in 2015. Since foreign technology workers are likely to enter the U.S. labour force through the U.S. university system – especially through graduate STEM education (Carnoy 1998), the availability of large numbers of post-baccalaureate foreign student graduates may be a key factor in explaining both the attractiveness of hiring foreign (mainly Asian) workers, and the rapid increase in the proportion of advanced degrees among technology professionals and managers. These trends in the overall technology industry provide the context for the next section which focuses specifically on the education and employment demographics of programmers, the 'prototypical' occupation in technology. We also examine the possible implications of the trend of employing non-citizen Asians as programmers for Asian-White wage gaps in Section 4.

4. The education and employment of programmers

Undergraduate and graduate degrees in computer science

One possible explanation for these changes in high tech employment is trends in the racial and gender demographics of STEM higher education programmes. This section discusses these dynamics for undergraduate and graduate computer science (CS) degree completions in California, a main region supplying the pool of potential programmer candidates in Silicon Valley. The analyses provide a description of the potential programmer pipeline by race and gender immediately prior to entry in the labour force. Although the potential technology labour force is not limited to California, it is likely that the demographic trends in the state's CS programmes heavily influence workforce composition in Silicon Valley.

A key factor explaining the increase in Asian employment in the technology industry is the major role that foreign graduates have come to play in the supply of high tech labour. Although international students have remained a relatively low percentage of total degrees earned in the U.S., up from 2.5% in the 1980 to 4.8% in 2015 (Institute of International Education, Inc 2015), they are increasingly concentrated in the STEM fields, particularly at the graduate level. By 2015, the proportion of graduate degrees in, for example, computer science, earned by foreign students was 56% nationally and 60% in California[13].

The countries of origin for these international students have become increasingly concentrated in East and South Asia. The percentage of international students from Asian countries has increased from 29% of all international students in 1980 to 64% by 2015[14]. Just several countries make up the bulk of these students. The most current Open Doors data indicates that over half of all international students are from China, India and South Korea (Institute of International Education, Inc 2015).

Trends for undergraduate and graduate international students are similar, but there has been and continues to be a higher concentration of international Asian students in graduate programmes (Table 1). In 1986, 37% of international undergraduates were from Asian countries whereas 55% of international graduate students were from Asian countries. These percentages increased dramatically by 2015, when 60% of international undergraduates and 72% of international graduate students were from Asian countries.

We use these data on the countries of origin of international students to construct the race and gender percentages over time for those who completed a degree in computer science in California (Figure 1). We impute race from the countries of origin to calculate the distribution of race among international students and assign race to foreign students, creating overall race-gender percentages of degree completions instead of by citizenship status. These percentages probably represent a lower bound for Asians, since Asians are more likely to pursue CS than other fields. The percentages of different race-gender groups show a more distributed demographic for degree completions than the labour force percentages. Furthermore, there are differences between the racial and gender distributions of bachelor's degree and graduate degree completions, which may reflect the more international population of those who obtain graduate degrees.

Table 1. United States: Percentage of international students from the region of origin, by academic level.

	Africa		Asia		Europe		Latin America		Middle East		North America		Oceania		World Total #	
Year	UG	G	UG	G	UG	G	UG	G	UG	G	UG	G	UG	G	UG	G
1985-1986	11.3	9.5	37.2	54.8	9.2	11.1	17.7	8.0	17.5	11.4	5.8	4.2	1.3	1.0	149,200	132,430
1989-1990	8.0	5.4	42.7	64.9	12.4	11.0	17.2	6.9	12.3	7.0	6.0	4.1	1.4	0.7	137,560	169,820
1994-1995	5.2	4.0	52.2	64.8	14.7	13.2	13.2	7.2	7.3	5.8	6.1	4.3	1.2	0.7	228,184	195,166
1999-2000	8.2	3.8	47.0	62.2	16.1	14.2	15.2	8.6	7.1	6.1	5.2	4.5	1.1	0.7	249,786	225,383
2004-2005	9.2	4.2	48.6	65.1	13.1	11.6	16.5	8.1	5.8	5.5	5.7	4.9	1.0	0.6	247,255	269,933
2009-2010	7.3	4.1	56.9	68.6	10.3	8.9	12.5	7.3	6.9	6.5	5.1	4.1	0.9	0.5	274,431	293,885
2014-2015	4.7	2.7	59.9	71.8	9.1	7.9	10.2	5.7	12.0	8.4	3.3	2.9	0.8	0.5	398,824	362,228

Source: Open Doors data, 1985–2015.

