Immigration, Science, and Invention
Lessons from the Quota Acts

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How did immigration quotas change American science and invention?

- National origins immigration quotas in the 1920s
  - Target low-skilled ”undesirable” Eastern and Southern Europeans (ESE)
- Rich biographical data > 90,000 US scientists in 1921 and 1956
  - Matched with US patents
  - Assigned to research fields using text analysis
- Nearly 1,200 missing scientists, roughly 40/year
- 68% decline in invention by US scientists in fields of ESE-born scientists
  - 60% decline in invention by US-born US scientists
- Mechanisms
  - Fewer scientists and fewer patents per scientist
  - Reduced collaborations
  - Not driven by selection into fields
- Substantial effects on aggregate invention
  - 53-percent decline in invention for firms employing immigrants
  - Gains for science in future Israel

How did immigration quotas change American science and invention?

- Ethnicity-based immigration quotas in the 1920s
  - Intended to keep out low-skilled ”undesirable” immigrants from Eastern and Southern Europe (ESE)
- Biographical data on > 90,000 US scientists in 1921 and 1956
  - Matched with US patents
- Missing ESE-born scientists
  - > 1,000 missing ESE-born scientists, 1925-50. 41/year
- Effects on patenting by US scientists
  - Compare changes in patenting after 1924 in pre-quota fields of ESE-born US scientists with changes in pre-quota fields of other US scientists
  - After quotas, patenting by US scientists grows by 60% less in ESE fields
- Effects on aggregate patenting
  - After quotas, aggregate US invention declines in ESE fields and ESE firms
- Mechanisms
  - Knowledge spillovers, selection into research fields, or ageing?

Dramatic change in immigration in the late 19th century

- Until 1880, 90% of migrants to America came from British Isles and German-speaking parts of Continental Europe
- After 1890, sources of migration shift to ES Europe
  - Expansion of rail and steamship links lowers costs of migration from Eastern and Southern Europe (Keeling 2012)
  - Competition with American grain reduces rural incomes (O'Rourke 1997)
  - Oppression and violence in Poland and Russia's Pale of Settlement
- Between 1870s and 1920, the share of migration from Italy and Eastern Europe increased from 8% to 80%

A surge in race-based nativism in the 1920s

- “Our country must cease to be regarded as a dumping ground. Which does not mean that it must deny the value of rich accretions drawn from the right kind of immigration….There are racial considerations too grave to be brushed aside for any sentimental reasons. Biological laws tell us that certain divergent people will not mix or blend. The Nordics propagate themselves successfully. With our races, the outcome shows deterioration on both sides. Quality of mind and body suggests that observance of ethnic law is as great a necessity to a nation as immigration law.”
- Calvin Coolidge (Vice President, 1921-1923, President 1923-1929)

Calvin Coolidge, “Whose Country is This?” *Good Housekeeping,* volume 72 Number 2, February 1921, pp. 13-14, 109

New York Times Editorial in 1921: “American institutions are menaced” by “swarms of aliens”

A Definition. The Locust—A Very Destructive Migratory Insect

Saturday Evening Post’/[National Archives Catalog]

The Immigration bill will serve as an index, a finger that points accusation. The need of restriction is manifest. Literally millions of workmen are out of employment. American institutions are menaced; and the menace centres in the swarms of aliens whom we are importing as "hands" for our industries, regardless of the fact that each hand has a mind and potentially a vote. With the diseases of ignorance and Bolshevism we are importing also the most loathsome diseases of the flesh. Typhus, the carrier of which is human vermin, has already been scattered among us, and neither Dr. Cope-

New York Times, Editorial, February 9, 1921, p.7

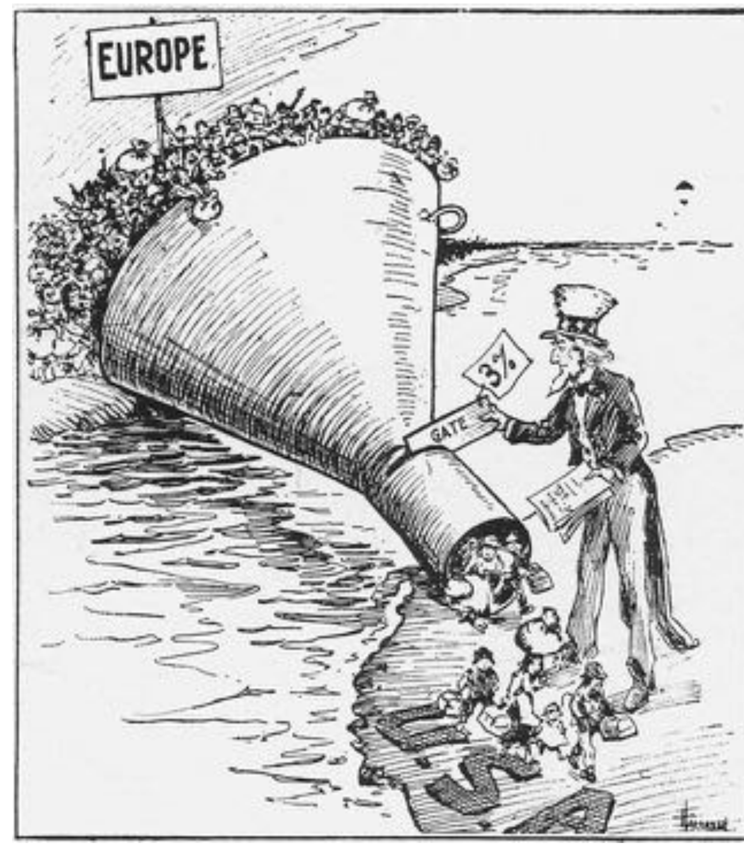
New York Times Editorial in 1921: "American institutions are menaced" by "swarms of aliens"

Image: Ram's Horn Press/ The Cartoon Research Library of Ohio State University

Images: Louis Dairymple/'Judge'/[Wikimedia Commons](); [Edwin Marcus]()

US tries to stem inflow of “undesirables” from Eastern and Southern Europe

- Literacy test of 1917
  - Refuse entry to anyone above 16 who cannot read and write
  - But only 1,450 in 800,000 excluded based on literacy
- National Origins Quota in 1921
  - Limits # immigrants/year to 3% of foreign-born US residents from that country in Census of 1910
  - But millions of immigrants from E and S Europe had arrived since 1890



Political cartoon from 1921, Source: National Archives

“Our New Nordic Immigration Policy”
Senator Reed (Rep., Pa.), 1924

“There has come about a general realization of the fact that the races of men who have been coming to us in recent years are wholly dissimilar to the native-born Americans […] From all this has grown the conviction that it was best for America that our incoming immigrants should hereafter be of the same races as those of us who are already here, so that each year’s immigration should so far as possible be a miniature America, resembling in national origins the persons who are already settled in our country….”

Johnson-Reed Immigration Act of 1924

- Limit of 165,000 immigrants per year
  - Less than 20% of pre-war average
- Restricts immigrants per year from a country to 2% of US residents in the US census of 1890 whose ancestors originate from that country
  - Allow inflows from Britain, Ireland, and Germany
- Reduces quota for S and E Europeans from 44 to 12%
  - 43 Stat. 153 (1924)

Courtesy of the New York "Times"

THE FLOW OF IMMIGRATION UNDER THE PROPOSED 2 PER CENT. LAW

Under the present law, which expires June 30, 357,801 immigrants are admitted. Under the proposed law 161,990 would be admitted. The smallest quotas would come from the lightly shaded countries and those shown in white, such as Austria, Rumania, Turkey, and Spain.

Massive decline in immigration, esp from S and E Europe

- Total immigration falls by more than half
  - 357,803 in 1923-24
  - 164,667 in 1924-25
- Disproportionate decline from Eastern and Southern Europe (ESE)
  - Immigration from Great Britain and Ireland fell by 19%
  - Immigration from Italy fell more than 90% (Murray 1976)
- Disproportionate decline for E European Jews
  - Use of US population in 1890 prevented mass migration from E Europe
  - 75% of Jews arriving in US immigrated from Russia (Levinson 2008)
- For some ESE countries, outflows exceed inflows
  - More Italians, Hungarians, Poles, Portuguese, Romanians, Lithuanians, Czechs, Yugoslavs, Chinese and Japanese leave than arrive (Koven and Götzke 2010)

Quotas stay in effect until October 3, 1965, when Pres. Johnson signs a New Immigration Bill

This bill that we will sign today [...] corrects a cruel and enduring wrong in the conduct of the American Nation. [...] This bill says simply that from this day forth those wishing to immigrate to America shall be admitted on the basis of their skills and their close relationship to those already here. [...] The fairness of this standard is so self-evident that we may well wonder that it has not always been applied. Yet the fact is that for over four decades the immigration policy of the United States has been twisted and has been distorted by the harsh injustice of the national origins quota system. Under that system the ability of new immigrants to come to America depended upon the country of their birth. Only 3 countries were allowed to supply 70 percent of all the immigrants. [...] Men of needed skill and talent were denied entrance because they came from southern or eastern Europe or from one of the developing continents. [...] Today, with my signature, this system is abolished. We can now believe that it will never again shadow the gate to the American Nation with the twin barriers of prejudice and privilege.

