Supporting Information

Why the United States Science and Engineering Workforce Is Aging Rapidly

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1. Data

The main source of data on US scientists is the Survey of Doctorate Recipients (SDR), a longitudinal sample survey of the population with a research doctorate in science, engineering, or health, earned in the US (http://www.nsf.gov/statistics/srvydoctoratework/). The sampling frame is the Survey of Earned Doctorates, an annual census of individuals receiving a research doctorate (http://www.nsf.gov/statistics/srvydoctorates/). Once in the sample, individuals are surveyed repeatedly until age 76. The sample is refreshed with new doctorate recipients at each wave. The SDR is sponsored by the National Science Foundation, and is usually administered every two years, with an occasional two and a half year gap. We use restricted-access microdata from nine survey waves conducted from 1993 through 2010, with detailed information on age, field of degree, job tenure, previous employment, occupation, and sector of employment.[1] The data contain observations on about 73,000 scientists aged 76 or less, with an average of four observations per sample member. We supplement the SDR with data from the Census Bureau.[2]

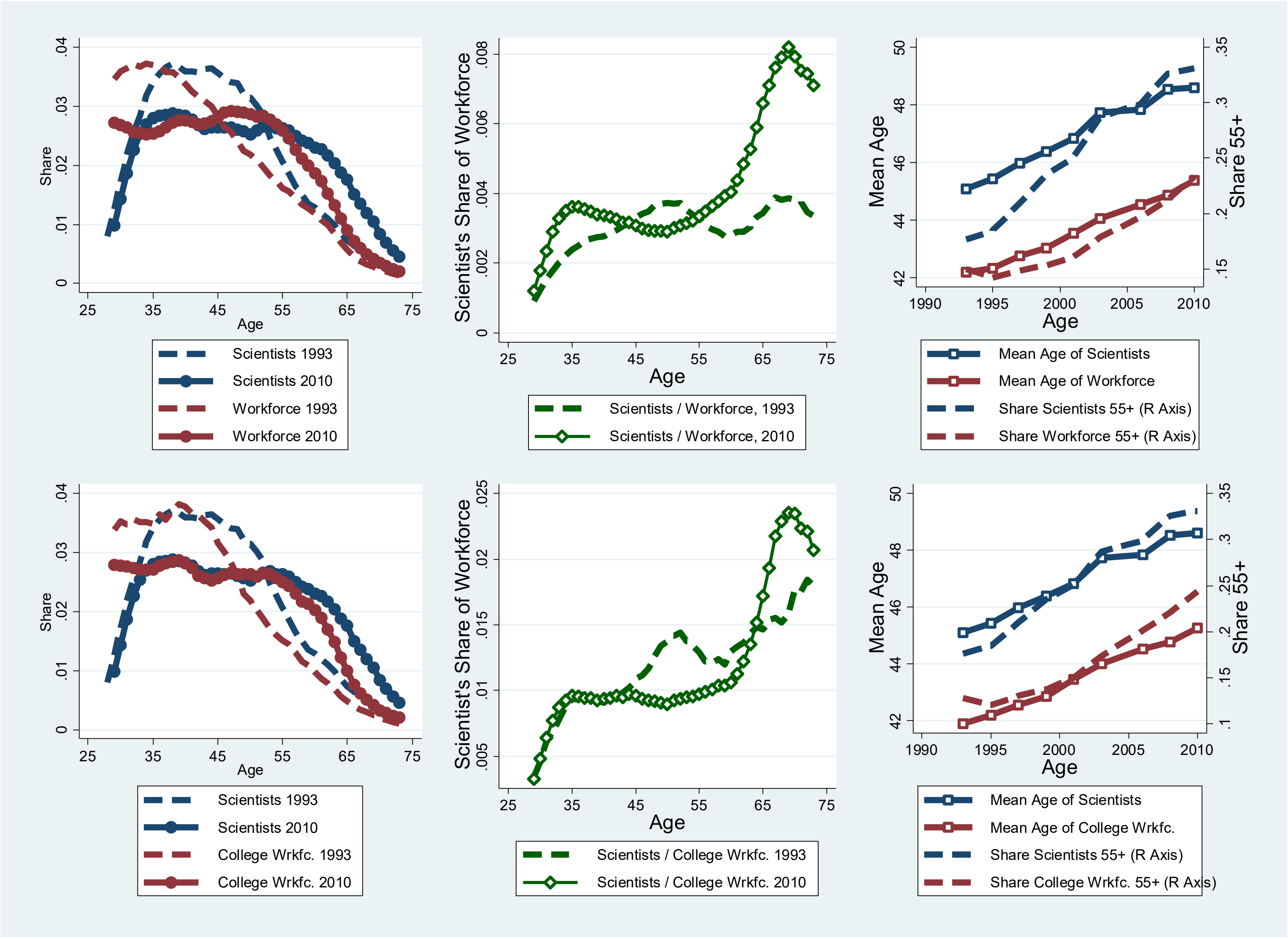
We define scientific workers as individuals with a research doctorate who are currently employed and work in a scientific occupation. Scientific occupations include the life sciences (biology, medical science, etc.), health-related occupations[3], physical sciences (chemistry, physics, astronomy, and geology), engineering, computer science and mathematics, and social science (economics, psychology, etc.). Scientific workers are employed in universities, hospitals, national laboratories, for-profit and not-for-profit corporations, and federal and state government

[1] Earlier waves are available but a redesign for the 1993 wave makes it difficult to use them in a trend analysis.
[2] The Census data were downloaded from IPUMS (https://usa.ipums.org/usa/).
[3] Health-related occupations include those physicians and other diagnosing and treating practitioners, nurses, pharmacists, and others who have a research doctorate.

agencies. 85% of the individuals we classify as scientists report that they were engaged in a research-related activity (basic, applied, development, programming, and design of equipment, structures, models, and processes). Over three-quarters (76%) reported that one of these activities is their primary or secondary activity, based on hours of effort.[4]

We use data from the American Community Survey (ACS) for information on scientists who obtained a PhD outside of the United States and then migrate to the US. We assume somewhat arbitrarily that if an individual with a PhD arrived in the US at age 32 or older, the PhD was completed abroad. However, the sample sizes are too small to produce meaningful results by year and age at arrival. Instead, we combine data from the ACS for the years 2000-2013 to compute the average annual *number* of recently arrived immigrant scientists. We cannot compute the *rate* of arrival because we do not have data on the population of scientists who obtained the PhD outside the US.

[4] We experimented with alternative definitions of the scientific workforce, based on whether research was the primary or secondary activity, and the results were very similar. We also tried a specification in which no distinction was made between scientists and non-scientists – all SDR respondents were treated as scientists regardless of their reported activity and occupation. This yielded virtually identical results.


Share
Age
Scientists 1993
Scientists 2010
Workforce 1993
Workforce 2010
Scientist's Share of Workforce
Age
Scientists / Workforce, 1993
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Mean Age
Share 55+
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Mean Age of Scientists
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Share Scientists 55+ (R Axis)
Share Workforce 55+ (R Axis)
Share
Age
Scientists 1993
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College Wrkfc. 1993
College Wrkfc. 2010
Scientist's Share of Workforce
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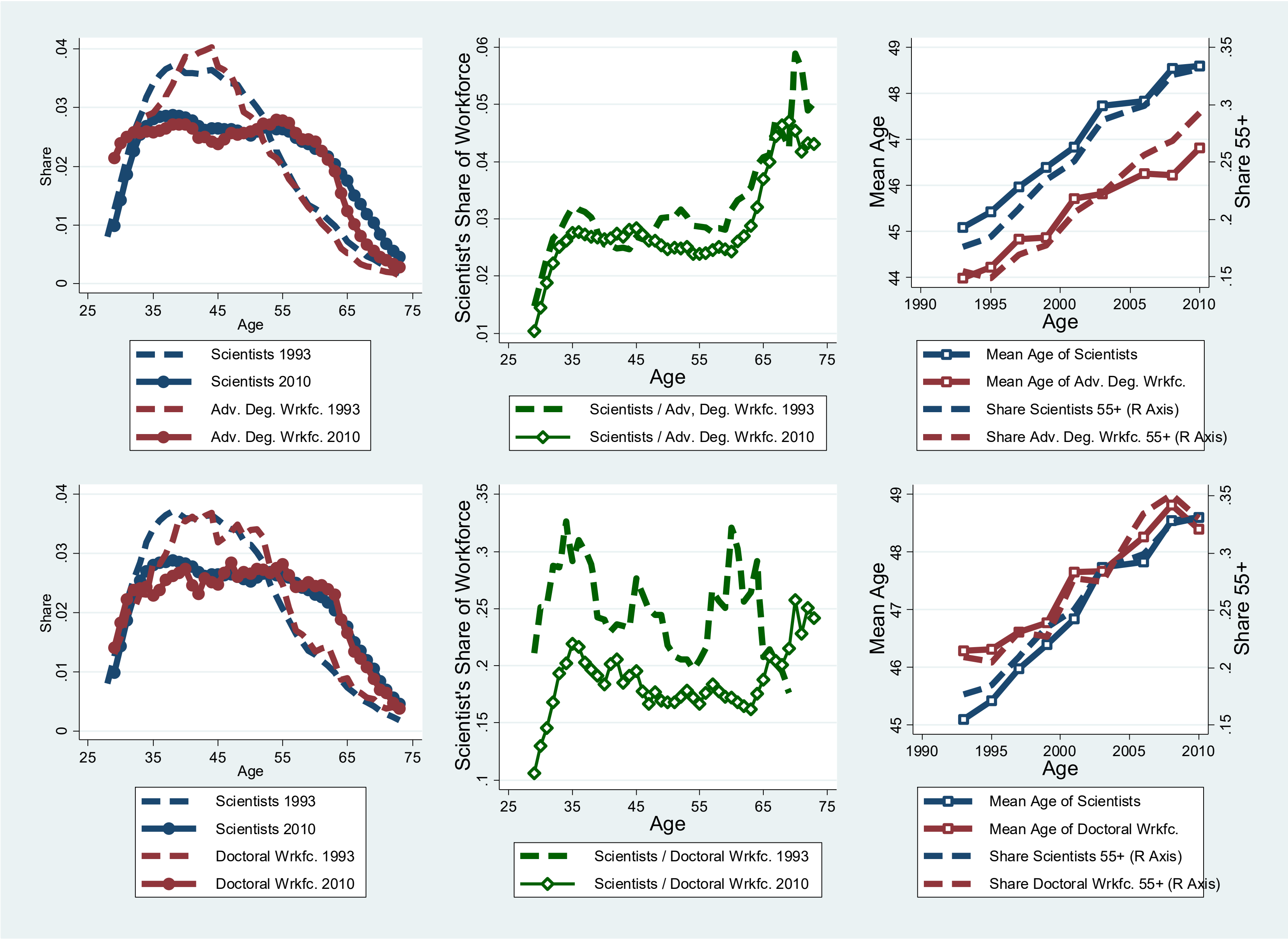
Share Scientists 55+ (R Axis)
Share College Wrkfc. 55+ (R Axis)



Share
Age
Scientists 1993
Scientists 2010
Adv. Deg. Wrkfc. 1993
Adv. Deg. Wrkfc. 2010
Scientist's Share of Workforce
Age
Scientists / Adv, Deg. Wrkfc. 1993
Scientists / Adv. Deg. Wrkfc. 2010
Mean Age
Share 55+
Age
Mean Age of Scientists
Mean Age of Adv. Deg. Wrkfc.
Share Scientists 55+ (R Axis)
Share Adv. Deg. Wrkfc. 55+ (R Axis)
Share
Age
Scientists 1993
Scientists 2010
Doctoral Wrkfc. 1993
Doctoral Wrkfc. 2010
Scientist's Share of Workforce
Age
Scientists / Doctoral Wrkfc. 1993
Scientists / Doctoral Wrkfc. 2010
Mean Age
Share 55+
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Mean Age of Scientists
Mean Age of Doctoral Wrkfc.
Share Scientists 55+ (R Axis)
Share Doctoral Wrkfc. 55+ (R Axis)

Figure SI1. The age distribution of the US scientific workforce and the US workforce, by level of education. The left panels show the age distribution of scientists (calculated from the Survey of Doctorate Recipients (SDR)) and the US workforce (calculated from the Current Population Survey (CPS)) for 1993 and 2010. The center panels show the share of scientists in the US workforce by age in 1993 and 2010. The right panel plots trends in the mean age of scientists and the US workforce as well as the share of scientists and the US workforce age 55 and over. The top panel includes the entire workforce (regardless of education). The second panel down focuses on the college workforce, defined as those with a 4 year college degree (or 16 years of school) or more. The third panel down focuses on workers with advanced degrees, defined as those with a masters or equivalent (or 17 years of school) or more. The last panel focuses on workers with doctoral degrees, defined as those with a doctorate or equivalent (or 20 years of school) or more. The figures show that the scientific workforce is aging overall and relative to the various populations. The aging is particularly pronounced when looking at the share of the workforce that is 55 and older. The aging of the scientific workforce is smallest relative to people with advanced degrees, but clear relative to the other groups, including people with doctorates.