Notes: For years 1979–80 & 1984–85 Open Doors data do not include a breakdown of country of origin by academic level, so 1985–86 data is the earliest year used. Starting in 2009–10, Cyprus & Turkey were re-categorised from Middle East to Europe. However, due to the quality of data from prior to 1995–96 data, it is not possible to re-categorise these countries so Cyprus & Turkey were re-classified as Middle East a 2009–2010 and 2014–2015 in this analysis. Cyprus represents 211 undergrads and 296 graduate students while Turkey represents 3,656 undergraduates and 6,585 graduate students in 2009–10. Cyprus represents 187 undergrads and 155 graduate students while Turkey represents 3,242 undergraduates and 5,357 graduate students in 2014–15.North America consists of Canada and Bermuda (vast majority is from Canada).

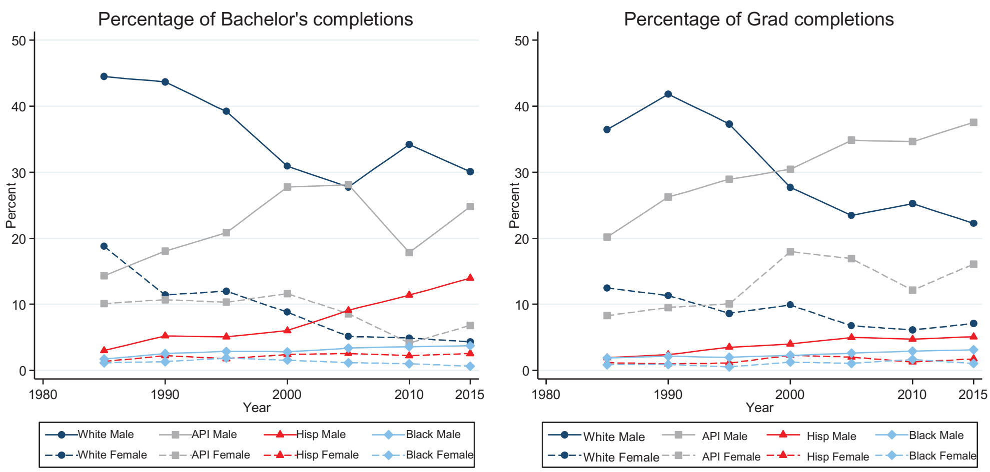

Figure 1. California: Percentage of degree completions in CS, by race and gender.

Source: IPEDS data on a number of degree completions in California, with the imputed race for international students, derived from authors' calculations from national Open Doors data.

In California, the number of computer science bachelor's degrees was 2,957 in 1985, rose after 1995, fell in the 2008–09 recession before rebounding to 5,518 in 2015 (Table 2). The number of graduate degrees in computer science showed a steadier increase, starting at 764 in 1985, with a small reduction in 2010 before increasing to 2,868 in 2015 (Table 2). These patterns were similar at the national level[15]. However, California had greater representation of Asians and Hispanics compared to nationally, particularly at the undergraduate level. Whites represented 63% and Asians, 24% of computer science undergraduate degrees in California in 1985. The percentage of Whites nearly halved while the percentage of Asians increased to 32% by 2015, although the percentage of Asian females decreased during this time. The percentage of Hispanics increased from 4% in 1980 to over 17% in 2015, the percentage of Black males increased from 3% to 4%, and the percentage of Black females declined.

The racial distribution at the graduate level in California began and remained less White and more Asian than at the undergraduate level. The percentages of Asian males and females almost doubled from 1985 to 2015, and of Hispanic males more than doubled, but from a much smaller base.

Table 2. California: Percentage of degree completions in CS, by race and gender (re-coded).

	1985	1990	1995	2000	2005	2010	2015
Bachelor's degree							
White Male	44.49	43.68	39.21	30.93	27.78	34.19	30.11
White Female	18.78	11.41	12.01	8.81	5.15	4.9	4.32
Asian Male	14.32	18.05	20.84	27.75	28.11	17.87	24.8
Asian Female	10.13	10.71	10.32	11.63	8.58	4.14	6.82
Hispanic Male	3.01	5.22	5.07	6.02	9.08	11.4	13.97
Hispanic Female	1.35	2.22	1.78	2.4	2.56	2.22	2.56
Black Male	1.72	2.54	2.89	2.83	3.38	3.6	3.73
Black Female	1.16	1.32	1.87	1.54	1.17	1.01	0.64
Unknown	0	4.04	5.53	7.56	13.48	19.20	8.90
Total observations	2957	2798	2479	3506	5585	3594	5518
Graduate degree							
White Male	36.46	41.8	37.3	27.71	23.47	25.25	22.25
White Female	12.48	11.33	8.64	9.9	6.75	6.12	7.09
Asian Male	20.2	26.25	28.94	30.46	34.84	34.64	37.57
Asian Female	8.29	9.52	10.08	17.98	16.92	12.15	16.09
Hispanic Male	1.92	2.4	3.5	4.01	4.98	4.72	5.09
Hispanic Female	1.14	0.99	1.11	2.28	2.02	1.27	1.73
Black Male	1.9	2.15	1.98	2.27	2.6	2.92	3.11
Black Female	0.86	0.88	0.54	1.25	1.07	1.66	1.05
Unknown	0	4.78	7.83	4.13	7.26	10.72	4.85
Total observations	764	1087	1188	1574	2425	2378	2868