Did ethnicity-based immigration rules discourage immigrant scholars?

- Ethnicity-based quotas that targeted "undesirables" have accidentally filtered out future professionals
- Future scientists and their families may have chosen to move elsewhere to avoid animus in the US

Hungarian Immigrant Family in Cleveland c.1900 (Greater Cleveland Ethnographic Museum)

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- Biographical data on > 90,000 US scientists in 1921 and 1956
  - Matched with US patents
- Did quotas discourage immigrant scientists?
  - An estimated 859 missing ESE-born American, 1925-50. 33 missing per year
- Effects on patenting by US scientists
  - Compare changes in patenting after 1924 in pre-quota fields of ESE-born US scientists with changes in pre-quota fields of other US scientists
  - After quotas, patenting by US scientists grows by 60% less in ESE fields
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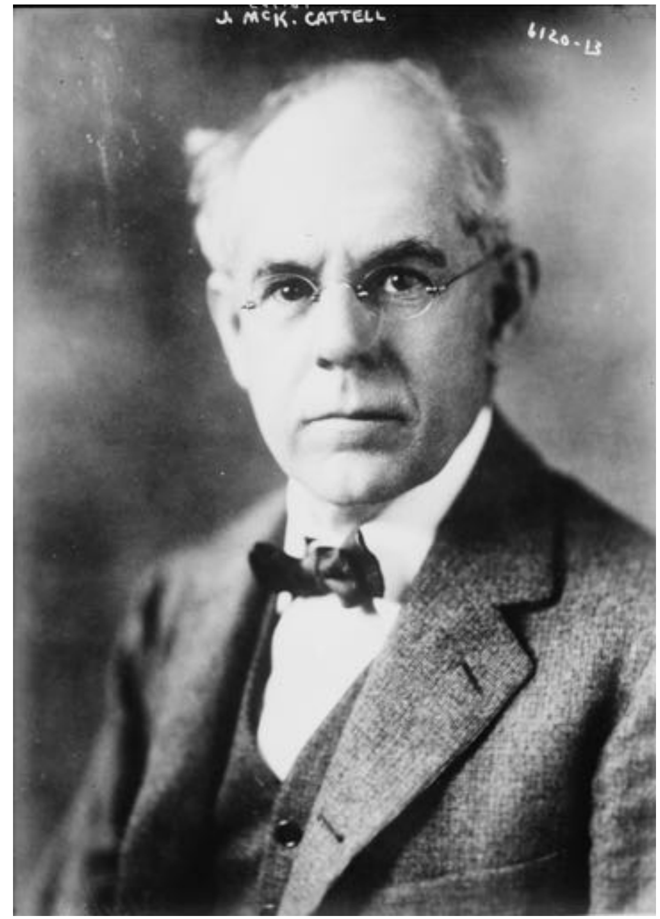
James McKeen Cattell (1860-1944)

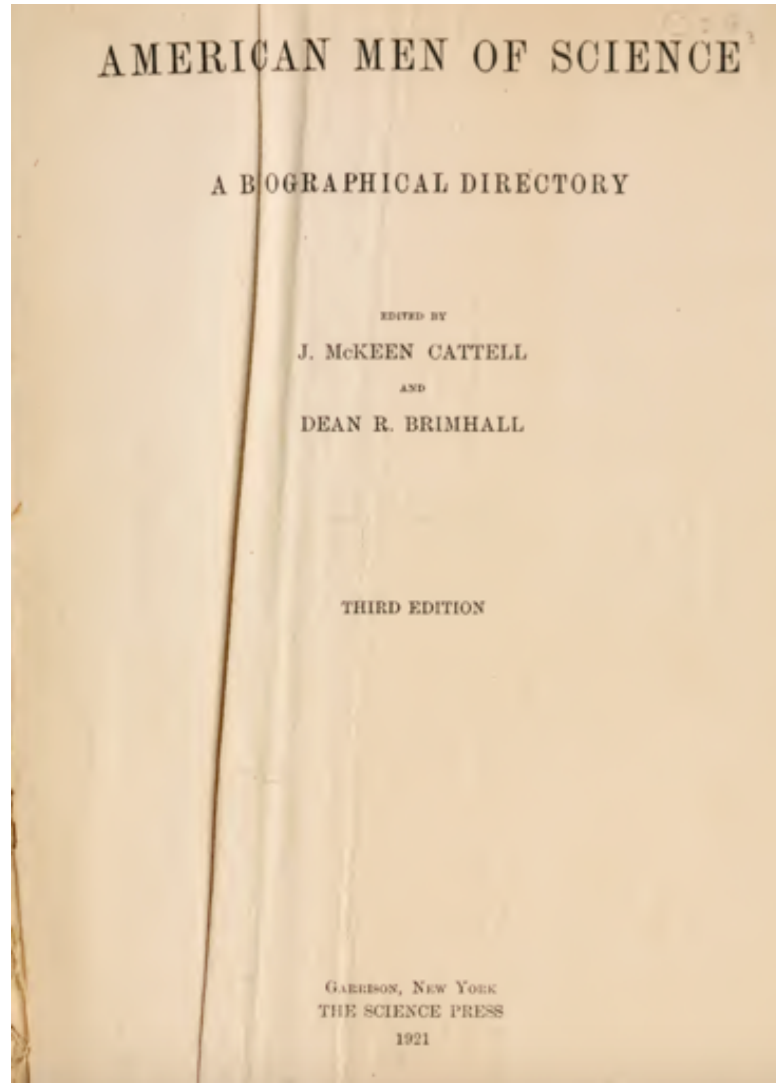
- First US professor of psychology
  - BA MA Lafayette College
  - PhD Leipzig
  - University of Pennsylvania in 1888
- Editor of *Science* for nearly 50 years
- Interest in eugenics
  - Offered his kids $1,000 each for marrying offspring of professor



By Bain News Service - This image is available from the United States Library of Congress's Prints and Photographs division under the digital ID ggbain.36662.T

"American Men of Science. A Biographical Directory" 1921 and 1956

- "...initially intended as a reference list for the Carnegie Institution of Washington....But the chief service it should render is to make men of science acquainted with one another and with one another's work." (Cattell 1921)
- All members of scientific societies
- Includes male and female scientists in Canada and the US
- Handcollected biographies of all scientists in MoS in 1921 and 1956



In 1921, MoS includes US and Canadian men and women in "the natural and exact sciences"

- All researchers in natural and exact sciences
  - "tolerably complete for those in North America who have carried on research work in the natural and exact sciences." (Cattell and Brimhall 1921, p.v)
- Exceptional people in other fields
  - "Some are admitted who are supposed to have advanced science by teaching, by adminstrative work, or by the preparation of text-books and compilations."
  - "There are also some whose work has been chiefly in engineering, medicine or other applied sciences, and a few whose work is in education, economics or other subjects not commonly included under the exact and natural sciences. But the book does not profess to cover these fields." (Cattell and Brimhall 1921, p.v)

Example: Dr. Truman Abbe

Current work address:
- Stoneleigh Court, Washington DC

Birth place:
- Washington

Birth date:
- November 1, 1873

Education:
- A.B. Harvard, 1895
- M.D. Columbia, 1899
- Berlin

Employment:
- Instruct. Physics, physiol. and surg, Georgetown, 0—05;
- physiol. George Washington, 06-10, surg. 10-

Member of
- Am. Med. Ass.

Research topics
- Radiotherapy; surgery

AMERICAN MEN OF SCIENCE

Aase, Prof. Hannah (Caroline), State College of Washington, Pullman, Wash. *Botany*. Elkpoint, S. Dak, July 12, 83. A.B, South Dakota, 06; Ph.D, Chicago, 14. Instr. *bot, Wash. State*, 14–19, *asst. prof, 19–* A.A; Bot. Soc. Plant morphology.

Abbe, Cleveland, Jr, Engineering and Mining Journal, Tenth Ave. and 36th St, New York, N. Y. *Geology, Climatology*. Washington, D. C, March 25, 72. A.B, Harvard, 94, A.M, 96; Ph.D, Hopkins, 98; Vienna and Paris, 01–03. Prof. nat. sciences, Winthrop Nor. and Indust. Col, 99–01; aid, U. S. Geol. Surv, 03–06; with U. S. Weather Bur, 06–19; *'Eng. and Mining Jour,' 19–* Asst, Md. Geol. Surv, 97–01; asst. ed. 'Monthly Weather Rev,' 08–09, 14–16, ed, 16–18; 'Sci. Am. Supplement,' 19. A.A; Geol. Soc; Wash. Philos. Soc; Berlin Gesell. für Erdkunde. Topographic development; climate of Guam, Alaska; fall line of east North America; Washington winters.