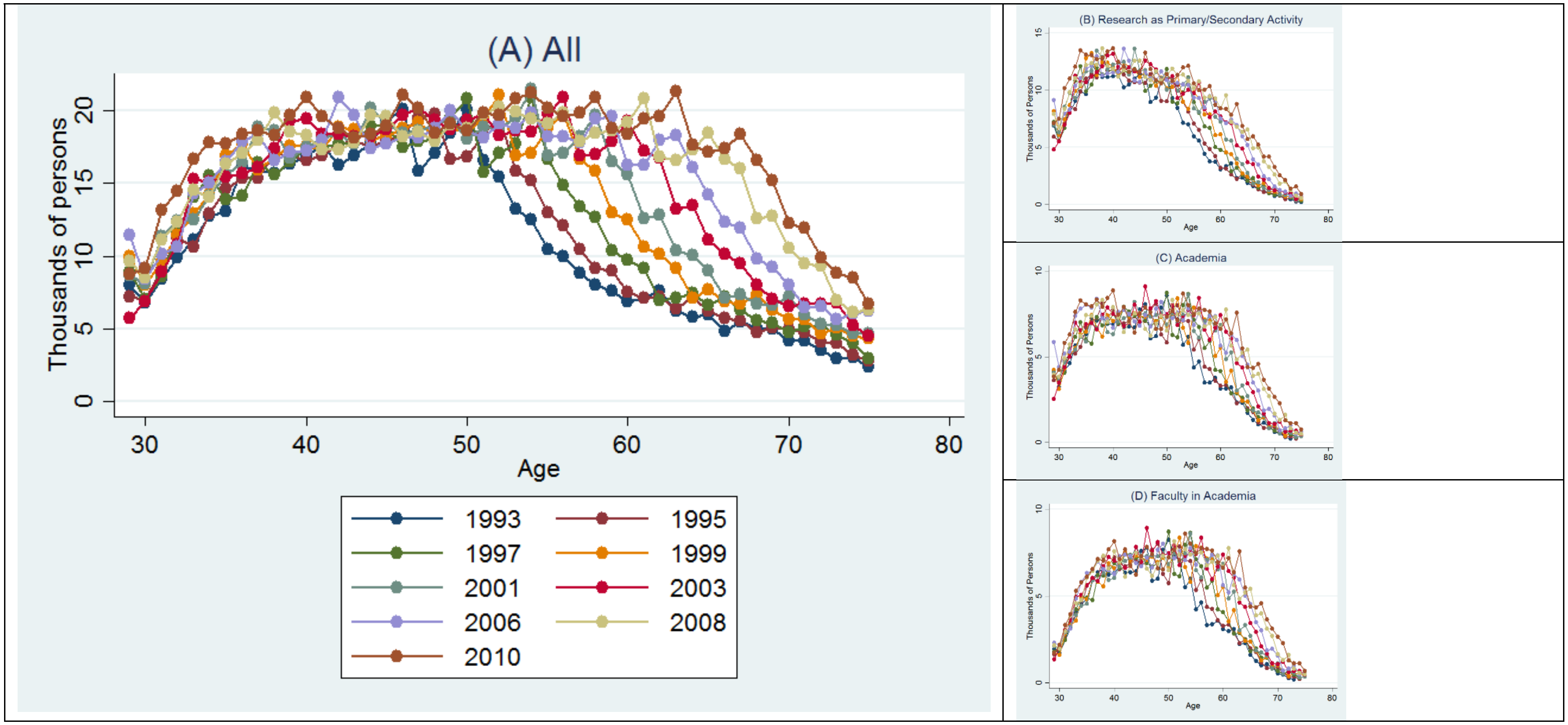


Figure SI.2. Age Distribution by Year. Panel A plots the size of the US research doctorate workforce in thousands, by age and year from 1993 to 2010. There are few research doctorates in their 20s, with a rapid increase in numbers around age 30. The counts continue to increase until the early 40s when they plateau. There is little discernable age trend from the early 40s to age 50. The age at which counts increase are relatively constant over time and while the counts begin to fan out in the 30s and remain spread out in the 40s, they do not exhibit clear trends. By contrast the data after age 50 show a remarkably strong pattern. The series for 1993 begins to turn down around age 50. That for 1995 begins to turn down two years later, 1997 is delayed by two more years. Each successive curve runs remarkably parallel to the series before it. Thus the aging of the workforce can be seen in the downturn in counts occurring at ever later ages. An important implication of the lack of consistent changes in the plateau and ever later downturns is that the size of the workforce is growing consistently over time. Estimates for people whose primary and secondary work activity is research (in Panel B) peak earlier, indicating that people move away from research positions as they age.

Academics as a whole (shown in Panel C) are similar to A but the curves for the later years remain high until later ages. Panel D shows the distribution for non-postdocs in academia. Because many people are in postdocs before age 40, this figure increases more rapidly until age 40. Despite these intuitive differences, the four samples show a remarkable and consistent aging pattern.

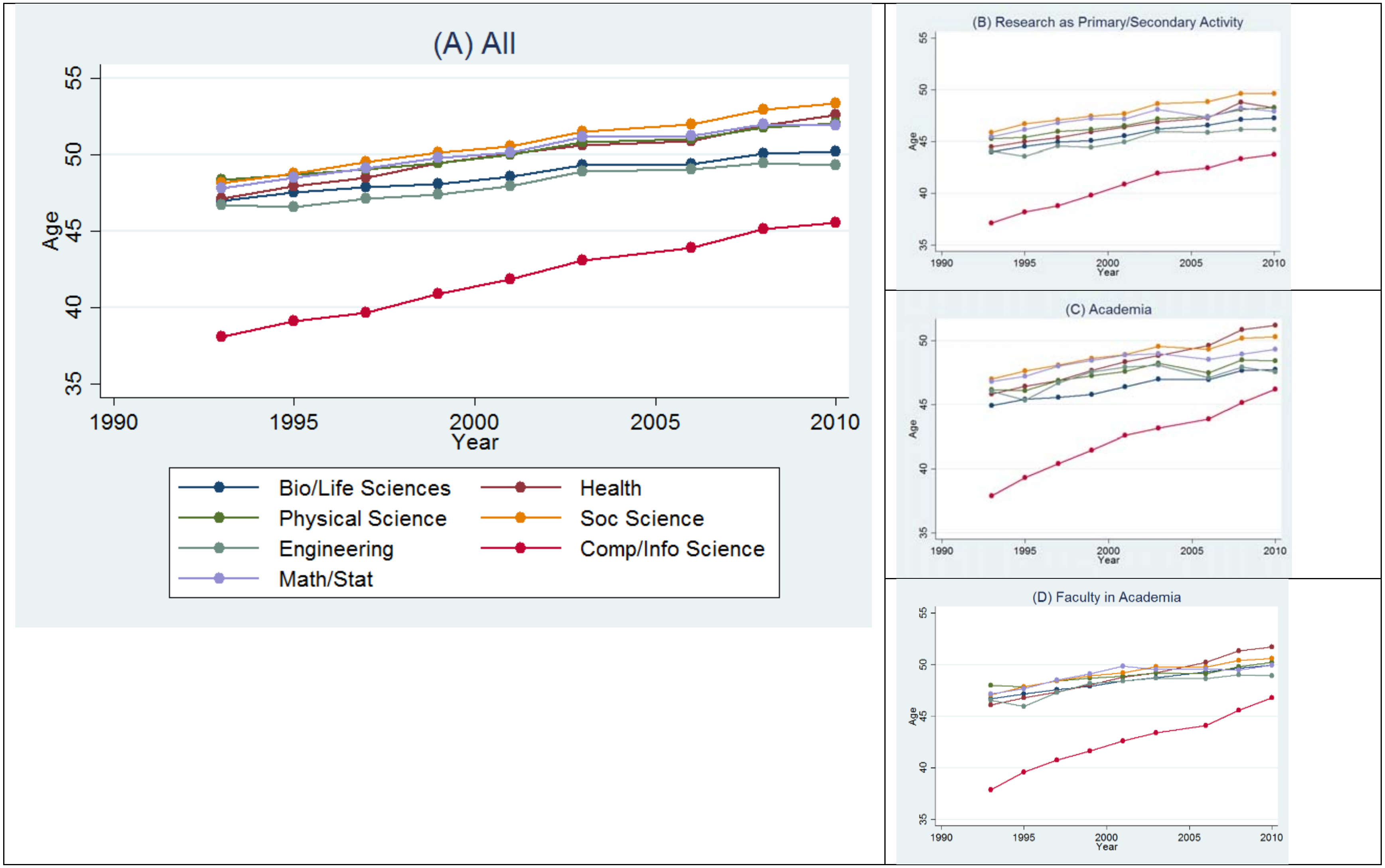


Figure SI.3. Mean Ages by Field. Panel A reports the mean age of the U.S. research doctorate workforce by field over time. The estimates show that the aging pattern is common across fields. The mean age in most of the fields is between 46 and 49 in 1993 and increases to between 49 and 54 in 2010. Computer and Information Sciences are the notable exception, with a mean age of only 38 in 1993. At the same time, Computer and Information Sciences age more rapidly than any of the other fields (by 7 years) to 2010. Within the other cluster of fields, the social sciences are the oldest while Engineering is the youngest. The aging of the biomedical research workforce, including the ages of principal investigators funded by the National Institutes of Health (NIH) has received considerable attention. It is therefore noteworthy that while Health shows the greatest increase in age among the non-Computer and Information Sciences cluster, the Biological and Life Sciences is among the youngest and does not age more rapidly than the other fields. As indicated by Panel B, scientists primarily or secondarily engaged in research are somewhat younger than the average scientist, indicating a tendency to move away from research at older ages. Academics (in panel C) are noticeably older than people whose primary or secondary activity is research, but the patterns are broadly similar to those in Panel A. Scientists employed in academia are only slightly older than those employed outside of academia (mean age of 45.9 in academia versus 45.7 outside). Perhaps not surprisingly, the largest difference between academia and non-academia is for engineering, where the age of academics is considerably older than their non-academic counterparts. Panel D further restricts the sample of academics to scientists who are not in postdocs. This restriction naturally increases the average age, with among the largest effects in biomedicine in recent years. This reflects the large size of the postdoc population in biomedicine. However, even after postdocs are excluded, the Biological and Life Sciences are not exceptionally old. (We have explored a range of methods to identify postdocs (1).