Source: IPEDS data on a number of degree completions in California, with the imputed race for international students, derived from authors' calculations from national Open Doors data.

In addition, there appears to be a growing gender gap in computer science higher education at the undergraduate level. The percentage of CS undergraduate degrees completed by females fell by nearly half, from 31% in 1985 to 14% in 2015, whereas the percentage in graduate degrees increased slightly, from 23% to 26%, the upward tick driven entirely by an increase of foreign females. The ratio of males to females receiving CS undergraduate degrees more than doubled for every racial group from 1985 to 2015 (Table 2). At the graduate level, the male to female ratio increased for each racial group except Asians, but by relatively small amounts.

The programmer workforce

Now that we have described the composition of the computer science pipeline, we can turn to employment patterns. Programmers are a key occupation among technology workers. The number of programmers in Silicon Valley increased dramatically in 35 years, from about 10,000 in 1980 to over 140,000 in 2015. Programmers have always had high levels of education, and the fraction of programmers with graduate degrees increased rapidly, especially after 1990. In 1980, educational attainment was primarily split between those with some college (31%), an undergraduate degree (33%) or a graduate degree (26%). By 1990, half of the programmers had undergraduate degrees and a fifth had graduate degrees, and by 2015, programmers were almost all college educated, and roughly equal percentages of programmers held undergraduate (46%) and graduate (48%) degrees. Education levels were similar between genders. However, even in 1980, Asians had much higher levels of education than Whites, Hispanics, or Blacks, and by 2015, more than half of Asian programmers had graduate degrees.[16]

In 1980, the percentage of foreign-origin employees who were working as programmers was generally no higher than their proportion in the overall technology industry back in the 1980s, but a key characteristic of Asians employed as programmers is the enormous increase after 1990 in those who were non-citizens. Of those with undergraduate degrees, beginning in 2000, about 40–50% of Asian males and 30-40% of Asian females were non-citizens – these percentages contrast sharply with White male undergraduate degree programmers, who, even in recent years, have been more than 85-90% U.S. citizens or White female programmers, who have also been almost entirely US citizens. Of programmers with graduate degrees, about 25–30% of White males and 16-25% of White females and more than 50% of Asians have been non-citizens since 2000. As we have noted, the proportion of programmers with graduate degrees reached almost half in 2015, which suggests that programmers are being increasingly drawn from a non-citizen, largely graduate degree labour pool (Figure 2). All races except Hispanics experienced an increase in the percentage of foreign programmers from 1980 to 2015.[17]

Driven in part by the increase in foreign (non-citizen) Asians in the occupation, a major demographic shift took place in the programmer workforce (Table 3). In 1980, over three-quarters of programmers were White and one-sixth were Asian. By 2015, Asians represented 58% and Whites, 35% of programmers, and a high and increasing fraction of these were non-citizens.

When race and gender groups are examined together, there is a clear transition from White males to Asian males as the dominant group of programmers, with the relative decline in the female programmer labour force also shifting from White to Asian females, and in both female groups, increasingly to non-citizens. The percentage of White females decreased to just 4%, whereas the percentage and the percentage of Asian females more than doubled (to 14%) during this time. Meanwhile, the low percentages of Hispanic and Black males and females declined even further. The male to female ratio increased for every race from 1980 to 2015, but it varied across race.

Comparisons between higher education and the labour force

The trends in computer science degree completions appear different from employment trends among programmers. Notably, the percentages of both undergraduate and graduate degree completions for Hispanics and Blacks were generally higher than their corresponding percentages in the labour force (i.e. programmers with only undergraduate degrees and programmers with graduate degrees).