Abbe, Dr. Robert, 11 W. 50th St, New York, N. Y. *Surgery*. New York, April 13, 51. A.B, Col. City of N. Y, 70; M.D, Columbia, 74. Prof. surg, Woman's Med. Col, N. Y, 86–88; Post-Grad. Med. Sch, N. Y, 88–96; clin. instr. *surg, Columbia*, 94–99, *assoc, 99–* Senior attending surgeon, St. Luke's Hosp, 84– A.A; Surg. Ass.

Abbe, Dr. Truman, Stoneleigh Court, Washington, D. C. *Medicine*. Washington, Nov. 1, 73. A.B, Harvard, 95; M.D, Columbia, 99; Berlin. *Instr.* physics, physiol. and surg, Georgetown, 02–05; physiol, *George Washington*, 06–10, *surg, 10–* Am. Med. Ass. Radiotherapy; surgery.

Abbot, C(harles) G(reeley), Smithsonian Institution, Washington, D. C. **Astrophysics*. Wilton, N. H, May 31, 72. B.S, Mass. Inst. Tech. 94, M.S, 95; D.Sc, Melbourne, 14. Asst, *Smithsonian Astrophys. Observatory*, 95–96, aid, acting in charge, 96–07, *director, 07–, asst. sec'y, Smithsonian Inst, 18–* Draper medal, Nat. Acad, 10. Nat. Acad. (home sec'y, 19–); A.A; Astron. Soc; Philos. Soc; Wash. Philos. Soc. (v. pres, 08–10); Wash. Acad; Soc. Astron. de Mex; Royal Astron. Soc; cor. mem. Meteor.

cian, McLean Hosp, 94–98; asst. supt, Boston City Hosp, 00–04; first asst. physician, McLean Hosp, 04–09; clin. pathologist, 09–17, *med. director, mental hygiene com, Public Charities Ass, Pa, 19–* Major, M.C, 17, chief, neuro-psychiat. clinic, 17–18. A.A; Am. Med. Ass; Psychol. Ass; Medico-Psychol. Ass; New Eng. Soc. Psychiat. Insanity; medical psychology.

Abbot, Gen. Henry Larcom, U. S. A. (retired), 23 Berkeley St, Cambridge, Mass. *Engineering, Physics*. Beverly, Mass, Aug. 13, 31. Grad, U. S. Mil. Acad, 54; LL.D, Harvard, 86. All grades from second lieut. to col, E.C, 54–95 (retired by law), brig. gen. retired, 04. Col, brevet brig. and maj. gen, U. S. Vols; chairman, group XVI, Centennial Expos, 76; higher jury of awards, Atlanta Expos, 95; pres, board of consulting engineers, Pittsburgh and Lake Erie Canal, 95–96; mem. Int. Commission Engineers, New Panama Canal Co, 97–00, consulting engineer, 00–04; prof. hydraul. eng, George Washington, 06–; mem. many govt. boards. Nat. Acad; Philos. Soc; Am. Acad; New Orleans Acad; cor. mem. Austrian Imperial Royal Geol. Soc. River and harbor improvements; coast defence; submarine mining; explosives; electricity; vertical fire; astronomy; canals; river hydraulics; climatology of the Isthmus of Panama; the Chagres River; the Panama Canal.

Abbott, Dr. A(lexander) C(rever), 4229 Baltimore Ave, Philadelphia, Pa. **Hygiene, Bacteriology*. Baltimore, Md, Feb. 26, 60. Baltimore City Col, 77; M.D, Maryland, 84, hon. Sc.D, 07; Hopkins, 84–87; Munich, 87–88; Berlin, 88–89. Asst. hygiene and bacter, Hopkins, 89–91; asst. in charge, lab. of hygiene, *Pennsylvania*, 91–96, *prof. hygiene and bacter. and director, lab. of hygiene, 97–, director, sch. hygiene and pub. health, 19–* Director, div. path, bacter. and disinfection, Bur. of Health, Phila, 97; chief, Bur. of Health, and pres, Board of Health, 03–09. A.A; Soc. Bact; Am. Physicians; Physiol. Soc; Soc. Exp. Biol; Am. Med. Ass; Pub. Health Ass; Philos. Soc. Bacteriology and preventive medicine; infection, intoxication and immunity.

Abbott, Dr. C(harles) H(arlan), Massachusetts

1956 includes "Biological Sciences" as well as "Social & Behavioral Sciences"

- I Physical Sciences
- II Biological Sciences
- III The Social & Behavioral Sciences

ARROW, PROF. KENNETH, 4 Aliso Way, Menlo Park, Calif. ECONOMETRICS. New York, N.Y, Aug. 23, 21; m. 47. B.S, City Col, 40; M.A, Columbia, 41, Ph.D.(econ), 51. Res. assoc, Cowles Cmn. Res. Econ, 47-49; asst. prof. econ, Chicago, 48-49; asst. prof. ECON. & STATIST, STANFORD, 49-50, assoc. prof, 50-53, PROF, 53- Consultant, Rand Corp. USAAC, 42-46, Capt. Econmet.S; I.Math.Stat. Theory of social choice; static and dynamic aspects of optimal allocation of resources; existence of equilibrium in a competitive economy. 'Import Substitution in Leontief Models'(Econometrica); 'An Extension of the Basic Theorems of Classical Welfare Economics'(Proc. Berkeley Symposium Math. Stat. & Probability); "Social Choice and Individual Values."

Identifying foreign-born American scientists

- Country of birth

UNRUH, CORNELIUS C(HARLES), 25 Castlebar Road, Rochester 10, N. Y. ORGANIC AND HIGH POLYMER CHEMISTRY. Russia, Nov. 11, 12, nat; m. 43; c. 1. B.Sc, Acadia, 33; M.A, Toronto, 34. MEM. RESEARCH STAFF, EASTMAN KODAK CO, 37- Chem. Soc. Preparation and properties of high polymers.

- University attendance

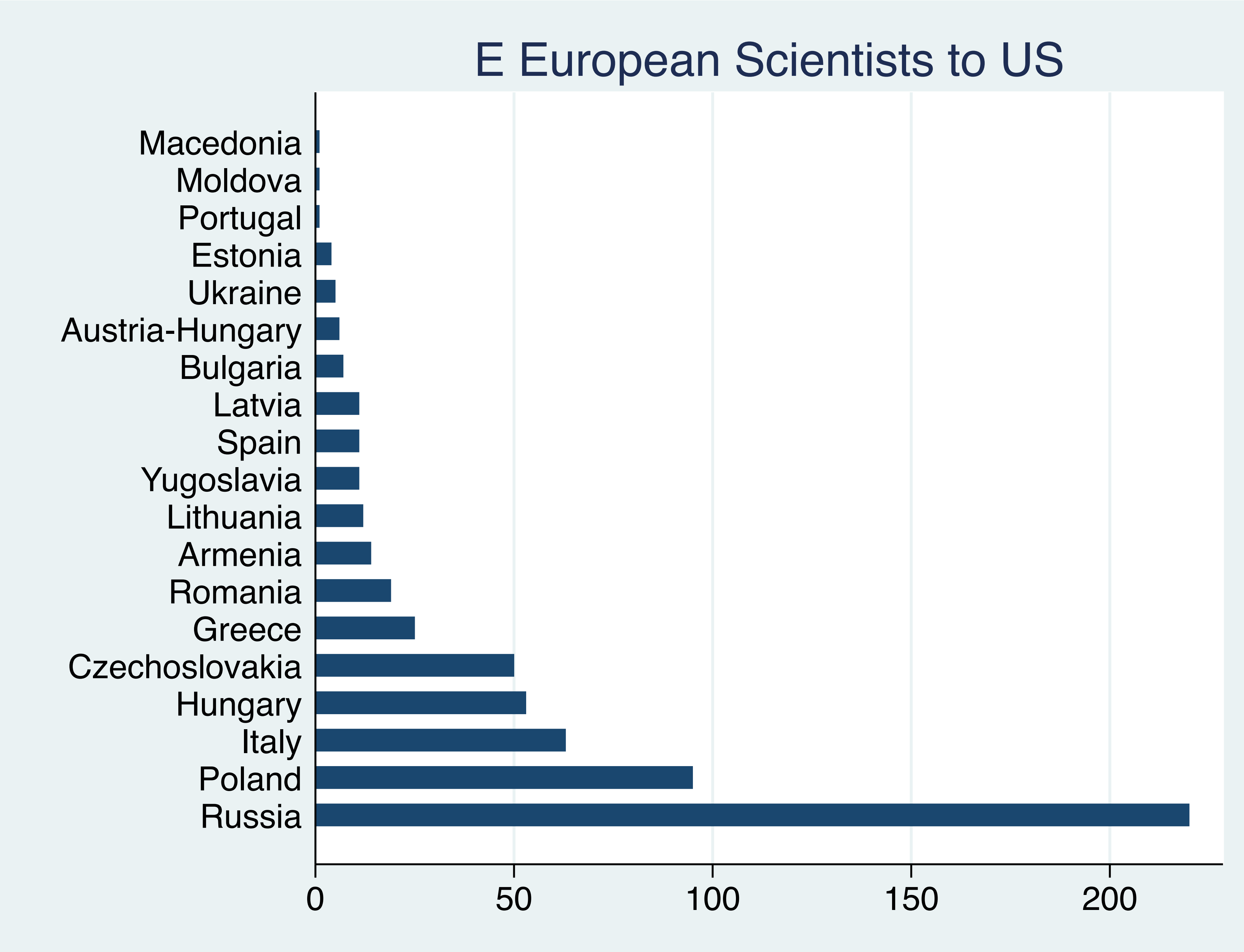
UNRUH, CORNELIUS C(HARLES), 25 Castlebar Road, Rochester 10, N. Y. ORGANIC AND HIGH POLYMER CHEMISTRY. Russia, Nov. 11, 12, nat; m. 43; c. 1. B.Sc, Acadia, 33; M.A, Toronto, 34. MEM. RESEARCH STAFF, EASTMAN KODAK CO, 37- Chem. Soc. Preparation and properties of high polymers.