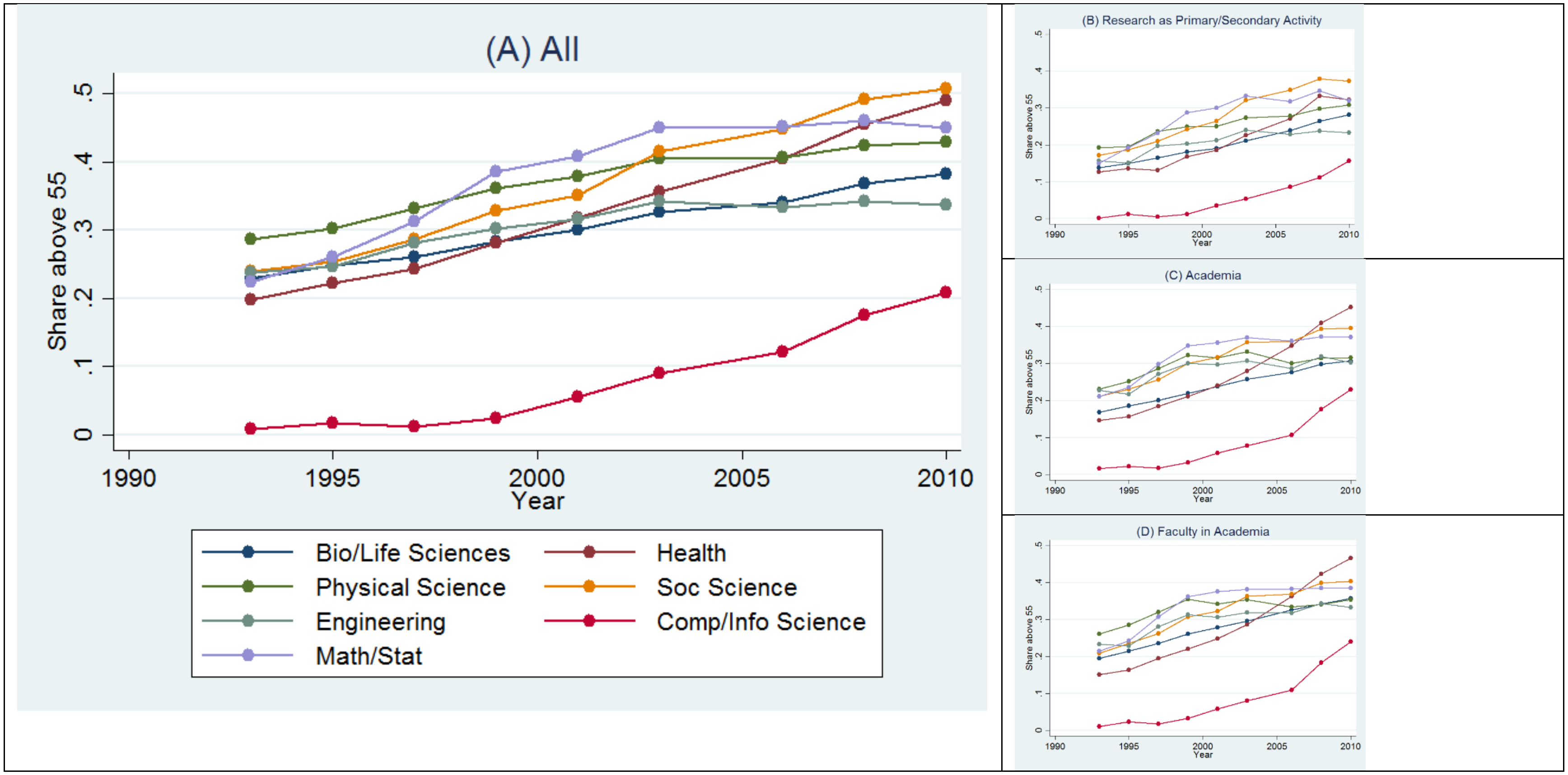


Figure SI 4. Share of Field above 55. The figure shows the share of the STEM workforce by field and position over age 55. Panel A reports the share of the U.S. research doctorate workforce over 55 by field over time. Like Figure SI.3, the estimates show that the aging pattern is common across fields, with Computer and Information Sciences initially being younger, but aging more quickly. Panel B shows that people primarily or secondarily engaged in research are somewhat younger than the average research doctorate. Academics (in panel C) are noticeably more likely to be over 55 than those whose primary or secondary activity is research. Academics are somewhat more likely to be over 55 (23.2%) than those employed outside of academia (21.3) (not shown). Again, the patterns are broadly similar to those in Panel A. Panel D further restricts the sample of academics to people who are not in postdocs.

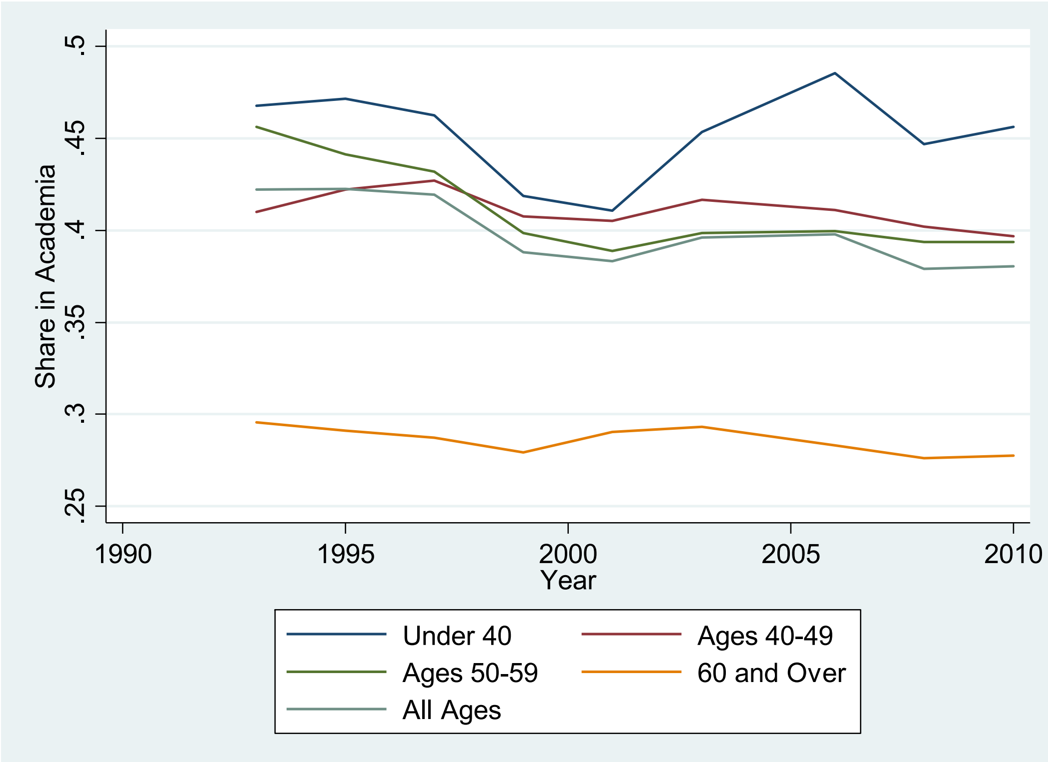


Figure SI.5. Share of scientists in academia. The figure shows that the share of scientists who are in academia declines with age and has been essentially flat within age categories. The share of scientists in academia (across all age groups) has declined because the scientific workforce has aged and older doctorates are less likely to be in academia than younger ones.

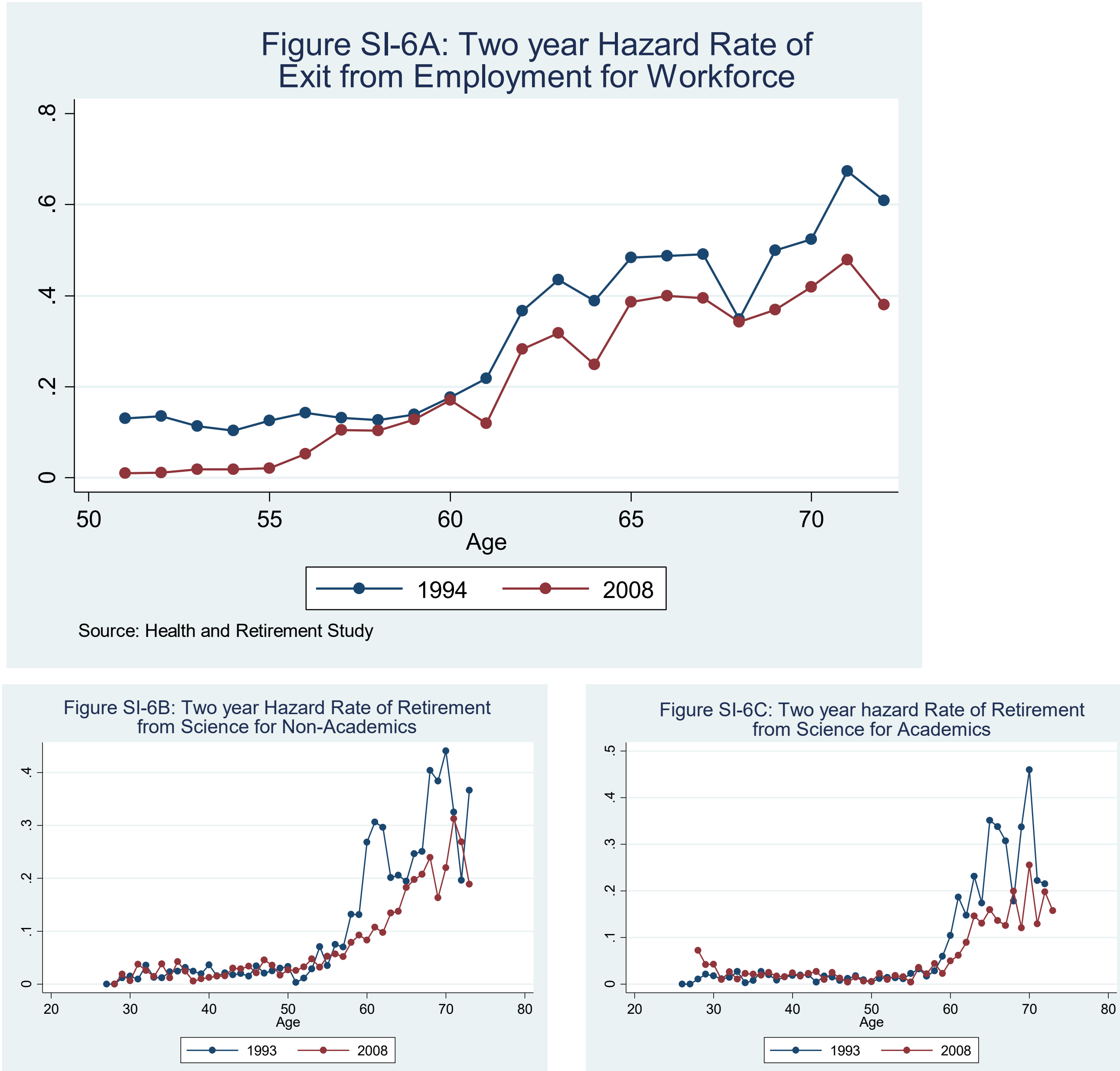


Figure SI.6. Panel A shows biannual transition rates from employment to non-employment for the US workforce, 1994 and 2008. The figure shows the share of employed workers 1994 (blue) and 2008 (red), who are not employed two years later. Panels B and C shows biannual transition rates from employment to non-employment for scientists employed outside of academia (Panel B) and in academia (Panel C) for 1993 (blue) and 2008 (red). These are calculated as the share of science doctorates employed in science in the 1993 (2008) survey, who were not employed as of the 1995 (2010) survey. The spike in the retirement hazard at age 70 in 1993 and the decline is more pronounced among scientists in academia than among those outside of academia.

2. Trends in Completion of a PhD in Science

We break the scientific PhD completion rate into three components: completion of a bachelor's degree, the share of science majors among bachelor's degree recipients, and the share of undergraduate science majors that completes a PhD in science. Figure SI-7 illustrates trends in these variables, going back to the 1960s.[5] The 4-year college completion rate as a share of births 22 years earlier has grown dramatically, from less than 20% in the 1960s to more than 40% since 2005. The share of bachelor's degrees earned in a scientific field trended down from 35% in the 1960's to 31% in 1990, and has fluctuated in a narrow range around 32% since the mid 1990's. The rate at which science majors who graduated with a bachelor's degree in year *t*-6 completed a science PhD by year *t* dropped from over 10% in the early 1970's to less than 6% in 1980.[6] It then rose back up to 8% by 1995, and has fluctuated between 6 and 8% since then. If we look at the 1993 to 2010 period covered by the SDR, there is no trend. Thus science is no more popular today than in the 1990s, but it is not much less popular. The dramatic increase in college completion has resulted in steady growth in the *number* of new science PhDs produced in the US, as shown in Figure SI-8, from around 12,000 in the 1960s to 35,000 recently.