In an illustrative exercise, we compare the percentages of race gender groups who obtain degrees in CS (Table 2) and their corresponding percentages in the younger programmer labour force. We restrict the labour force to younger workers (30 years and younger), although similar results hold for other age ranges or when using lagged data (i.e. labour market data from 5 years after higher education data). Hispanic males made up 5% of undergraduate CS degree completions and 3% of employed programmers with only undergraduate degrees in 1990 (Table 4). In 2015, the percentage of Hispanic males rose to 14% of CS undergraduate degree completions, yet represented only 7% of employed programmers with only undergraduate CS degrees in 2015. Similarly, Hispanic males made up about 2% of graduate degree completions and 3% of programmers with graduate degrees in 1990 and increased to 5% of graduate degree completions yet dropped to just over 1% of programmers with graduate degrees in 2015. These percentages are smaller for Hispanic females and Blacks, yet generally follow the same pattern of representing a higher proportion of degrees than programmers employed in the technology labour force.

The differences between the percentages of degree completions in computer science and the labour force suggest that there may be differential rates of CS degree completers entering the programmer occupation. In general, Asians make up a higher proportion of the programmer labour force than their proportion of computer science degrees, whereas Hispanics and Blacks represent a larger proportion of degree completions than their proportions in the labour force. Whites have had decreasing representation in both degrees and in the labour force, yet have varied between greater or less representation in undergraduate CS degrees than in the employed programmer labour force. White females have higher representation among younger programmers than among undergraduate CS degree completions. At the graduate level, White females have been a larger proportion of CS degree completers than their proportion in the programmer labour force. These trends indicate that for certain groups, such as Hispanic males, or White females with graduate degrees, getting degrees in computer science does not seem to increase their corresponding proportion into the programmer labour force, and that other groups, such as White females with

Figure 2. Silicon Valley (Bay Area): Percent of professionals with an undergraduate or graduate degree who are foreign.
Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).

Table 3. Silicon Valley (Bay Area): Programmers by race and gender percentages.

	1980	1990	2000	2010	2015
White Male	56.16	53.99	41.38	31.96	31.51
White Female	20.35	18.38	8.49	3.96	3.74
Asian Male	9.59	11.26	31.5	46.12	44.26
Asian Female	6.07	8.4	11.06	12.92	14.05
Hispanic Male	3.52	3.37	2.58	1.92	2.34
Hispanic Female	0.78	1.04	0.83	0.16	0.5
Black Male	2.15	2.29	1.02	0.18	1.02
Black Female	0.98	0.98	0.67	0.57	0.07
Total	10,220	24,264	77,532	88,137	143,286

Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).
Note: Only full-time (at least 35 h of work a week) full-year (at least 50 weeks in the previous year) workers in labour force (16+ years old).

Table 4. Silicon Valley (Bay Area): Race and gender percentages of young programmers.

	Undergraduate					Graduate				
	1980	1990	2000	2010	2015	1980	1990	2000	2010	2015
White Male	49.41	44.42	33.85	29.73	29.35	40.62	46.52	25.27	12.2	14.86
White Female	23.53	24.37	5.32	2.34	5.66	28.13	15.55	2.76	2.49	3.04
Asian Male	10.59	12.63	43.67	54.41	38.67	12.5	24.01	48.97	68.45	54.25
Asian Female	10.59	11.02	11.63	5.49	13.6	12.5	11.46	18.35	12.1	18.79
Hispanic Male	3.53	3.19	2.45	0.61	7.32	3.13	2.46	0.97	0.74	1.22
Hispanic Female	0	0.61	0	0	0.57	0	0	0	0	0.65
Black Male	1.18	2.67	0.45	0	1.11	0	0	0.05	0	6
Black Female	1.18	1.09	0.14	0	0	3.13	0	0	1.03	0
Observations	1700	4608	11,254	9374	18,547	640	733	6273	7953	14,573

Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).
Note: Only full-time (at least 35 h of work a week) full-year (at least 50 weeks in previous year) workers in labour force who are 30 years old and under. This age restriction is to approximate the demographic of degree completers.

undergraduate degrees, are declining as a proportion of the programmer labour force as least partly because they are not maintaining their share of undergraduate degrees in computer science.

There are other possible explanations for the observed gaps between the completion percentage and the labour force percentage. For example, the supply of potential programmers extends beyond state or national borders, those who complete CS degrees may not work as programmers, or programmers may not necessarily complete degrees in computer science (Stackoverflow 2015). There may be distinctions in degree quality that are not reflected in the number of degree completions. However, our analyses also suggest that Hispanic males may face barriers to the programmer occupation after higher education, whether these are internal (choosing not to go into programming) or external (facing discrimination in hiring).