- Employment

UNRUH, CORNELIUS C(HARLES), 25 Castlebar Road, Rochester 10, N. Y. ORGANIC AND HIGH POLYMER CHEMISTRY. Russia, Nov. 11, 12, nat; m. 43; c. 1. B.Sc, Acadia, 33; M.A, Toronto, 34. MEM. RESEARCH STAFF, EASTMAN KODAK CO, 37- Chem. Soc. Preparation and properties of high polymers.

82,094 American scientists in 1956, including 2,066 from ES and 4,029 from WN Europe

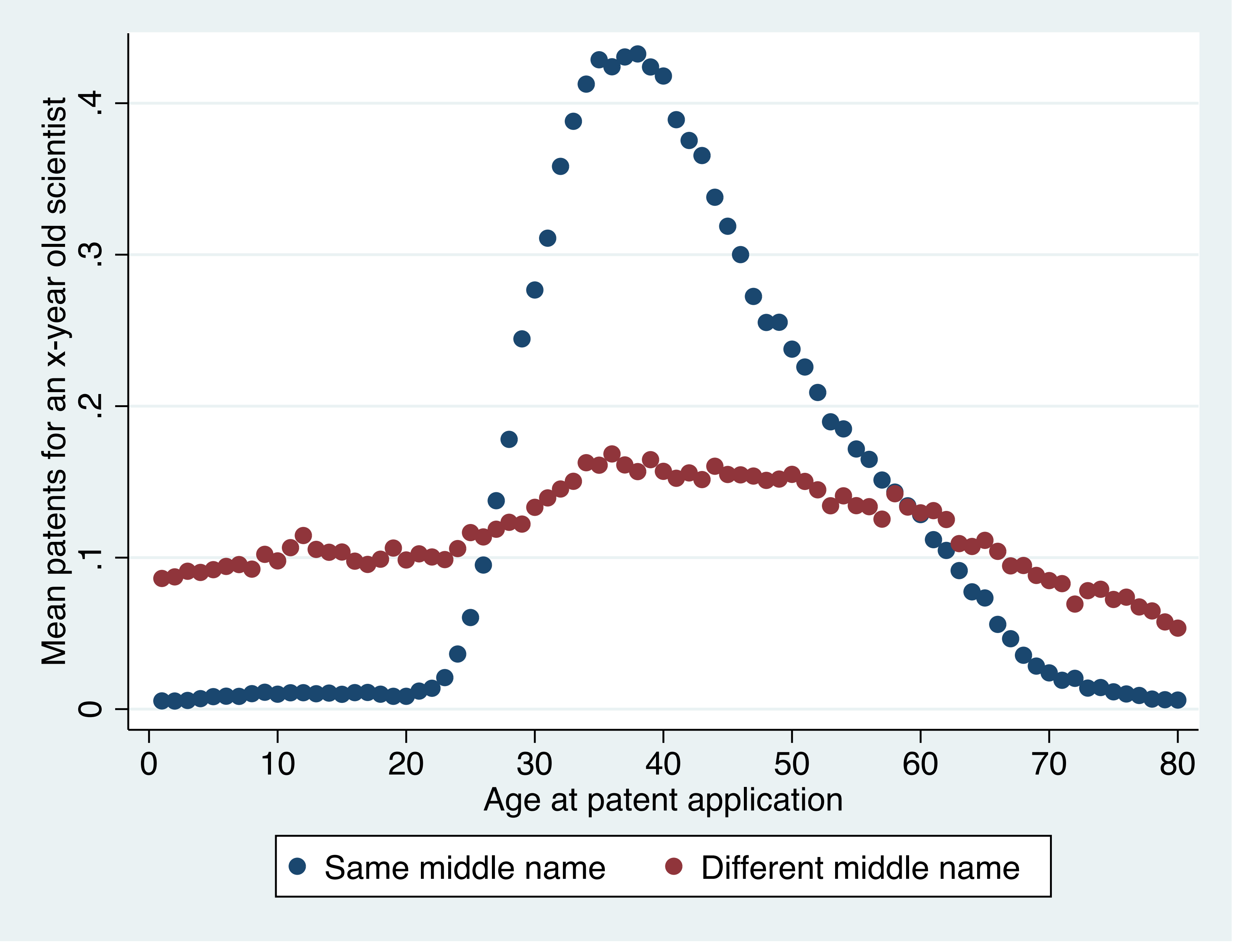
	All Scientists	ESE	WNE	Other
N Scientists	82,094	2,066	4,029	75,999
Age in 1956	47.02	50.22	48.76	46.84
Married	85.23%	82.96%	83.97%	85.36%
Children	1.61	1.25	1.38	1.63
Female	3.26%	3.58%	2.61%	3.28%


E European Scientists to US
Macedonia
Moldova
Portugal
Estonia
Ukraine
Austria-Hungary
Bulgaria
Latvia
Spain
Yugoslavia
Lithuania
Armenia
Romania
Greece
Czechoslovakia
Hungary
Italy
Poland
Russia
0
50
100
150
200

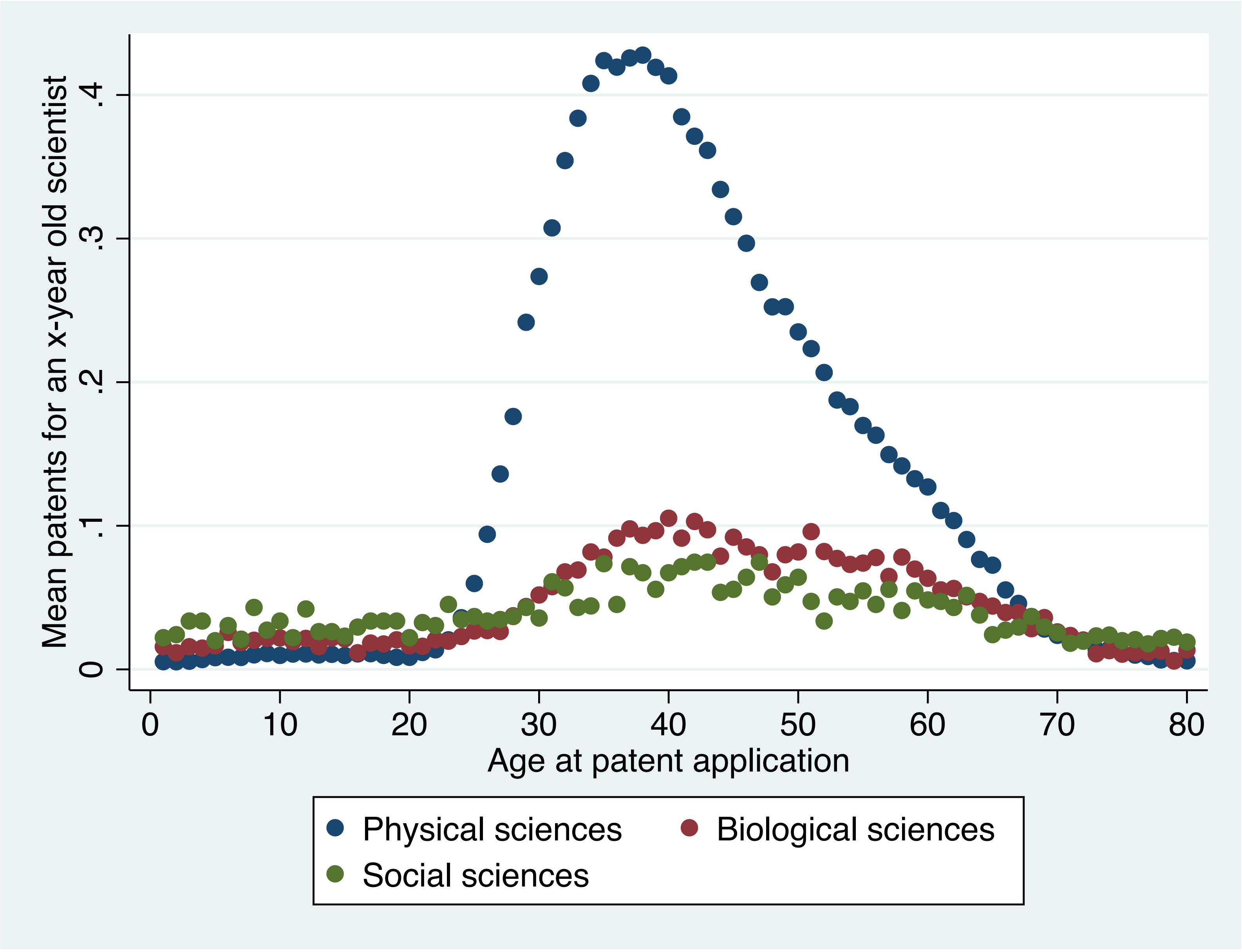
Matching scientists with patents

- Match using first, middle, and last names
  - Levenstein distance measure
  - Allow 1 letter to be difference
- Use age to filter out improbable matches
  - Use patents between 0 and 18 to calculate error rate
- Disciplines
  - Physical, biological, and social sciences
- Frequency of names
  - Drop the top 20 percent of frequent names