[5] The data described in this paragraph are from the NCSES web site (https://nces.ed.gov/datatools/index.asp?DataToolSectionID=4), and are derived from the Survey of Earned Doctorates (SED) and the Survey of College Graduates (SCG).
[6] We use a six year lag to approximate the average time to completion of a PhD. The trend is very similar using other lags.

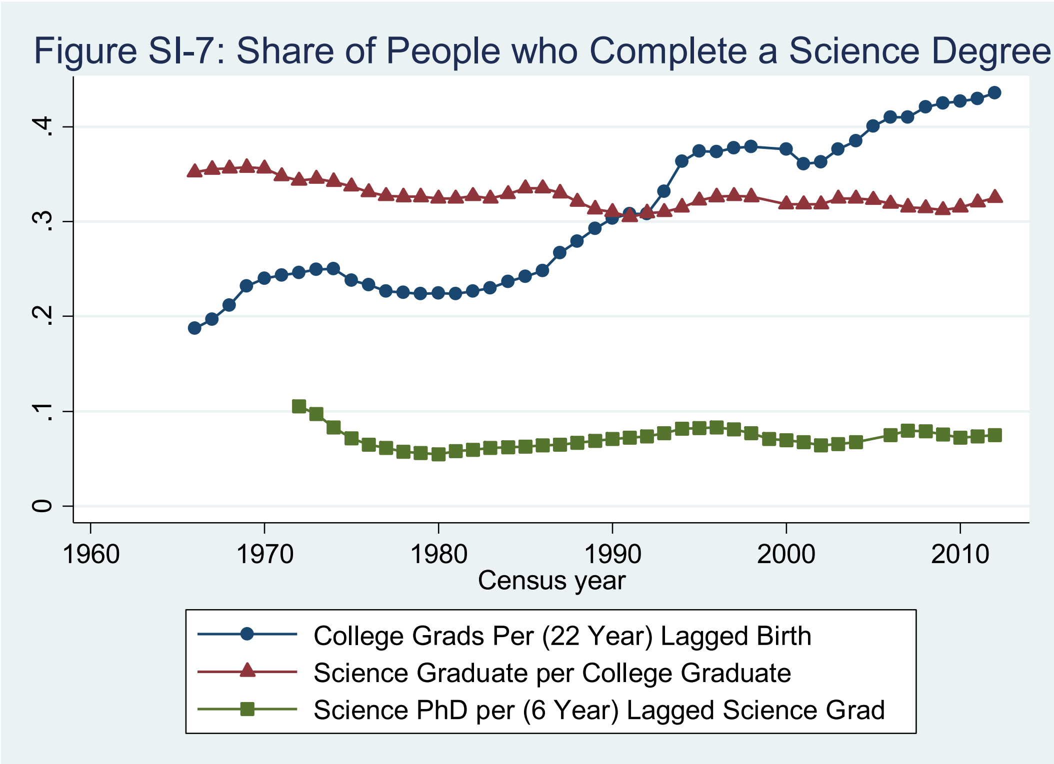


Figure SI-7: Share of People who Complete a Science Degree
0
.1
.2
.3
.4
1960
1970
1980
1990
2000
2010
Census year
College Grads Per (22 Year) Lagged Birth
Science Graduate per College Graduate
Science PhD per (6 Year) Lagged Science Grad

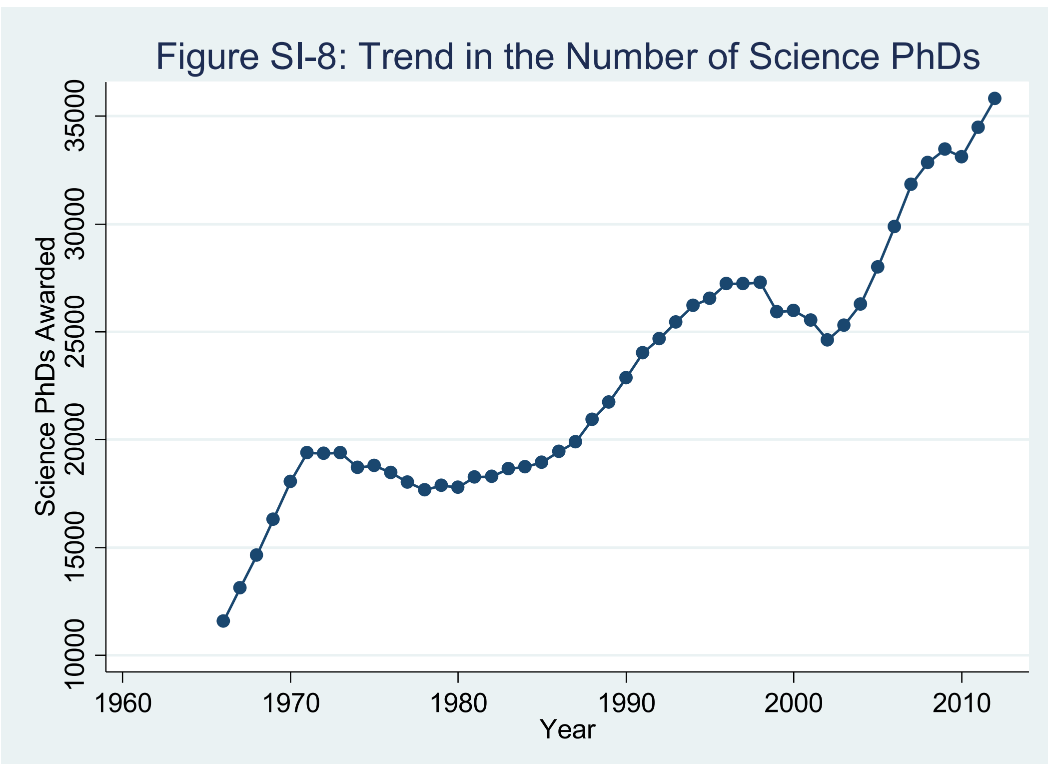


Figure SI-8: Trend in the Number of Science PhDs
Science PhDs Awarded
10000
15000
20000
25000
30000
35000
1960
1970
1980
1990
2000
2010
Year

3. Model

Here, we analyze the change in the age distribution of scientists between 1993 and 2008.[7] We use a simulation model to generate a predicted 2008 age distribution of the scientific workforce conditional on the observed 1993 distribution and the observed set of survey-wave-and-age-specific transition rates among the employment states of (1) scientific worker, (2) non-scientific worker, and (3) not employed.[8] The population is individuals who earned a PhD in a science field in the US. The model incorporates hazard rates for movements among the three states, as well as birth rates, death rates, PhD completion rates, and the share of foreign-born among US science PhDs (for brevity we refer to these factors collectively as transition rates). We use the model to explore explanations for the aging of the scientific workforce by conducting counterfactual simulations in which each transition rate is held fixed at its 1993 age-specific values.

Define N_{at}^{S} as the number of individuals with a PhD in science who are employed as scientific workers of age a in year *t*, N_{at}^{N} as the number of individuals with a PhD in science who are employed outside of science, and N_{at}^{O} as the number of individuals with a PhD in science who are out of the labor force. Define h_{at}^{ij} as the biannual hazard rate for a transition from state *i* to state *j*, *i*, *j* = *S*, *N*, *O*, between years *t* and *t*-2. The age-specific transition equation for the scientific workforce from *t*-2 to *t* is

$$N_{at}^{S} = N_{a-2,t-2}^{S}(1 - h_{at}^{sn} - h_{at}^{so} - m_{sat}) + N_{a-2,t-2}^{N}h_{at}^{ns} + N_{a-2,t-2}^{O}h_{at}^{os} + (B_{t-a}g_{a-1,t-1} + B_{t-a-1}g_{a-2,t-2})(e_{at} + \alpha_t f_{at})$$

Here, m_{sat} is the biannual age-a mortality rate of scientists, B_{t-a} is the number of births *t-a* years ago, g_{at} is the proportion of individuals born in period *t-a* who obtain a science PhD in period *t* at age a, e_{at} is the proportion of US science PhD graduates who obtained a PhD at age a-1 in year *t*-1 or age a-2 in year *t*-2 that are in the scientific workforce at *t*, f_{at} is the corresponding proportion for foreign students, and α_t is the ratio of foreign to native US students

[7] We use 2008 instead of 2010, the last year of the SDR available to us, because the 2010 SDR does not contain complete data on all PhDs awarded in 2009.

[8] We do not distinguish scientists employed in academia from those employed in industry because the differences in the age distribution are not large, nor are there large time trends – roughly 52% of scientists are in academia compared to 48% outside. See figure S.5.

completing a US scientific PhD program. h_{at}^{so} is the biannual hazard rate of exiting the scientific workforce to out of the labor force, i.e. the retirement hazard. Note that we have dropped the intermediate step of obtaining a Bachelor's degree in science because we do not have information on the number of students completing such a degree by age in a given year. We allow for PhDs obtained at ages 27-57, since there is quite a dispersed distribution of the age at PhD completion. We have annual data on new PhDs, so we aggregate these data to a biannual basis, as indicated in the equation. There are similar equations for transitions into non-science employment and out of the labor force.

The share of science PhDs earned by women has grown from 10% in 1970 to more than 40% in 2010 (see Figure SI-13) and women have longer life expectancy. We modify the model to allow for sex-specific mortality and PhD completion rates as follows. Let the r superscript denote gender, r = m for males and f for females.

$$N_{at}^{Sr} = N_{a-2,t-2}^{Sr}(1 - h_{at}^{sn} - h_{at}^{so} - m_{sat}^{r}) + N_{a-2,t-2}^{Nr}h_{at}^{ns} + N_{a-2,t-2}^{Or}h_{at}^{os} + (B_{t-a}g_{a-1,t-1}^{r} + B_{t-a-1}g_{a-2,t-2}^{r})(e_{at} + \alpha_t f_{at})$$

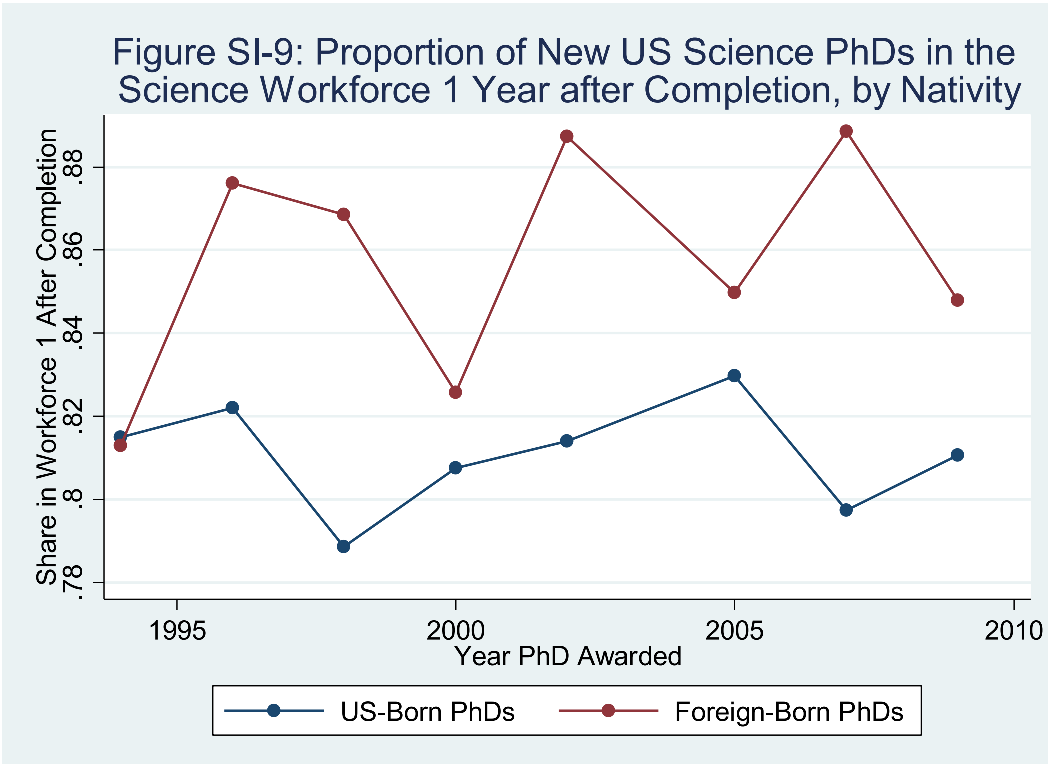
There are similar transition equations for non-science and not employed, in each case differentiated by gender. Note that we allow mortality and the PhD completion rate to differ by gender, but we assume that the hazard rates, the initial entry rates into science (e and f) and the share foreign born are the same. We relax this restriction in Section SI.6.