5. Programmer wages and race/gender employment patterns

Wage differences by race and gender have been well documented in the overall labour market (Altonji and Blank 1999) and in the technology labour force (Beede et al. 2011; American Institute for Economic Research 2014). Although it is difficult to attribute wages to observable characteristics such as race or gender (see Altonji and Blank 1999, for a review), wages have been suggested as a potential source of racial differences in the technology labour market (Salzman, Kuehn, and Lowell 2013). Wages and race are also intertwined with the non-citizen status of many programmers, since most are Asians, and there is a strong belief that non-citizens serve as a cheaper source of labour for the technology industry. We focus our wage analysis on a specific occupation, programmers, to minimise biases across occupations. The programmer wage data are limited to Whites and Asians due to the limited numbers of Hispanic and Black programmers.

Table 5. Silicon Valley (Bay Area): Wages of programmers, by race and gender.

		1980	1990	2000	2010	2015
Bachelor's degree						
White Male	Mean	25.77	26.97	39.72	40.00	50.98
	SE	0.60	0.76	1.24	1.80	3.05
	Obs	1,440	4,415	11,324	9,124	14,440
White Female	Mean	23.33	24.40	33.57	30.77	32.40
	SE	1.44	0.55	1.75	3.06	3.17
	Obs	580	2,097	2,321	860	1,667
Asian Male	Mean	21.52	25.36	34.13	36.10	42.54
	SE	1.15	0.88	0.90	1.04	1.86
	Obs	260	1,176	9,594	14,705	20,466
Asian Female	Mean	22.48	22.50	32.24	32.58	29.49
	SE	1.37	1.02	1.08	1.06	1.29
	Obs	140	1,146	3,224	3,730	6,176
Graduate degree						
White Male	Mean	26.76	30.01	40.43	42.03	58.37
	SE	1.02	1.37	1.40	2.17	3.59
	Obs	1,160	2,089	6,222	5,356	10,117
White Female	Mean	18.94	25.25	31.88	32.02	49.59
	SE	1.74	1.21	1.42	2.20	9.00
	Obs	360	435	1,206	411	1,281
Asian Male	Mean	26.03	34.08	38.89	38.90	43.95
	SE	2.52	2.70	0.97	1.41	1.59
	Obs	260	623	10,507	17,510	25,658
Asian Female	Mean	20.52	27.22	34.25	37.58	40.99
	SE	1.67	1.03	0.80	1.22	2.25
	Obs	220	612	3,632	4,871	8,548

Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).
Note: Sample for wage analyses are full-time (at least 35 h of work a week) full-year (at least 50 weeks in previous year) workers in labour force with positive wages. The sample is further limited to workers between 25 and 44 years old.

Except for a dip in employment for Whites in 2000–2010, the number of White and Asian programmers generally increased from 1980–2015. These increases were accompanied by increases in wages, but with relatively flat wages during the 2000–2010 period (Table 5).[18] We also showed that, as measured by the numbers of CS degree completers, the supply of potential White and Asian programmers increased from 1985–2015. The fact that wages kept increasing despite increases in supply suggests an increase in demand for programmers in most years.

Even so, wage patterns appear to differ by race/ethnicity, gender, and education level (Figure 3). At the undergraduate level, White males consistently have had the highest average hourly wage, and, on average, Asian males earn less. The gap between White and Asian males appears to be relatively steady, although the difference is only statistically significant in 1980 and 2000. Meanwhile, White and Asian females appear to have similar wages during this period. Finally, although the differences were not always significant in prior years, the gender gaps for both Whites and Asians became larger and statistically significant in 2015.

These overall wage differences suggest that somewhat lower wages for non-citizens in recent years may be one factor that promotes hiring more non-citizen programmers and yet are high enough to create an increasing supply of foreign workers with CS degrees. At the same time, if women are paid lower wages, this should increase the demand for women workers, but the wages may not be high enough compared to alternatives to convince U.S. citizen women to major in computer science to prepare for jobs as programmers. U.S. citizen White women may also be less inclined to join a male-dominated field even if wages were somewhat higher for female programmers than alternative work in other fields.

We also estimate programmer wages for non-U.S. citizens and U.S. citizens, Asian and White for 25–44-year-olds. The results suggest that for White males and Asian females, the wages are essentially the same for citizens and foreign workers with either undergraduate or graduate degrees throughout this period (Figure 4(a,b)). This is also true for Asian males with an undergraduate degree.