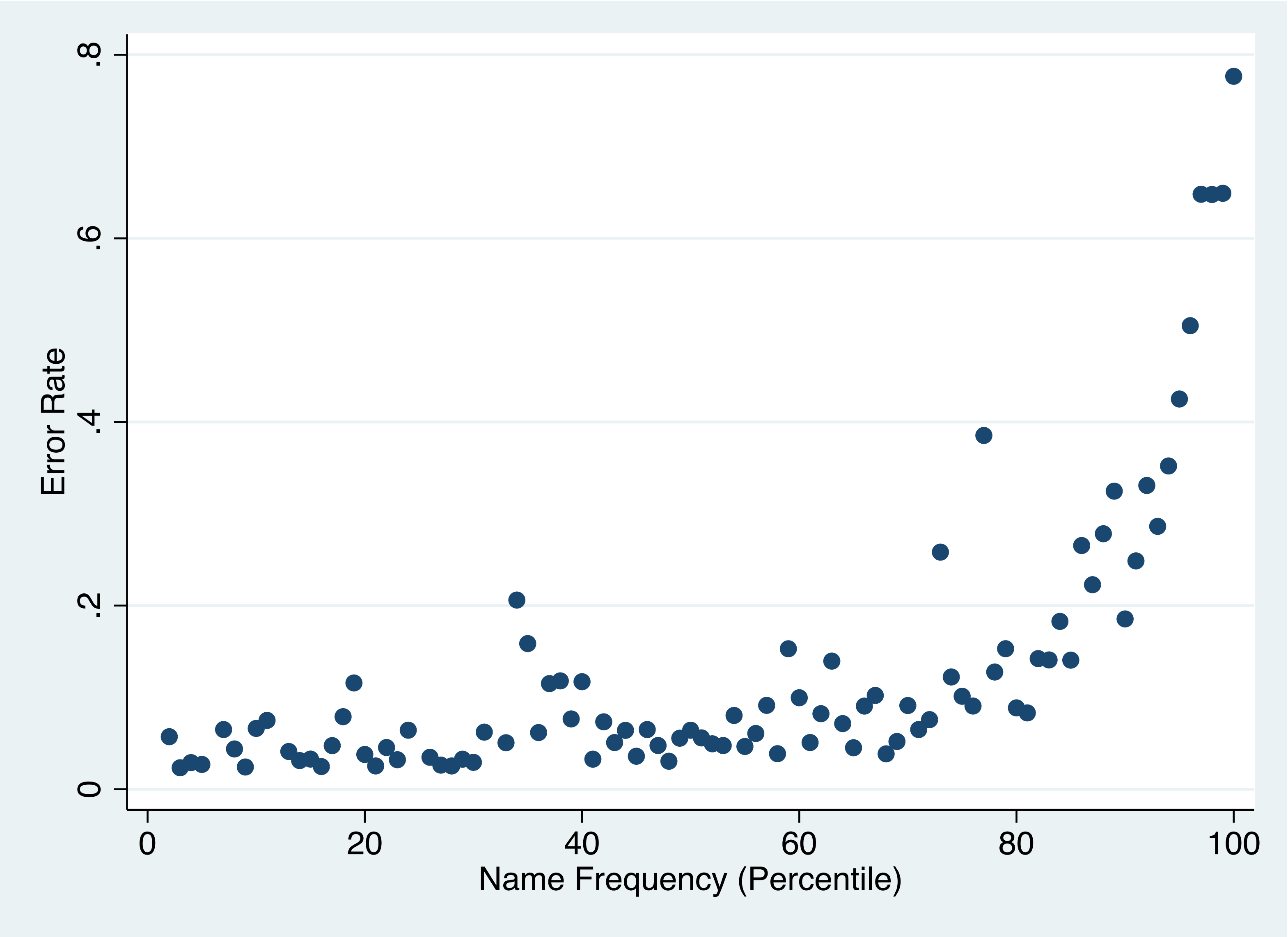
Match on middle initial



Focus on physical sciences: chemistry, physics, math

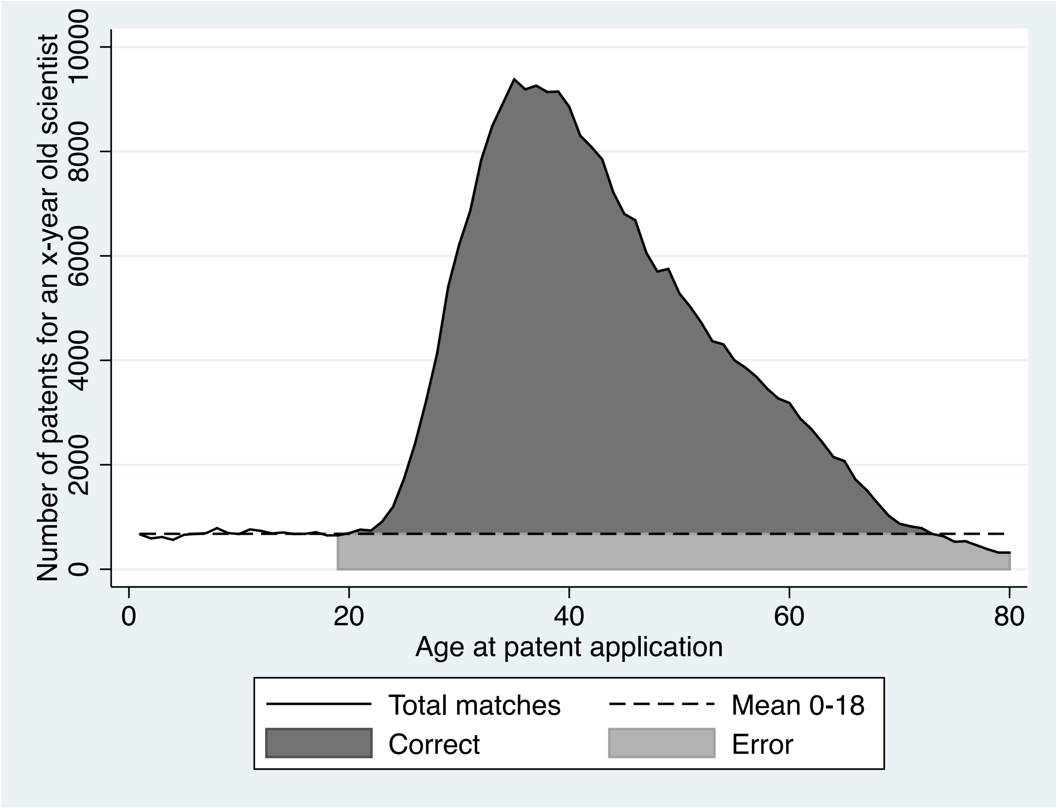


Low match quality for common names, esp above 80%



Calculate error rate
by dividing unlikely matches / total matches

$$\text{Error Rate} = \frac{False\ Positives_{18-80}}{Total\ Matches_{18-80}}$$



Highest quality match using middle names, focusing on physical sciences, and dropping common names

	All	Physical Sciences	Biological Sciences	Social Sciences
Scientists in MoS (1956)	82,094	41,096	25,505	15,493
A. Patent applications made when scientists are 18-80 years old				
Scientists with at least 1 patent	43,929	27,527	10,777	5,625
Patents	1,496,170	887,658	384,058	224,454
Patents per scientist	18.23	21.60	15.06	14.49
Error rate	83.3%	75.0%	96.2%	92.9%
B. Scientists and patentees have matching middle names				
Scientists with at least 1 patent	27,030	20,743	4,506	1,781
Patents	250,707	216,475	23,113	11,119
Patents per scientist	3.05	5.27	0.91	0.72
Error rate	22.1%	14.2%	72.3%	81.6%
C. Matching middle name & excluding frequent names				
Scientists with at least 1 patent	18,035	15,146	2,311	578
Patents	164,892	154,883	8,064	1,945
Patents per scientist	2.01	3.77	0.32	0.13
Error rate	6.3%	4.2%	32.8%	67.9%

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- Biographical data on > 90,000 US scientists in 1921 and 1956
  - Matched with US patents
- Missing ESE-born scientists
  - 1,165 missing ESE-born scientists, 1925-55
- Effects on patenting by US scientists
  - Compare changes in patenting after 1924 in pre-quota fields of ESE-born US scientists with changes in pre-quota fields of other US scientists
  - After quotas, patenting by US scientists grows by 60% less in ESE fields
- Effects on aggregate patenting
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- Mechanisms
  - Knowledge spillovers, selection into research fields, or ageing?