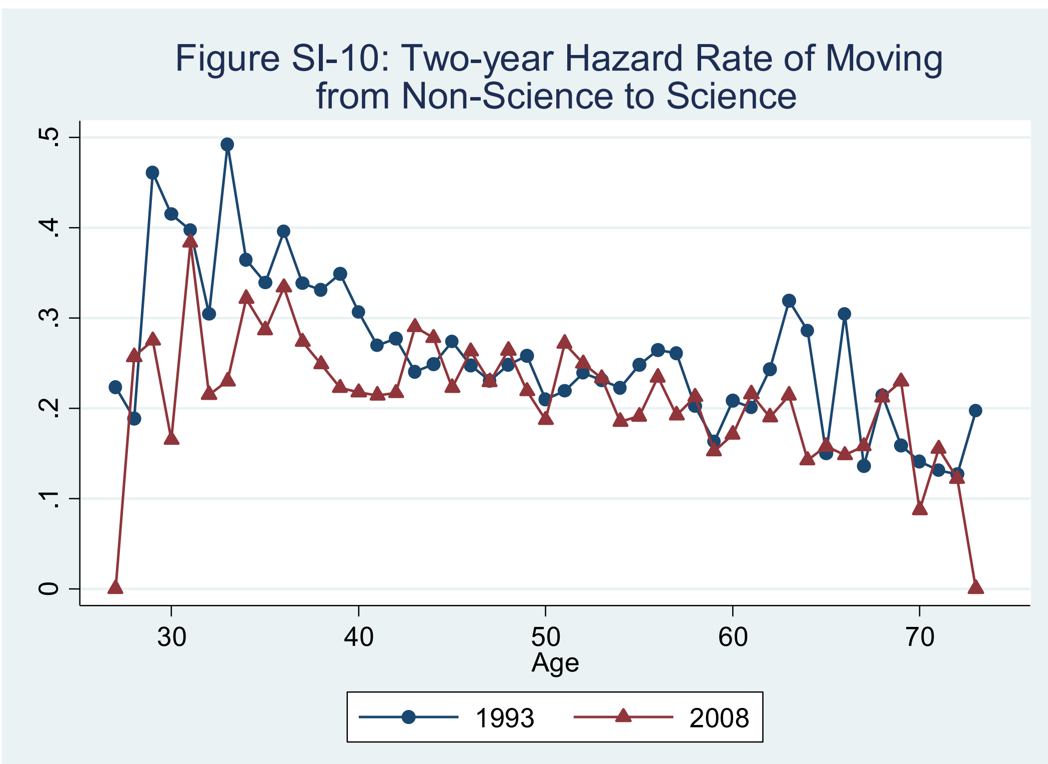
As noted in the main text, we use biannual hazard rates because the SDR has been conducted biannually, with one triannual exception. The precise length of the intervals between the surveys is not always exactly two (or three) years. This is not a problem because our goal is to explain the observed changes in the age-specific stock of scientists from wave to wave, and the hazard rates for transitions from wave *w* to wave *w*+1 should correspond to the actual interval between the periods. We do not attempt to adjust the biannual mortality and PhD completion rates for differing intervals between survey waves.

4. Entry to the Scientific Workforce

Figure SI-9 shows the trend in the share of individuals who obtained a science PhD in year *t* who are part of the US scientific workforce in year *t*+1, by nativity. Roughly 80% of natives who obtain a US science PhD enter the scientific workforce quickly, within one year. Foreign-born students who obtained a PhD in the US and who stayed in the US are on average about five percentage points *more* likely than US-born PhDs to be in the US scientific workforce one year after the PhD, indicating the important role of foreign born recipients of US PhDs. Figure SI-10 shows the biannual hazard rate of entry to the scientific workforce from a non-science occupation, conditional on having a science PhD.[9] There is considerable mobility of individuals with a science PhD into the scientific workforce, with evidence of a modest increase between 1993 and 2009 at younger ages.

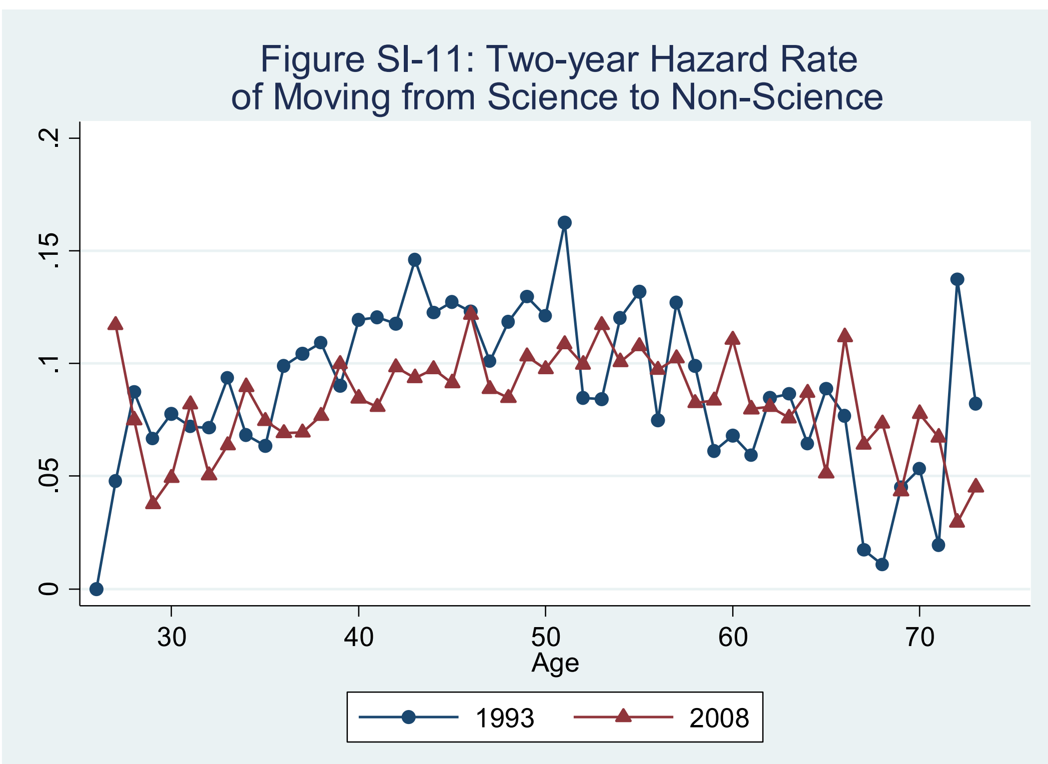
[9] The hazard of entry is the proportion of all individuals with a US science PhD working in a non-science field in year *t* who had entered the scientific workforce by year *t*+2.





5. Exit from the Scientific Workforce

Figure 2 in the text shows the biannual hazard rate of exit from the scientific workforce to non-employment in 1993 and 2008. This includes exits for any reason, but we will refer to it as the hazard rate of retirement, since most exits to non-employment are in fact self-reported as being due to retirement. There is very little exit from the labor force until around age 58. In 1993, the retirement hazard at older ages looked much like the typical pattern of retirement, with large jumps at certain ages. The hazard rate of exit from the scientific workforce decreased substantially after age 60 between 1993 and 2008. The biannual hazard of retirement at age 70 declined by almost half from 0.45 in 1993 to 0.23 in 2008. The large spike at age 70 in 1993 had disappeared by 2008. There is evidence that this is due to the termination in 1994 of a special exemption from the 1986 Age Discrimination Act that allowed universities to impose mandatory retirement at age 70 (2). Figure SI-11 shows the hazard rate of exiting the scientific workforce to a non-science occupation in 1993 and 2008. The exit rate from science to non-science dropped by a modest amount between these years, mainly at younger ages. A lower rate of exit at younger ages would tend to increase the share of older workers.



The third source of exit from the scientific workforce is death. Life tables from the Centers for Disease Control indicate that the annual risk of death at age 65, conditional on being alive at age

64, was .021 for men and .012 for women in 1993, and had declined to .015 and .009, respectively, by 2010. There is a strong mortality gradient by education, so the mortality decline among scientists may have been different than for the population as a whole. It is possible to estimate mortality rates by level of education using micro data from the National Health Interview Survey Linked Mortality File (3). The highest education category in their analysis is college graduate. Using their results, it is possible to compute the ratio of mortality of college graduates to mortality of the population as a whole for several age groups. In the 2000-2006 period, the ratios are 0.69 at 45-54, 0.55 at 55-64, and 0.51 at 65-74. We use these figures in the analysis below.

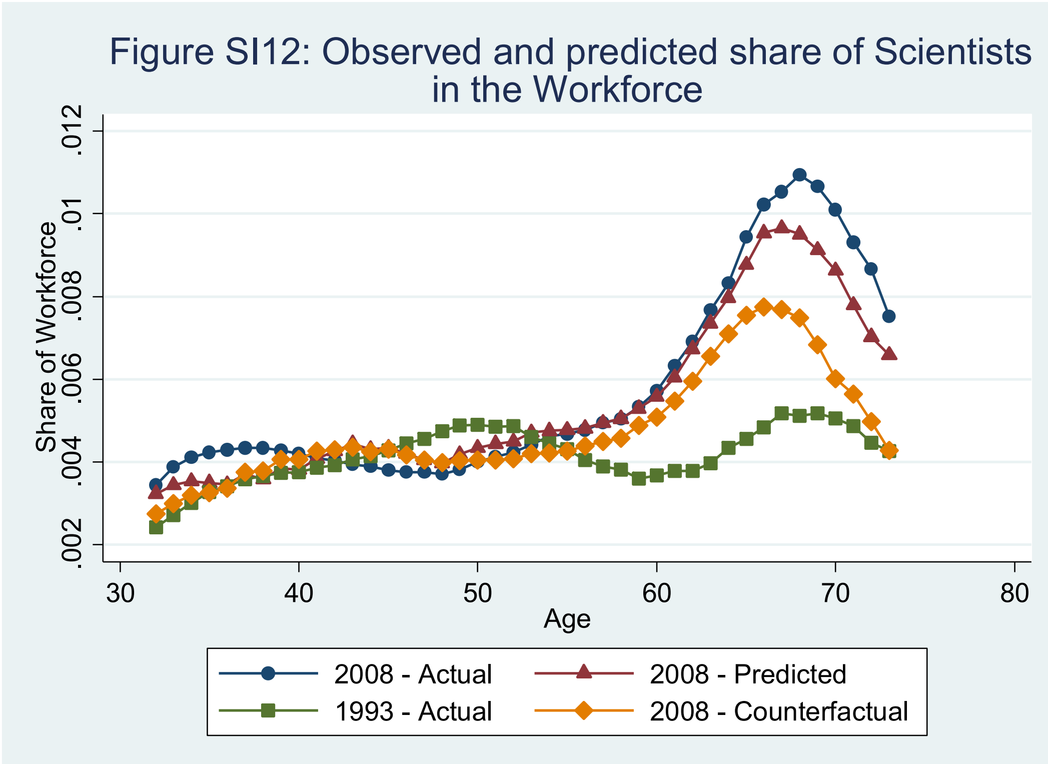


Figure SI-12 shows the age distribution of the share of scientific workers in the workforce in 1993 (green squares) and 2008 (blue circles). It also shows the 2008 distribution predicted by the model based on the observed hazard, PhD completion, and birth and death rates for each year (red triangles), and the counterfactual predicted 2008 distribution, using the same model, but holding all transition rates fixed at their 1993 values (yellow diamonds).