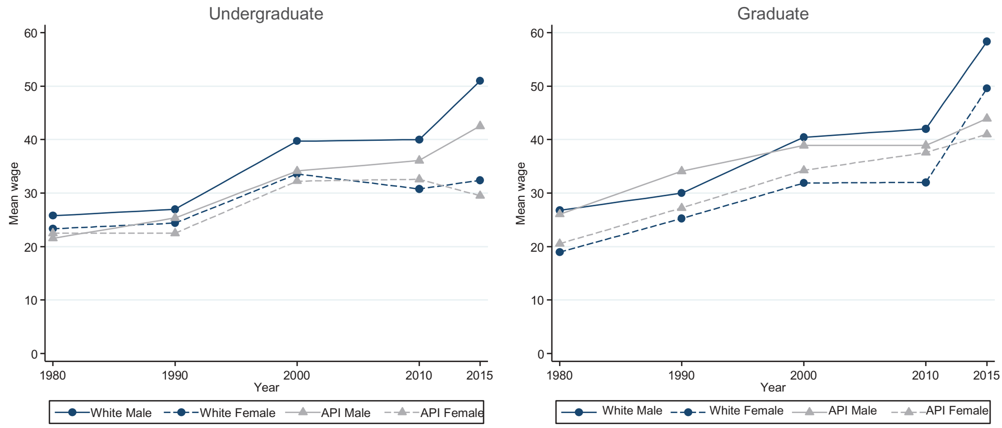

Figure 3. Silicon Valley (Bay Area): Mean hourly wages of programmers, by race and gender.

Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).

Note: Sample for wage analyses are full-time (at least 35 h of work a week) full-year (at least 50 weeks in previous year) workers in labour force with positive wages using 1999 dollars. The sample is further limited to workers between 25 and 44 years old.

However, for Asian males with a graduate degree, after 2000, non-U.S. citizens earn somewhat less than their citizen counterparts, and, in 2015, considerably less than U.S. citizen Whites with graduate degrees. Generally, then, there is some limited support for the notion that firms in the Valley are hiring non-citizen Asian programmers because they are paid lower wages than U.S. citizen Whites.

To the contrary, females have lower wages than males, yet males greatly outnumber their female counterparts. Although there may be other unobserved factors involved, higher wages for males may indicate a greater demand for males over females. Overall, then, the relationships between wage and labour force representation suggest that wage differences provide neither a consistent nor an especially strong explanation for differences in employment of race/gender groups in the programmer labour force, and that we need to look elsewhere to understand these employment patterns.

6. Discussion

In this paper, we have tried to draw insights into whether increasing women's and minority groups' university STEM education can contribute significantly to their employment in high wage high tech jobs – specifically, in rapidly expanding programmer jobs. If universities paid more attention to attracting more women and minorities into STEM majors, would this change employment patterns in the high tech industry?

Our analysis of graduates by race and gender in computer science indicates that the answer may vary by group. White females' share of degree completions in computer science declined from 1985 to 2015, which supports the argument that their rapidly declining share in programming jobs is largely a result of too few White females majoring in STEM. This argument is also supported by the increasing proportion of Asian females in programmer jobs in this period, suggesting that the overall lower presence of females is not due to gender bias in hiring. That said, gender gaps among programmers appear to be increasing across all races, including Asians. Further, female programmers with bachelor degrees earn much lower wages than male programmers of similar age and with the same level of education.

Other groups also do not necessarily align with the pipeline argument. The most salient example is that Hispanic males have become an increasingly large proportion of degree completers in computer science, yet their representation in the programmer labour force has declined. It appears that certain groups such as Hispanic males may face barriers to working as programmers that other