Changes in arrivals

- Naturalization
  - Immigrants eligible for naturalization after 5 years
  - Known for 2,775 foreign-born scientists, 33.5% of all scientists
  - Average ESE-born scientists was 32.9 years old when they arrived in the United States (st. dv. 10.8, median 33 years)
- Employment histories
  - First US job
  - 465,918 institutions of employment for 82,094 American scientists in MoS (1956), 5.7 unique institutions per scientist, yielding 117,606 unique institutions
  - Using a three-step algorithm, we determine country of job locations for 79,908 of 82,094 American scientists (97.3%)
- Education
  - Use start year of US university to proxy first in United States

Naturalization records

- Example: Dr. Elias Klein, naturalized in 1912
- Must have lived in United States 5 years earlier, in 1907

KLEIN, DR. ELIAS, Naval Research Lab, Washington 20, D. C. PHYSICS. Wilno, Poland, Jan. 11, 90; nat. 12; m. 24; c. 2. B.S, Valparaiso, 11, B.C.E, 12; Howard fellow, Yale, 20-21, Ph.D.(physics), 21. Instr. physics, Valparaiso, 12-17; teaching asst, Sheffield Sci. Sch, Yale, 17-21; instr, Saskatchewan, 21-22; research, Chicago, 22; asst. prof, Lehigh, 22-25, assoc. prof, 25-27; PHYSICIST, NAVAL RESEARCH LAB, 27- Fel. Physical Soc; fel. Acoustical Soc. Acoustics; ultrasonics; shock and vibration; underwater sound; spark spectrum of gallium in air and hydrogen.

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Estimating arrivals through employment histories

- Klein started his first US job in 1912, when he became an instructor of physics at Valparaiso

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Estimating arrivals through university enrollment

- Klein graduated with a B.S. from Valparaiso in 1911
- Estimate start year as 1909 using median undergrad (2 years)

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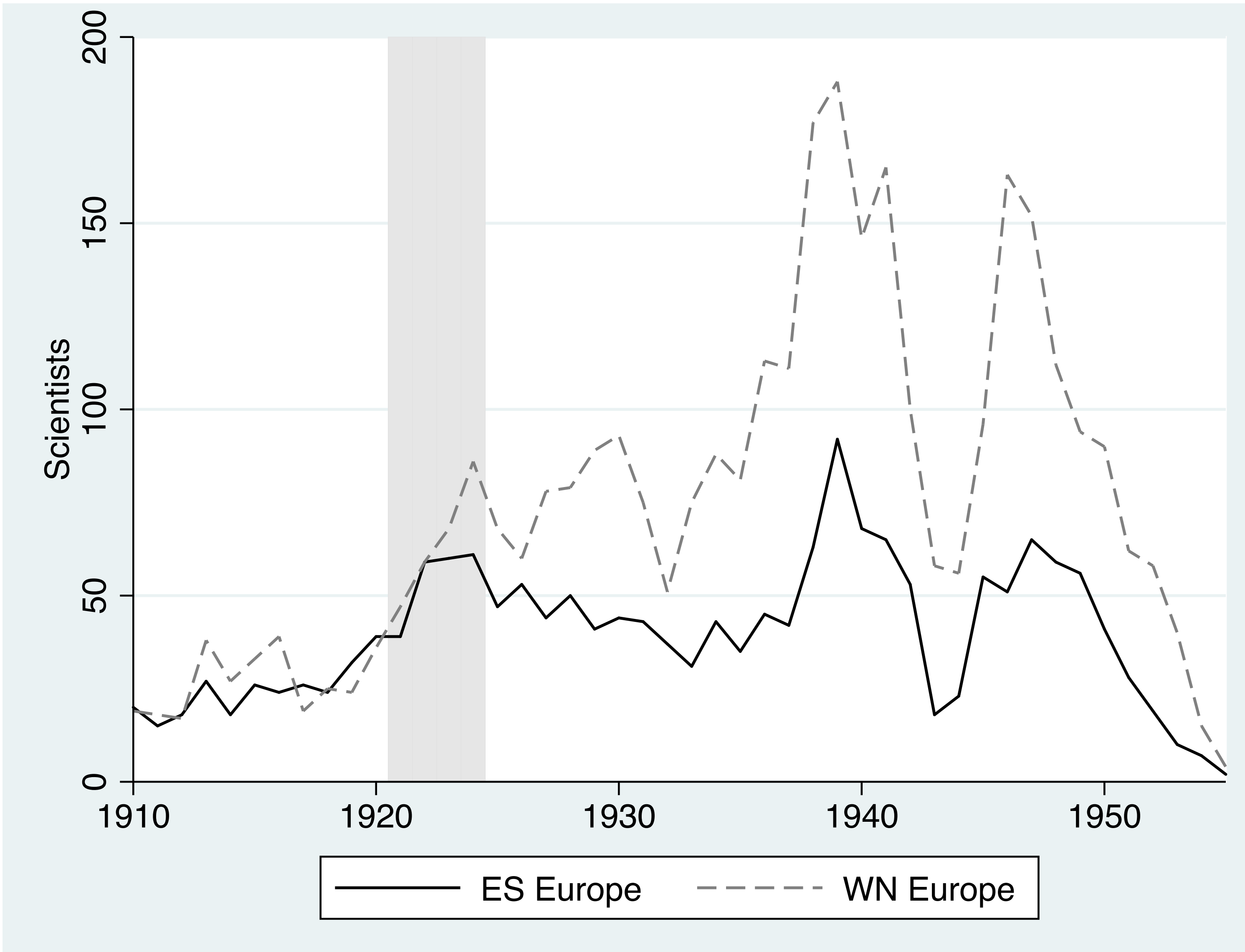
Earliest year of US presence implied by naturalization, employment, and naturalization

- 1907 based on naturalization
- 1909 based on education
- 1912 based on employment

KLEIN, DR. ELIAS, Naval Research Lab, Washington 20, D. C. PHYSICS. Wilno, Poland, Jan. 11, 90, nat. 12; m. 24; c. 2. B.S, Valparaiso, 11, B.C.E, 12; Howard fellow, Yale, 20-21, Ph.D.(physics), 21. Instr. physics, Valparaiso, 12-17; teaching asst, Sheffield Sci. Sch, Yale, 17-21; instr, Saskatchewan, 21-22; research, Chicago, 22; asst. prof, Lehigh, 22-25, assoc. prof, 25-27; PHYSICIST, NAVAL RESEARCH LAB, 27- Fel. Physical Soc; fel. Acoustical Soc. Acoustics; ultrasonics; shock and vibration; underwater sound; spark spectrum of gallium in air and hydrogen.

Before quotas, 32.5 ESE-born scientists per year 1910-24 (37.0 WNE-born)
After quotas, 42.9 ESE-born per year, less than half 91.5 WNE-born



1,165 missing ESE scientists, 1925-55, 38 missing scientists per year

- Key assumption
  - Without quotas, ESE /WNE scientists = constant
- Then we can estimate the count of missing ESE scientists
  - ESE/WNE = 488/555 for 1910-1924
  - WNE = 2,837 for years 1925-1955
  - To keep ESE/WNE constant, ESE for years 1925-1955 should have been 488/555 * 2,837 = 2,495.
  - Actual number of ESE scientists in 1925-1955 = 1,330
  - 2,495 - 1,330 = 1,165
- 1,165 missing ESE scientists in 1925-1955
- 38 missing scientists per year

1,165 missing scientists across all disciplines 553 in the physical sciences alone

	US Scientists				Counterfactual ESE-born scientists post 1924	**Missing # ESE-born scientists post 1924**
	ESE-born		WNE-born			
	pre 1924	post 1924	pre 1924	post 1924		
All disciplines						
Arrivals by year of scientist's						
naturalization	250	403	244	962	986	**583**
start year of US job or enrollment in US university	428	1,435	516	2,891	2,398	**963**
naturalization, US job, or US university enrollment	488	1,330	555	2,837	2,495	**1,165**
Physical sciences only						
Arrivals by year of scientist's						
naturalization	148	250	144	624	641	**391**
start year of US job or enrollment in US university	189	692	273	1,569	1,086	**394**
naturalization, US job, or US university enrollment	235	637	304	1,539	1,190	**553**

How did immigration quotas change American science and invention?

- Ethnicity-based immigration quotas in the 1920s
  - Intended to keep out low-skilled ”undesirable” immigrants from Eastern and Southern Europe (ESE)
- Biographical data on > 90,000 US scientists in 1921 and 1956
  - Matched with US patents
- Did quotas discourage immigrant scientists?
  - An estimated 1,065 missing ESE-born American, 1925-55. 38 missing per year
- Effects on patenting by US scientists
  - Compare changes in patenting after 1924 in pre-quota fields of ESE-born US scientists with changes in pre-quota fields of other US scientists
  - Use text analysis (*k*-means clustering) to define fields
  - After quotas, patenting by US scientists grows by 60% less in ESE fields
- Effects on aggregate patenting
  - After quotas, aggregate US invention declines in ESE fields and ESE firms
- Mechanisms
  - Knowledge spillovers, selection into research fields, or ageing?