	Median of the age-specific fraction explained	Fraction of the change in mean age explained	Fraction of the change in the share age 55 and above explained
Observed transition rates	0.955	1.203	0.973
Holding all transition rates at 1993 levels	0.808	1.079	0.835
Fraction explained using observed transition rates except holding the following at 1993 values, one at a time:			
Retirement hazard	0.875	1.119	0.897
All hazards	0.878	1.053	0.874
Birth rate	0.842	0.963	0.832
Mortality rate	0.932	1.185	0.957
PhD completion rate and age distribution of new PhDs	1.022	1.440	1.059
PhD completion rate	0.929	1.310	0.959
Age distribution of new PhDs	1.046	1.348	1.072
Foreign born share of PhDs	0.958	1.208	0.977

Table SI.1. Fraction of the change in the age distribution of the scientific workforce from 1993 to 2008 explained by the simulation model. Fraction explained = (predicted 2008 – observed 1993) / (observed 2008 – observed 1993). The first row reports the fraction explained using the observed transition rates for each year (with averages of adjacent years for non-survey years). The second row shows the fraction explained if all transition rates had remained at their 1993 values. The remaining rows quantify the importance of each factor by using the observed 2008 rates except for the one indicated, for which the 1993 rate is used. For example, holding the retirement hazard constant at its 1993 level reduces the fraction explained from 0.955 to 0.875, for a loss of 0.08 in the fraction explained.

6. Model extensions

We extend the model in two directions in order to determine whether other factors might help account for the aging of the scientific workforce. First, if male and female scientists have different transition rates, in addition to the different mortality and PhD completion rates already incorporated in the model, the change in gender composition of the scientific workforce, shown in Figure SI-13, could affect the change in the overall age distribution. Figures SI-14 and SI-15 depict the biannual hazard rate of exit from science to non-science by gender in 1993 and 2008. The data are somewhat noisy (even using a five-year moving average) but show somewhat higher transitions out of scientific careers for women in the 40s, when many women have young children in the household. Otherwise the gender differences are modest. Figures SI-16 and SI-17 show the retirement hazards by gender. In both 1993 and 2008, women retired from science at a *slower* rate than men. As the female share of scientists increased, this would have tended to cause aging of the scientific workforce. However in quantitative terms, the gender difference is small compared to the rapid decline in the retirement hazard for both men and women. The quantitative results from a version of the model that allows hazard rates to differ by gender indicate that the change in gender composition of new PhDs can explain less than 2% of the observed aging of the scientific workforce, and none of the change in the age distribution of the fraction of the scientific workforce.

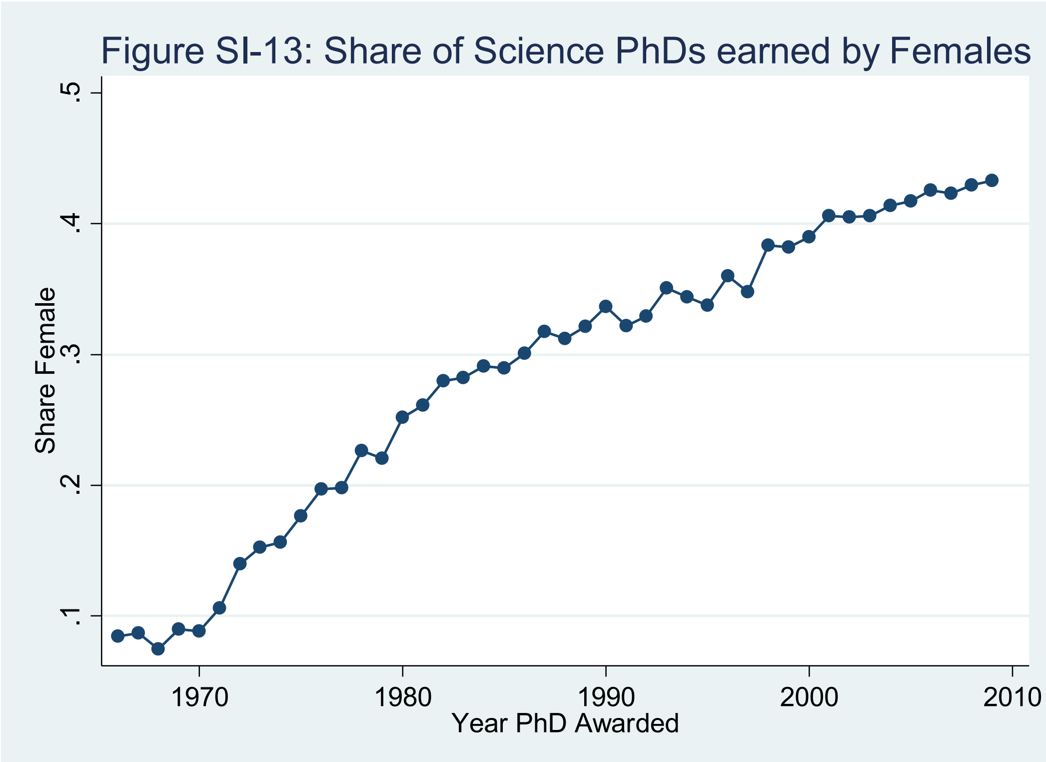


Figure SI-13: Share of Science PhDs earned by Females
Share Female
.1
.2
.3
.4
.5
1970
1980
1990
2000
2010
Year PhD Awarded

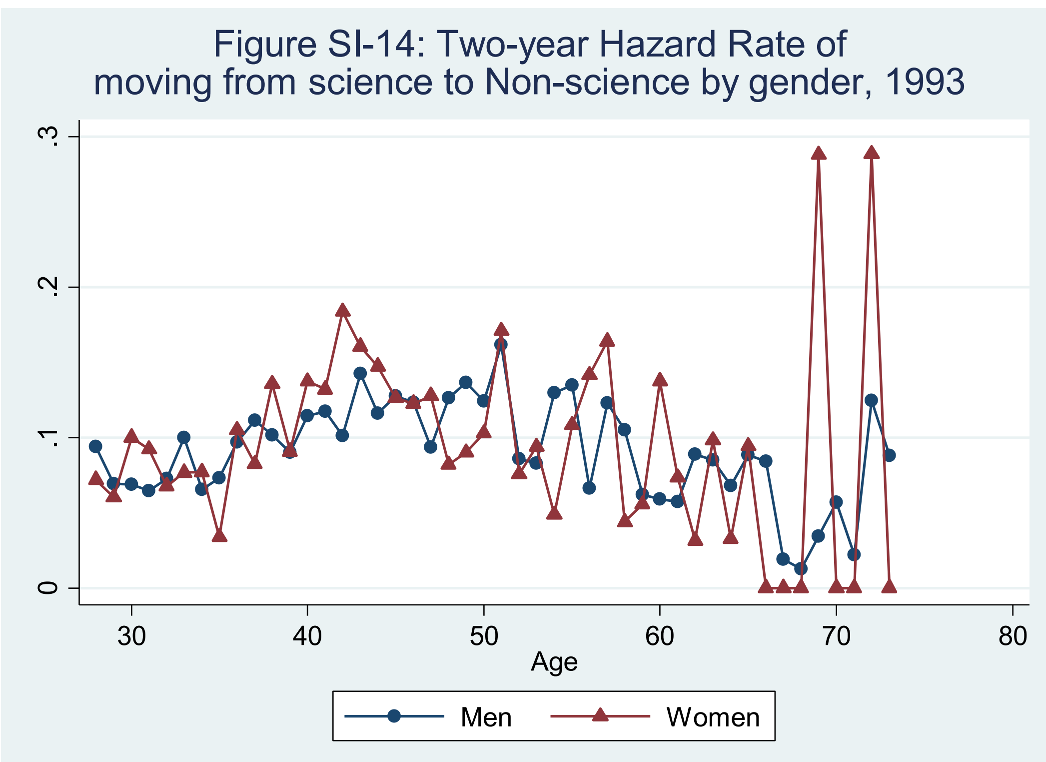


Figure SI-14: Two-year Hazard Rate of
moving from science to Non-science by gender, 1993
0
.1
.2
.3
30
40
50
60
70
80
Age
Men
Women

Figure SI-15: Two-year Hazard Rate of moving from science to Non-science by gender, 2008

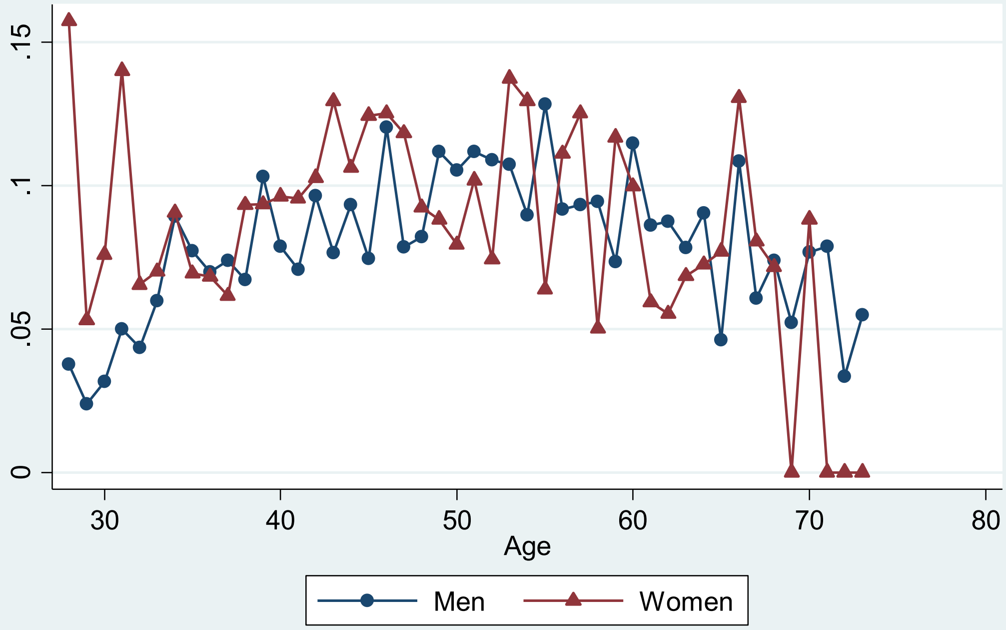
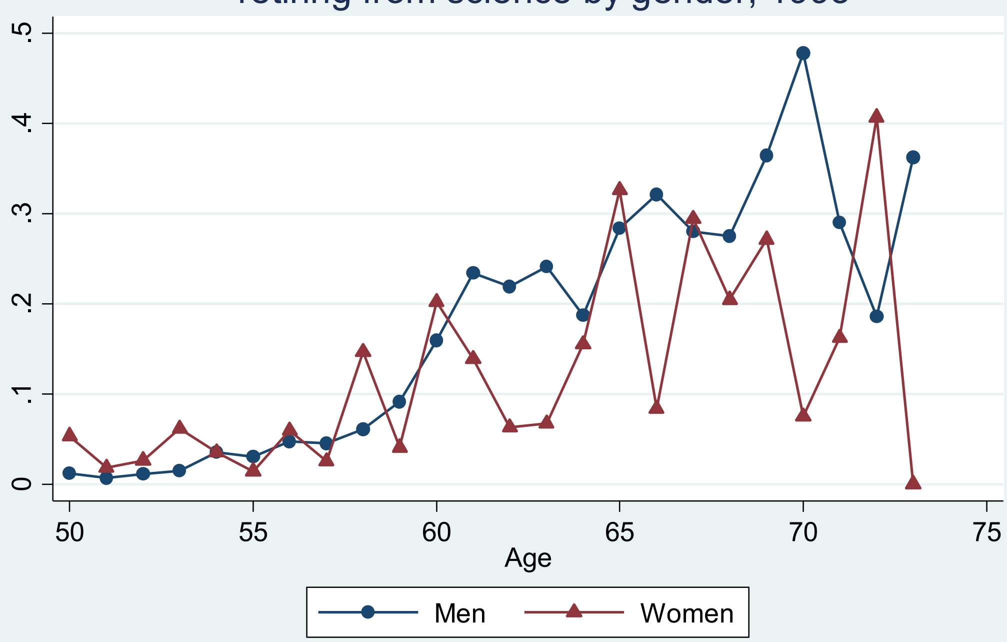
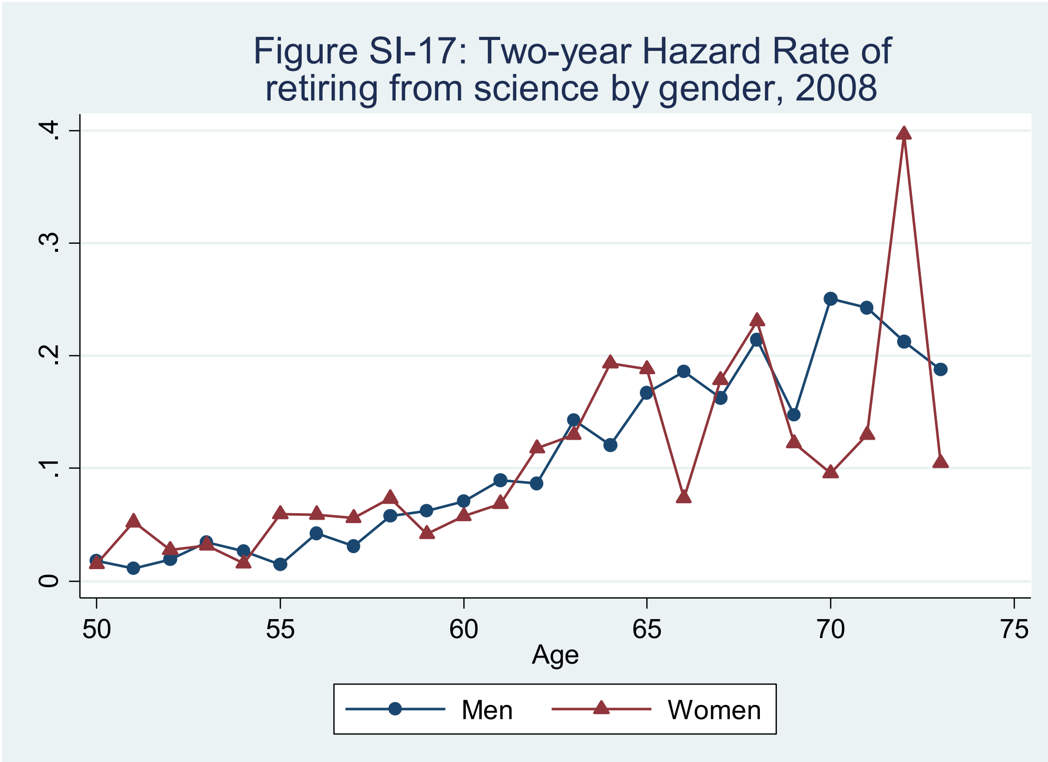