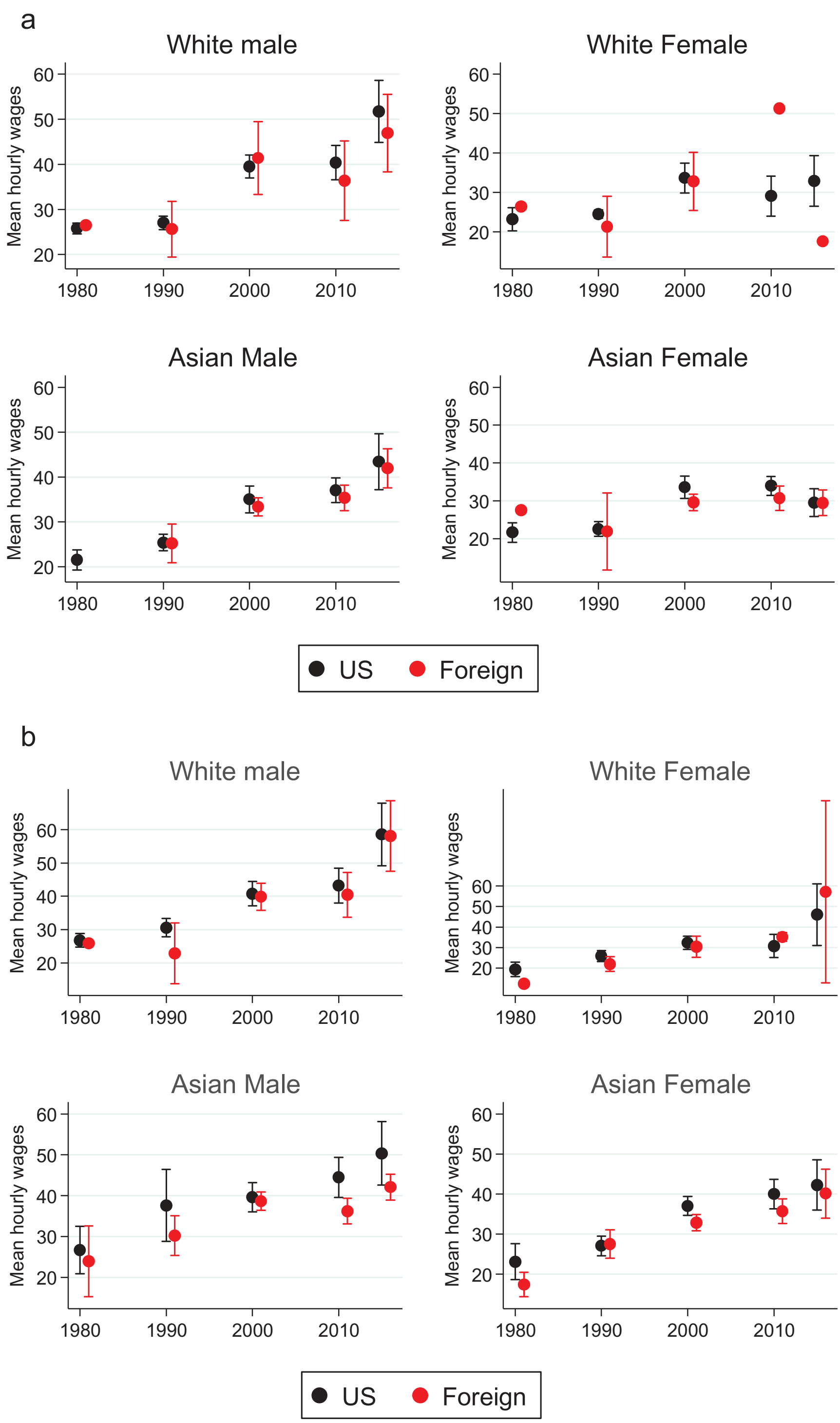

Figure 4. (a) Silicon Valley (Bay Area): Wages of programmers with an undergraduate degree, by race, gender and citizenship status. Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).(b) Silicon Valley (Bay Area): Wages of programmers with a graduate degree, by race, gender and citizenship status. Source: Authors' calculations from Census and ACS data for Silicon Valley (six counties).

groups, such as Asians do not. The Hispanic sample was too small to estimate their relative wages by level of education, but lower wages for Asian males compared to Whites may partly explain the rapidly increasing presence of Asians among programmers, and why much of the increase in Asian employment has been in non-U.S. citizen programmers, most with graduate degrees, where the wage gap in recent years has been highest.[19]

Thus, these findings suggest that inducing more women to study computer science and enter the programmer occupation could increase their average wages relative to males in the overall economy. Yet, it may not be easy to induce more women into computer science, since programming and high tech more generally has become increasingly male-dominated. Although many analyses assume that the main problem for young women entering the STEM pipeline – especially into engineering and computer science majors – is maths and physical science aversion (for example, Xie, Fang, and Shauman 2015), the work climate for women in high tech may be an even more important factor (U.S Equal Employment Commission 2016). Therefore, policies designed to attract White females may need to focus on getting them to major in computer science, which may also require changes in the culture of the technology industry such as raising wages, and perhaps creating a more female-friendly culture in the industry.

On the other hand, our results suggest that inducing more disadvantaged minorities into computer science degrees may not address the main barrier to employment for underrepresented minorities. Hispanic males, after graduating with a degree in computer science are apparently not being hired into programming jobs. While it is important to encourage minority participation in CS higher education, this paper shows that there appear to be important barriers even after obtaining CS degrees for minority programmers in the labour force. Thus, policies designed to employ disadvantaged minorities much more clearly need to focus either on inducing more of them to apply for programming/other tech jobs or convincing employers to hire more disadvantaged minority programmers. This suggests that the work climate in high tech may need to be altered to be more hospitable for minority workers, similar to making the work climate better for females.