Identification strategy

- Compare changes in patenting after the quotas in pre-quota fields of ESE-born immigrant scientists
- Use text analysis (*k*-mean clustering) to identify research fields of ESE scientists
  - Assign scientists in 1956 to fields using their research topics
  - Match scientists in 1921 to these fields 1956
- ESE field
  - field with 1 or more ESE-born scientists in 1921
  - field with > median % of ESE-born scientists in 1921

Disciplines and research topics define fields

VOLKOFF, PROF. G(EORGE) M(ICHAEL), Dept. of Physics, Uni-
versity of British Columbia, Vancouver 8, B. C. Can. PHYS-
ICS. Moscow, Russia, Feb. 23, 14, Can. citizen; m. 40; c. 3.
B.A, British Columbia, 34, M.A, 36, hon. D.Sc, 45; Royal Soc.
Can. fellow, California, 39-40, Ph.D.(theoret. physics), 40.
Asst. prof. physics, British Columbia, 40-43; assoc. research
physicist, Montreal lab, Nat. Research Council Can, 43-45, re-
search physicist and head theoret. physics branch, Atomic
Energy Proj, Montreal and Chalk River, 45-46; PROF. PHYSICS,
BRITISH COLUMBIA, 46- Ed. 'Can. Jour. Physics,' 50- Mem.
Order of the British Empire, 46. A.A; Asn. Physics Teachers;
Physical Soc; fel. Royal Soc. Can; Can. Asn. Physicists. The-
oretical nuclear physics; neutron diffusion; nuclear magnetic
and quadrupole resonance.

- Use Volkoff's field "Physics" and topics "theoretical nuclear physics; neutron diffusion; nuclear magnetic and quadrupole resonance" to define Volkoff's field of research
- Find other people who work in the same field ("cluster") and check how their patenting changes when Volkoff moves

k-mean clustering (1/3)
Create a matrix of words

- Partition *n* observations into *k* clusters assigning each observation to cluster with nearest mean
- First, concatenate all fields and topics of a scientist into a list of words ("document")
  - Remove punctuation and stop words (Nothman, Qin & Yurchak 2018)
- Represent research topics as bags of words
  - E.g., Volkoff's bag of words "physics theoretical nuclear physics neutron diffusion nuclear magnetic quadrupole resonance"
- Corpus of documents represented by a matrix
  - 1 row per document
  - 1 column per word occurring in the corpus
  - Entries counting occurrences of words in each document

k-mean clustering (2/3)
Inverse frequency weights: less weight on frequent words

- Frequent words like "theory" or "research" carry less information than rarer words like "neutron" or "polymer"
  - E.g. "theoretical" in Volkoff's back of word, "physics theoretical nuclear physics neutron diffusion nuclear magnetic quadrupole resonance"
  - Feeding them into a classifier would overshadow frequencies of rarer but more interesting terms
- Implementing Baeza-Yates & Ribeiro (2011)

$$tf\_idf(w,d) = tf(w,d) \times idf(w),$$

where n is the number of documents, and

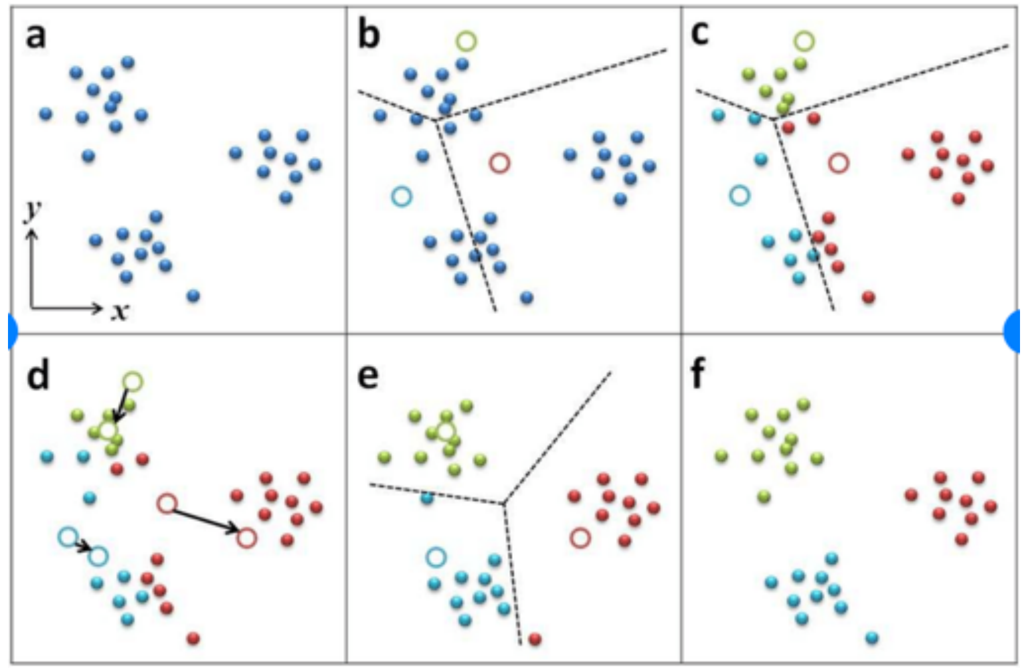
$idf(w) = \log\frac{1+n}{1+df(w)} + 1$

df(w) is the number of documents that contain word *w*

$tf(w,d)$ is the frequency of word w in document d.

k-mean clustering (3/3) Minimizing distance within clusters

- Cluster data by separating documents in k disjoint clusters
  - Each described by the mean of the vectors in the cluster
- Minimizing within-cluster sum-of-squares (Forgy 1965)
  - Python scikit-learn
- Set number of clusters e.g., k=100



Schematic illustration of the k-means algorithm for 2-dimensional data clustering from Chen, Yu-Zhong & Lai, Ying-Cheng. (2016). Universal structural estimator and dynamics approximator for complex networks.

cluster	9	19	29	39	49
title	Servomechanism	Chemical engineering	Organic chemistry	Neutron radiation	nternal combustion engin
scientists	594	232	648	749	204
field_1	electrical engineering	chemical engineering	organic chemistry	physics	mechanical engineering
field_2				nuclear physics	engineering
field_3				nuclear chemistry	chemical engineering
field_4			try	chemistry	chemistry
field_5	el			experimental physics	physics
word_1				nuclear	combustion
word_2				physics	engines
word_3				energy	internal
word_4				spectroscopy	mechanical
word_5				cosmic	engineering
word_6				rays	fuels
word_7				scattering	fuel
word_8				reactor	engine
word_9				reactions	jet
word_10				neutron	gas

Example: Volkoff falls into cluster 39:

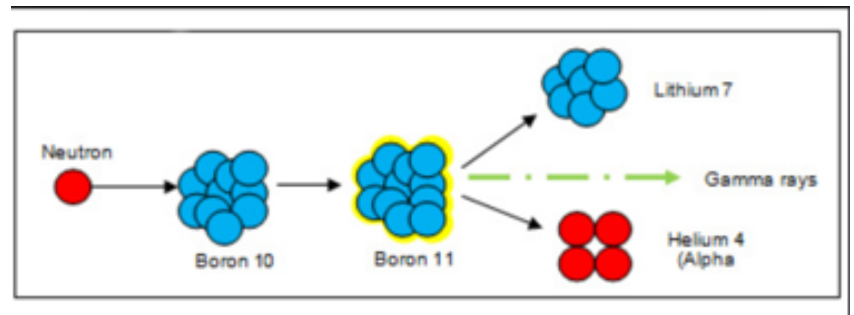
Common words:
"nuclear, physics, energy, spectroscopy, cosmic, rays, scattering, reactor, reactions, neutron"

Cluster 39 has 749 scientists incl. Volkoff

cluster				89	99
title				Calculus of variations	Adsorption
scientists	182	889	377	101	1109
field_1	aeronautical engineering	mathematics	chemistry	mathematics	physical chemistry
field_2	engineering	applied mathematics	organic chemistry	pure mathematics	chemistry
field_3	aeronautics	physics	chemical engineering	applied mathematics	physics
field_4	physics	actuarial mathematics	physical chemistry	mathematical analysis	hysical organic chemistry
field_5	mechanical engineering	engineering	physics	physics	oceanography
word_1	aeronautical	mathematics	rubber	calculus	physical
word_2	aircraft	analysis	chemistry	variations	chemistry
word_3	engineering	topology	synthetic	mathematics	properties
word_4	structures	functions	plastics	equations	kinetics
word_5	design	mathematical	latex	differential	thermodynamics
word_6	control	applied	organic	theory	adsorption
word_7	flight	series	compounding	analysis	chemical
word_8	research	functional	polymerization	functions	catalysis
word_9	stability	numerical	technology	mathematical	surface
word_10	guided	spaces	accelerators	problems	structure