Figure SI-16: Two-year Hazard Rate of retiring from science by gender, 1993





The second extension is to allow for differences in behavior of native and foreign-born scientists who earned a PhD in the US (recall that the SDR does not include scientists who immigrated to the US after earning a PhD abroad). If transition behavior differs by nativity, the increasing share of foreign-born PhDs could have affected the age distribution of the scientific workforce. However, the hazard rates for natives and non-natives who obtained the PhD in the US are quite similar. A quantitative analysis allowing hazard rates to differ by nativity was not possible because the sample of non-natives was too small.

7. Immigration

We rely here on the ACS/Census, which is the only source for information on immigrants who obtained a PhD outside the US (the sample size of immigrant scientists in the CPS is too small to be useful). The ACS/Census data do not contain information on the age at which the PhD was obtained. We assume somewhat arbitrarily that if an individual with a PhD arrived in the US at age 32 or above, the PhD was completed abroad. However, even in the ACS and Census, the sample sizes are too small to produce meaningful results disaggregated by year and age at arrival. Instead, we show trends in the overall share of immigrants in the US scientific workforce, including those who obtained a PhD in the US. An immigrant is defined as an individual who was not born in the US.

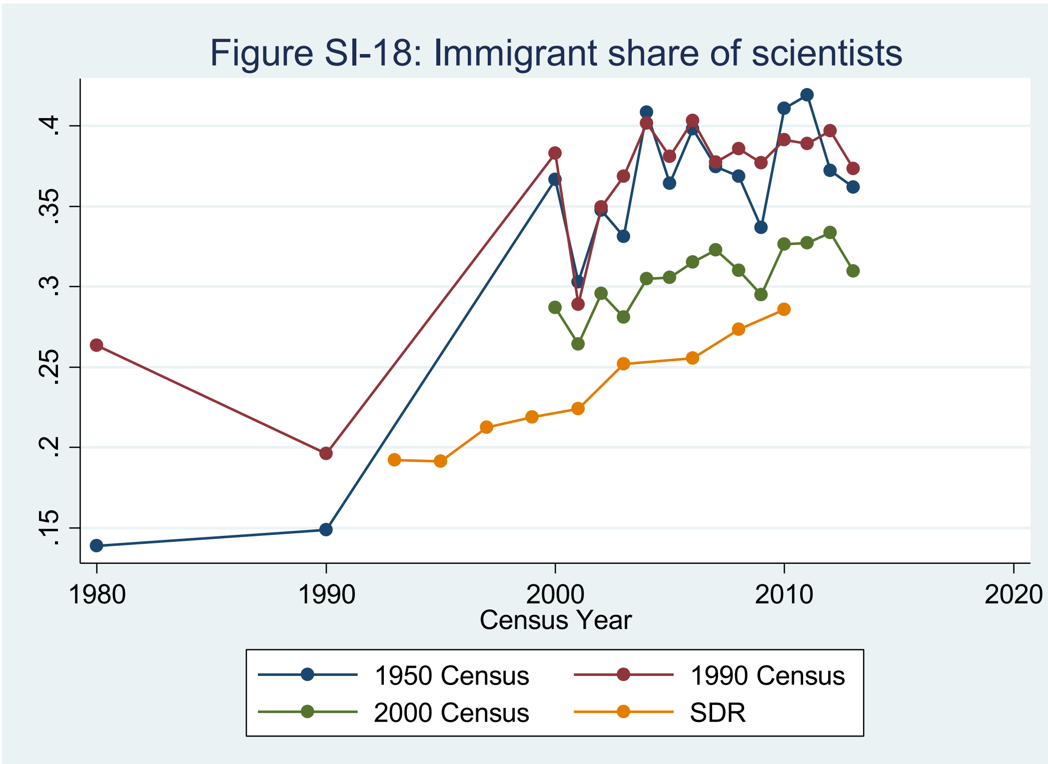


Figure SI-18 shows trends in the immigrant share of scientists using three alternative Census occupational coding schemes: one based on the 1950 occupational classification, a second based on the 1990 classification, and a third based on the classification used since 2000. The IPUMS provides recoded occupations for all years based on the 1950 and 1990 classifications, but the more detailed codes used in the 2000 classification cannot be used to recode earlier years.[10] For comparison, the proportion foreign born in the SDR is also shown. The share of immigrant scientists differs substantially in 1980 for the 1950 and 1990 classifications, differs moderately in 1990, and hardly differs at all since 2000. Both the 1950 and 1990 classifications show an immigrant share 5-10 percentage points higher than the measure based on the 2000 classification system. The latter in turn is about 5 percentage points higher than the share based on the SDR. This is expected, since the ACS/Census includes all immigrant scientists, while the SDR includes only those who obtained a PhD in the US. Despite uncertainty about the level of

[10] The 2000 classification system changed in a few minor ways since 2000.

immigration, all of the series show an upward trend, more or less parallel since the 1990s. The immigrant share of the scientific workforce was between 30% and 40% in 2010.

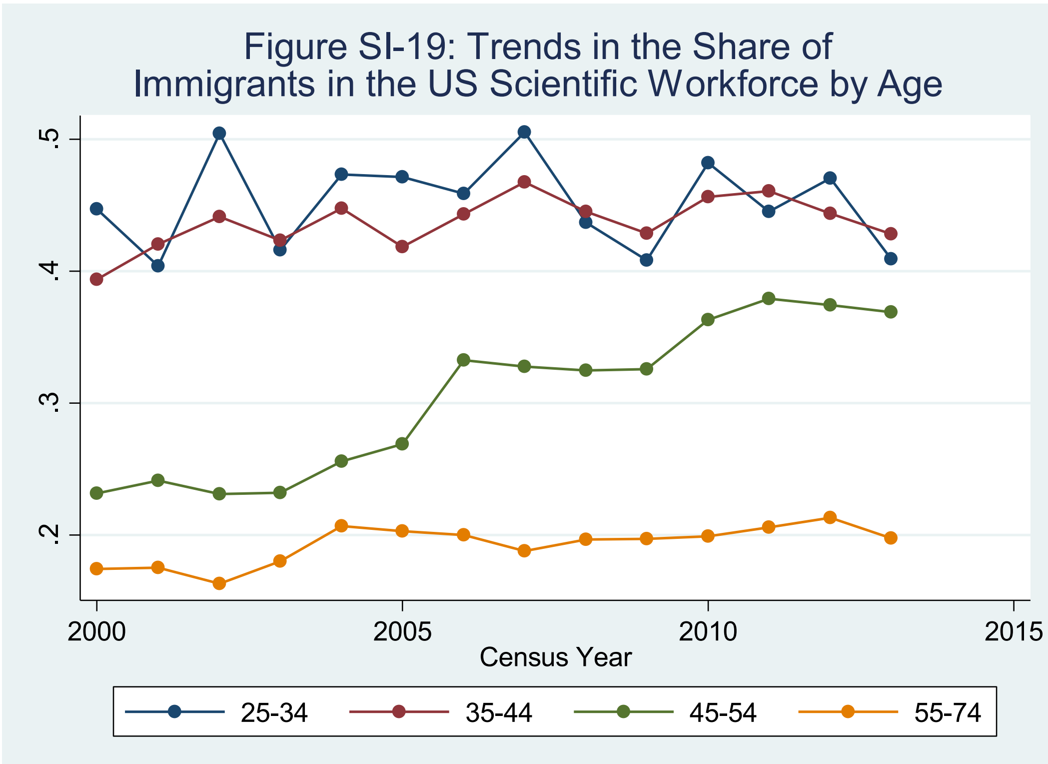


Figure SI-19 based on the 2000 classification system shows that the immigrant share is highest at younger ages, but the share at younger ages has not been increasing in recent years. In contrast, there was a sharp upward trend in the immigrant share at ages 45-54, and a modest upward trend at ages 55-64.

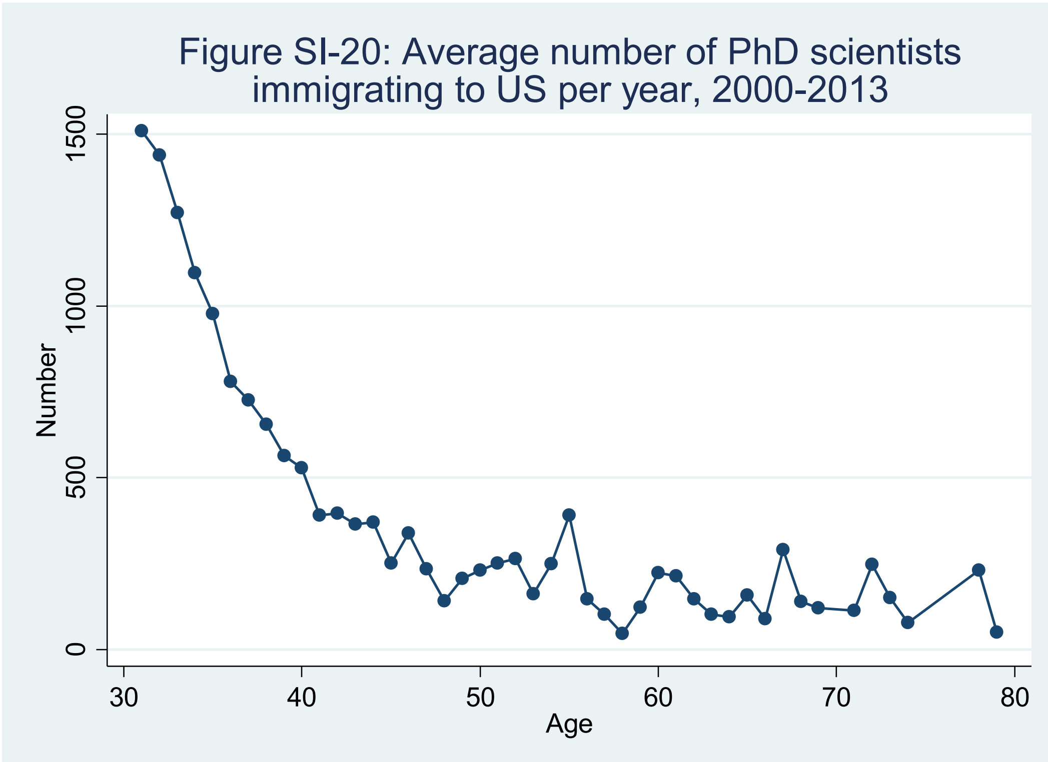


Figure SI-20 combines data from the ACS for the years 2000-2013 to illustrate the number of *new* immigrant scientists (arrived in the year of or the year before the survey) by age at arrival. The sample size is too small to do this separately by year. The number drops sharply from 1,500 at age 31 to 500 at age 40 and 250 by age 50. Summing over age, the data indicate that the total number of scientists trained abroad immigrating to the US was around 17,000 per year since 2000. This compares to about 35,000 new PhDs produced in the US per year (see Figure SI-8 above), including those earned by non-natives.