It is not within the scope of this paper to explore important alternatives in the programmer pathway; not all who complete CS degrees work as programmers and not all programmers hold degrees in CS. While it is important to recognise that there are multiple pathways into programming, our data suggest that it is likely that getting a programming job (and other tech jobs) in the Valley seems to require increased formal academic training, given the increasing percentages of those with degrees, particularly graduate degrees in CS. Thus, this paper focuses on the dynamics within CS higher education and the programmer labour force.

The broader lesson is that higher education policies that increase women and underrepresented minorities in CS and other high tech-related STEM education may not be sufficient; parity in technology appears to also depend on the hiring processes and work environments of the technology sector itself. If the technology industry caters to certain categories of employees, increasing the supply of graduates who do not fit those categories will not likely result in much change. Alternatively, if the industry is known to be unfriendly to certain groups, talented individuals from these groups will be much less likely to respond to incentives to enter programming or other technology professions.

Notes

1. Burke and Mathis, 2007; Marginson et al. 2013. For the U.S., see, National Academy of Sciences, 2007, and Xie, Fang, and Shauman (2015). UNESCO has also focussed on gender gaps in access to STEM jobs and job mobility. http://www.unesco.org/new/en/natural-sciences/priority-areas/gender-and-science/improving-measurement-of-gender-equality-in-stem.
2. Open Doors is a comprehensive report on international students studying in the U.S. and U.S. students studying abroad, supported by the U.S. Department of State and published by the Institute of International Education.
3. We recognise that the Silicon Valley technology labour market may be a national market, but restrict the higher education analysis to California for comparability.
4. The long form of the population census ceased in 2000.

5. This includes respondents in the following counties: Alameda, Contra Costa, San Francisco, San Mateo, Santa Clara and Santa Cruz. Silicon Valley is not an official government designation and thus we use an inclusive geographic region in our analyses.
6. The National Centre for Education Statistics uses these definitions of full-time and full-year.
7. We use the harmonised occ1990 occupation category of 229 (programmers) which is defined as computer software developers and computer scientists/analysts (occ1990).
8. In the year 2015 census data uses intervalled wage data unlike the other census years, and thus the average of these intervals is used as the wages for 2015.
9. However, changes in the demographics of Silicon Valley's labour force differed from those in the rest of the country. From 1980 to 2015, Silicon Valley's White and Black labour force across all industries declined more than nationally, but Hispanics and Asians increased much more rapidly, reaching 50% of all workers, compared to 30% nationwide.
10. We define an industry as belonging to the technology industry if the industry is listed as 'Computers and related equipment' (#322), 'Radio, TV, and communication equipment' (#341), 'Electrical machinery, equipment, and supplies, nec' (#342), 'Guided missiles, space vehicles, and parts' (#362), 'Scientific and controlling instruments' (#371), 'Computer and data processing services' (#732), 'Engineering, architectural, and surveying services' (#882) or 'Research, development, and testing services' (#891) in the harmonised industry variable (ind1990). Manufacturing industries were industries with the codes 100-392 in the harmonised industry variable (ind1990), excluding those in the computer category. High services industries were industries with the codes 700-712, 721,732, and 812-893 in the harmonised industry variable (ind1990), excluding those in the computer industry.
11. Occupations are categorised as Manager with the codes 004-022 in the harmonised occupation category (occ1990). These do not include management-related occupation such as accountants or HR specialists and include executives (there were too few executives to be a separate category). Occupations are categorised as Professionals with the codes 043-200 (Professional Speciality list), 229 (programmers), and 23-37 (Management-Related occupations) in the harmonised occupation category (occ1990). All other occupations are categorised as 'Other' in these analyses (includes occupations such as cook, bookkeeper, waiter, office clerk, etc.).
12. Data tables are available upon request.
13. Authors calculated these percentages from IPEDS data (data available upon request).
14. Authors calculated these percentages from Open Doors data (data available upon request).
15. Data used in analyses are from IPEDS/Open Doors and are available upon request.
16. Detailed data are available upon request.
17. Detailed data are available upon request.
18. Unfortunately, because of the small sample sizes for Hispanics and Blacks, we are forced to restrict the wage analyses to White and Asian full-time full-year workers. We also limit the sample to 25-44-year-olds, include only positive wages, and separate analyses into programmers with undergraduate degrees only and programmers with graduate degrees–this to provide less biased wage comparisons.
19. As mentioned above, non-US citizens may continue to major in CS and accept lower pay than their U.S. citizen counterparts because they face much lower wages should they return home. A more complex question is why US citizen Asian males with undergraduate degrees receive lower wages than their White male counterparts.

Disclosure statement

No potential conflict of interest was reported by the authors.

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