A note of caution is warranted here. The ACS/Census data are hardly ideal for measuring immigration of scientists by age, but they are the only data available. Differences in the share of immigrants as a function of occupation coding scheme, illustrated in Figure SI-18 above, and the small sample sizes available for measuring trends in immigration by age suggest considerable uncertainty about the level and age distribution of immigration of scientists.

	Mean age	Fraction aged 55+
Observed in 2008	48.6	0.331
Steady state with 2008 transition rates	50.9	0.393
Observed in 1993	45.1	0.176
Steady state with 1993 transition rates	50.0	0.361
Counterfactuals:		
1993 retirement hazard	49.7	0.353
1960 birth rate	47.6	0.283
1980 birth rate	51.1	0.401
No immigration of scientists	50.2	0.371
1993 death rate	50.8	0.389
1966 PhD completion rate	50.3	0.375
1993 PhD completion rate	51.2	0.402
1966 share of foreign born among new US PhDs	50.9	0.394
1993 share of foreign born among new US PhDs	50.9	0.393

Table SI.2: Steady state age distribution implications of alternative values of transition rates. 2008 transition rates are based on one-year transitions estimated from biannual transition rates observed between the 2008 and 2010 survey waves. 1993 transition rates are based on one-year transitions estimated from biannual transition rates observed between the 1993 and 1995 survey waves. The annual rates are estimated from the biannual rates under the assumption that the annual rates are equal between survey years. If b is the biannual rate and a is the annual rate, then $b = a + (1-a)a$. This equation is solved for a to obtain measures of the annual rates. The row labelled "1993 retirement hazard" uses observed 2008 transition rates except for the retirement hazard, which is set to its 1993 level. The other counterfactuals have a similar interpretation.

8. Additional steady state model simulation results

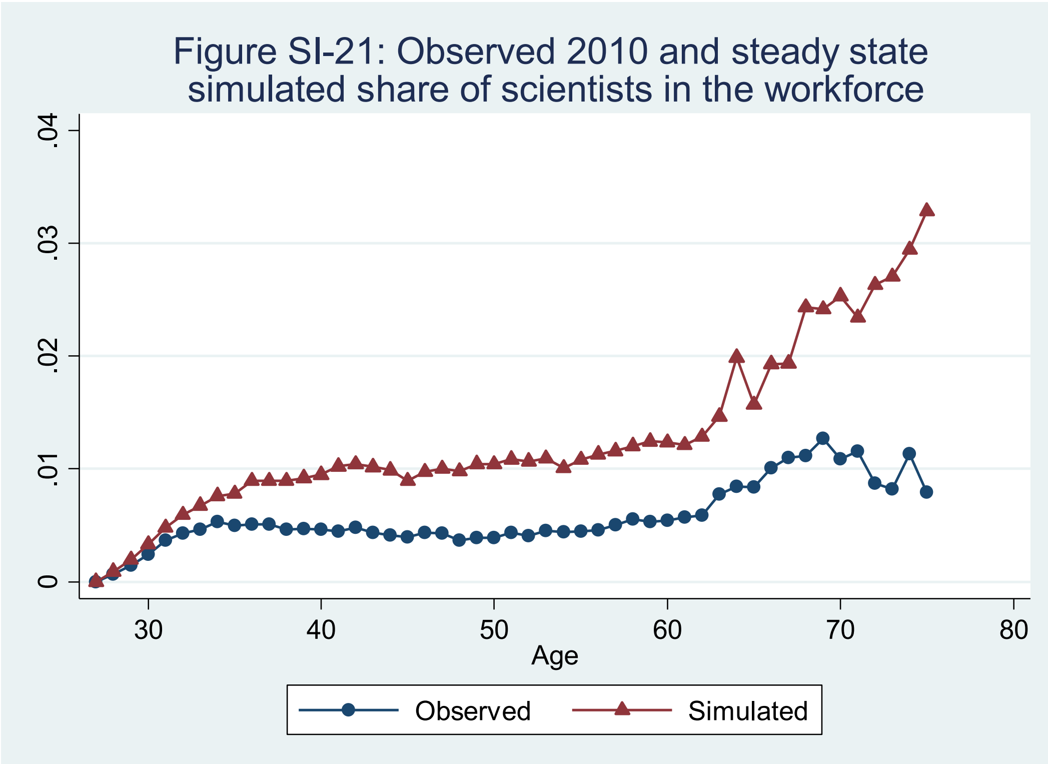


Figure SI-21 shows the observed 2010 share of scientists in the workforce by age, along with the simulated steady state share using 2008 transition rates. As noted in the text, the workforce as a whole is aging but the scientific workforce is aging much more rapidly, resulting in an increasing share at all ages, but especially beyond age 65.

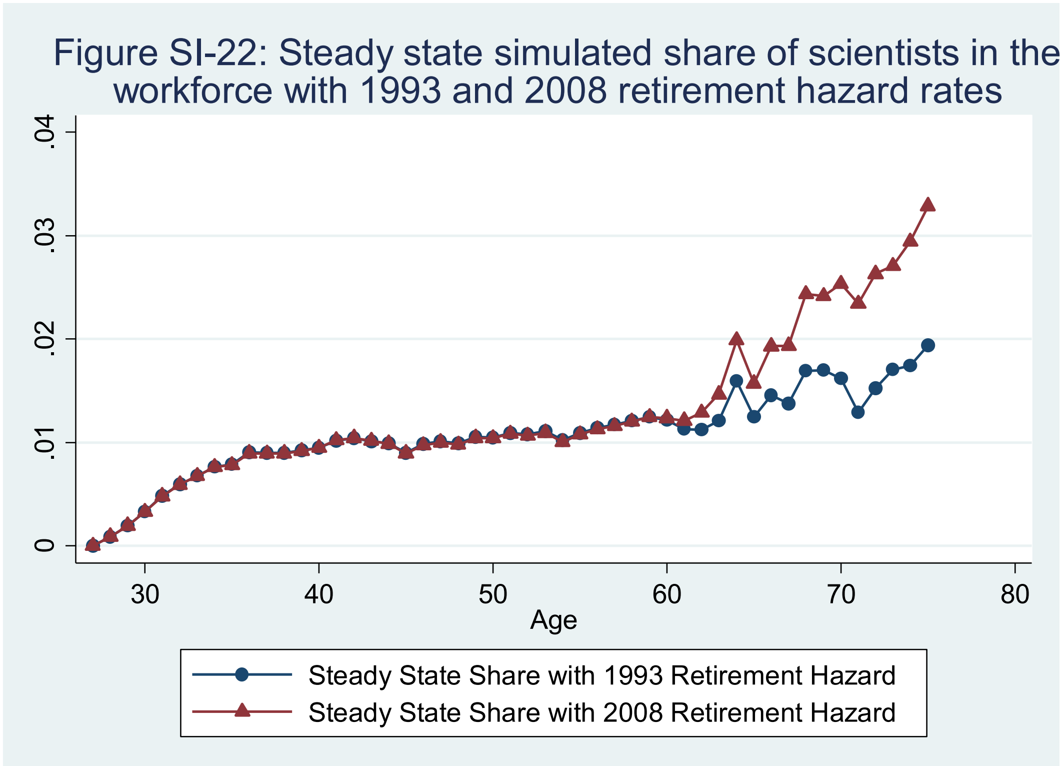


Figure SI-22 shows the steady state share of scientists in the workforce by age using 1993 and 2008 retirement hazard rates. The pre-mandatory retirement (1993) hazard rate implies a substantially lower share of scientists in the workforce at older ages.

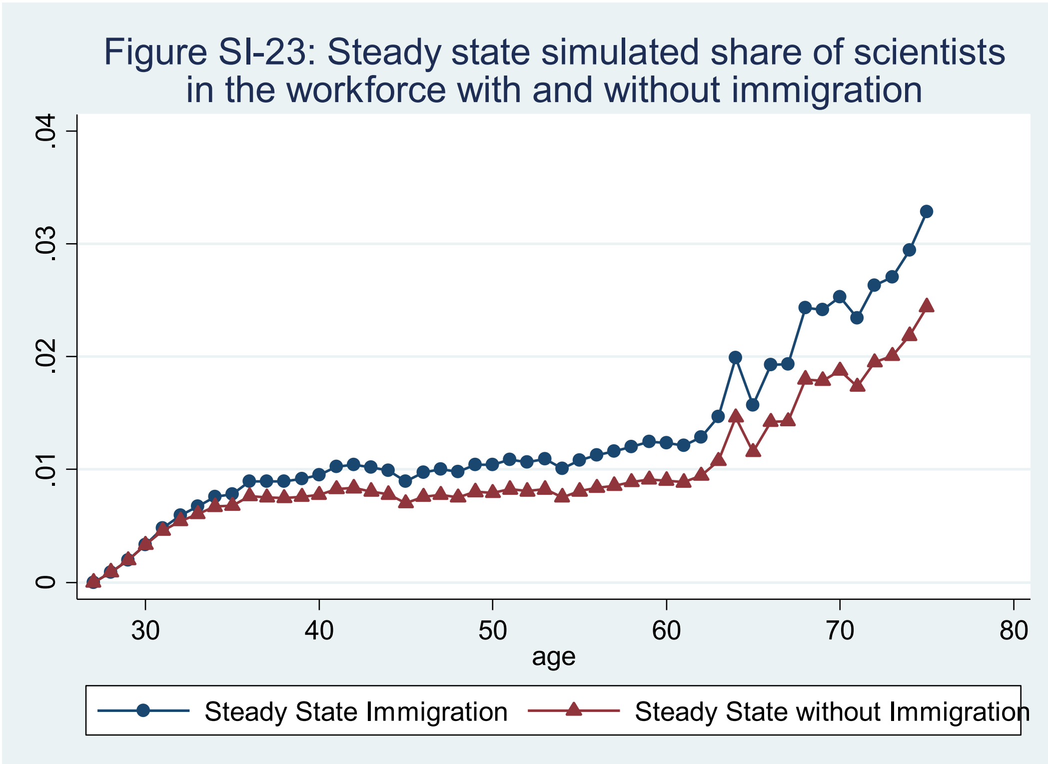


Figure SI.23 shows the steady state share of scientists in the workforce by age using current immigration rates of scientists and assuming no immigration of scientists. In the absence of immigration, share of scientists in the workforce would be lower, with the largest decline at older ages.

References

(1) Ginther D, Kahn S. (2013) Postdoctoral Training and the Career Outcomes of Biomedical PhDs. University of Kansas. Working Paper.

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(3) Montez JK, Hummer RA, Hayward MD, Woo H, Rogers RG. (2011) Trends in the Educational Gradient of U.S. Adult Mortality from 1986 to 2006 by Race, Gender, and Age Group. *Research on Aging* 33(2): 145–171.