Sanity check: Let Google name our clusters and check whether names make sense

- Python spits out numbers
- To name clusters, we enter each cluster's common words into Google
- E.g., cluster 39, which includes Volkoff's research has the following common words *nuclear physics energy spectroscopy cosmic rays scattering reactor reactions neutron*
- Google returns "Neutron radiation"
- Just a sanity check, we do not use names in the analysis



Neutron radiation: Neutrons released from the nucleus during interactions such as nuclear fission or fusion

cluster	9	19	29	39	49
title	Servomechanism	Chemical engineering (Catalysis)	Organic chemistry	Neutron radiation	nternal combustion engin
scientists	594	232	648	749	204
field_1	electrical engineering	chemical engineering	organic chemistry	physics	mechanical engineering
field_2	physics	engineering	chemistry	nuclear physics	engineering
field_3	engineering	chemistry	physical organic chemistry	nuclear chemistry	chemical engineering
field_4	chemistry	industrial and chemical engineering	organic and polymer chemistry	chemistry	chemistry
field_5	electrical and chemical engineering		biochemistry	experimental physics	physics
word_1	electrical	chemical	organic	nuclear	combustion
word_2	engineering	engineering	chemistry	physics	engines
word_3	power	process	synthetic	energy	internal
word_4	electric	development	polymer	spectroscopy	mechanical
word_5	machinery	industrial	medicinal	cosmic	engineering
word_6	circuits	chemistry	steroids	rays	fuels
word_7	transmission	catalysis	research	scattering	fuel
word_8	servomechanisms	plastics	pharmaceuticals	reactor	engine
word_9	electronics	kinetics	syntheses	reactions	jet
word_10	measurements	organic	medicinals	neutron	gas

cluster	59	69	79	89	99
title	Aircraft	Mathematical analysis	Vulcanization	Calculus of variations	Adsorption
scientists	182	889	377	101	1109
field_1	aeronautical engineering	mathematics	chemistry	mathematics	physical chemistry
field_2	engineering	applied mathematics	organic chemistry	pure mathematics	chemistry
field_3	aeronautics	physics	chemical engineering	applied mathematics	physics
field_4	physics	actuarial mathematics	physical chemistry	mathematical analysis	physical organic chemistry
field_5	mechanical engineering	engineering	physics	physics	oceanography
word_1	aeronautical	mathematics	rubber	calculus	physical
word_2	aircraft	analysis	chemistry	variations	chemistry
word_3	engineering	topology	synthetic	mathematics	properties
word_4	structures	functions	plastics	equations	kinetics
word_5	design	mathematical	latex	differential	thermodynamics
word_6	control	applied	organic	theory	adsorption
word_7	flight	series	compounding	analysis	chemical
word_8	research	functional	polymerization	functions	catalysis
word_9	stability	numerical	technology	mathematical	surface
word_10	guided	spaces	accelerators	problems	structure

k-means clustering able to captures the essence of a scientists' research topics

FRAGOLA, CAESAR (FRANCIS), Sperry Gyroscope Co, Great Neck, L. I, N. Y. ENGINEERING. Brooklyn, N. Y, June 1, 16; m. 42; c. 5. B.E.E, Polytech. Inst. Brooklyn, 37, fellow, 39-40, M.E.E, 40. Develop. engineer, Root Research Lab, New York, 38-39; asst. project engineer, SPERRY GYROSCOPE CO, 40-44, project engineer, 44-48, HEAD ENG. SECT, 48- Assoc. Inst. Elec. Eng; assoc. Inst. Radio Eng. Aircraft instrumentation engineering; development of aircraft flight and navigation instruments; individual components and complete system components for stabilized remotely located aircraft compasses and flight directors.

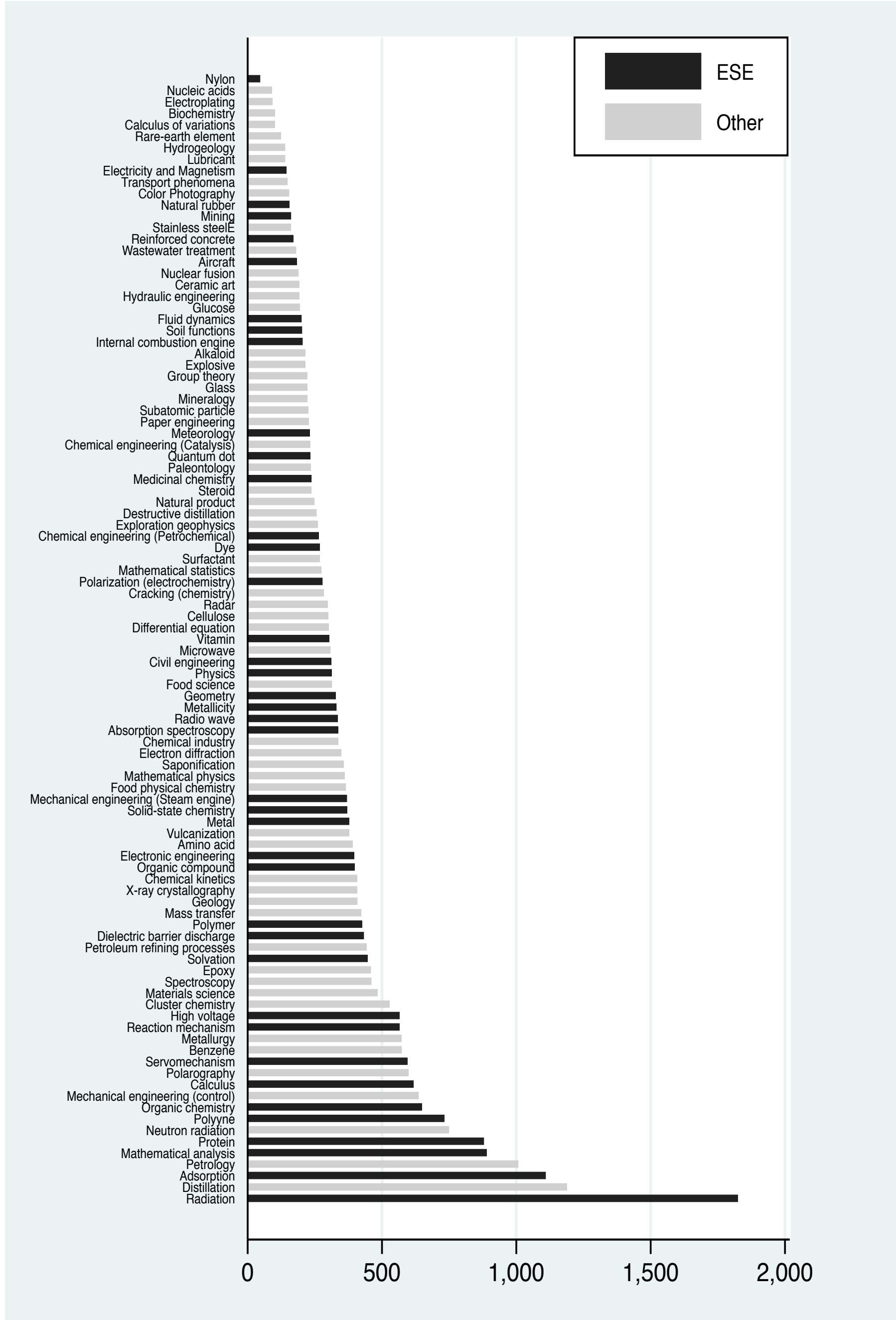
Caesar Fragola:
Discipline: engineering

de TURK, ELDER P(ATTISON), Armament Test, Naval Air Test Center, Patuxent River, Md. PHYSICS. Reading, Pa, Dec. 13, 11; m. 40; c. 3. B.S, Texas, 39, M.A, 42. Asst. project engineer, Sperry Gyroscope Co, 42-44; instr. physics, Texas, 44-46, staff mem, war research lab, 44-46; physicist, ARMAMENT TEST, NAVAL AIR TEST CENTER, 46-47, head, assessment and ground test, 47-52, ASST. CHIEF PROJECT ENGINEER, 52- Civilian with Office Sci. Research & Develop; A.F; U.S.N, 44. Physical Soc; Asn. Physics Teachers. Design and development of aircraft instruments; test of gravity meters; test, development and evaluation of aircraft armament systems.

Elder de Turk:
Discipline: physics

- Simple classification by discipline would have missed connection between Fragola and de Turk
- *k*-means connects them through the field of "aircraft"

Counts of scientists per cluster in ESE and control clusters



How did quotas affect invention by US scientists?

- Compare changes in invention after 1924 by American scientists in pre-quota fields of ESE scientists with changes in other fields

Estimate

$$\ln(y_{it}) = \beta_t \, ESE_i + \gamma_i + \delta_t + \epsilon_{ct}$$

y_{it}	patents by American scientists in field i and year t.
ESE_i	indicates pre-quota fields of ESE scientists
γ_i and δ_t	field and year fixed effects
1918-20	is excluded period

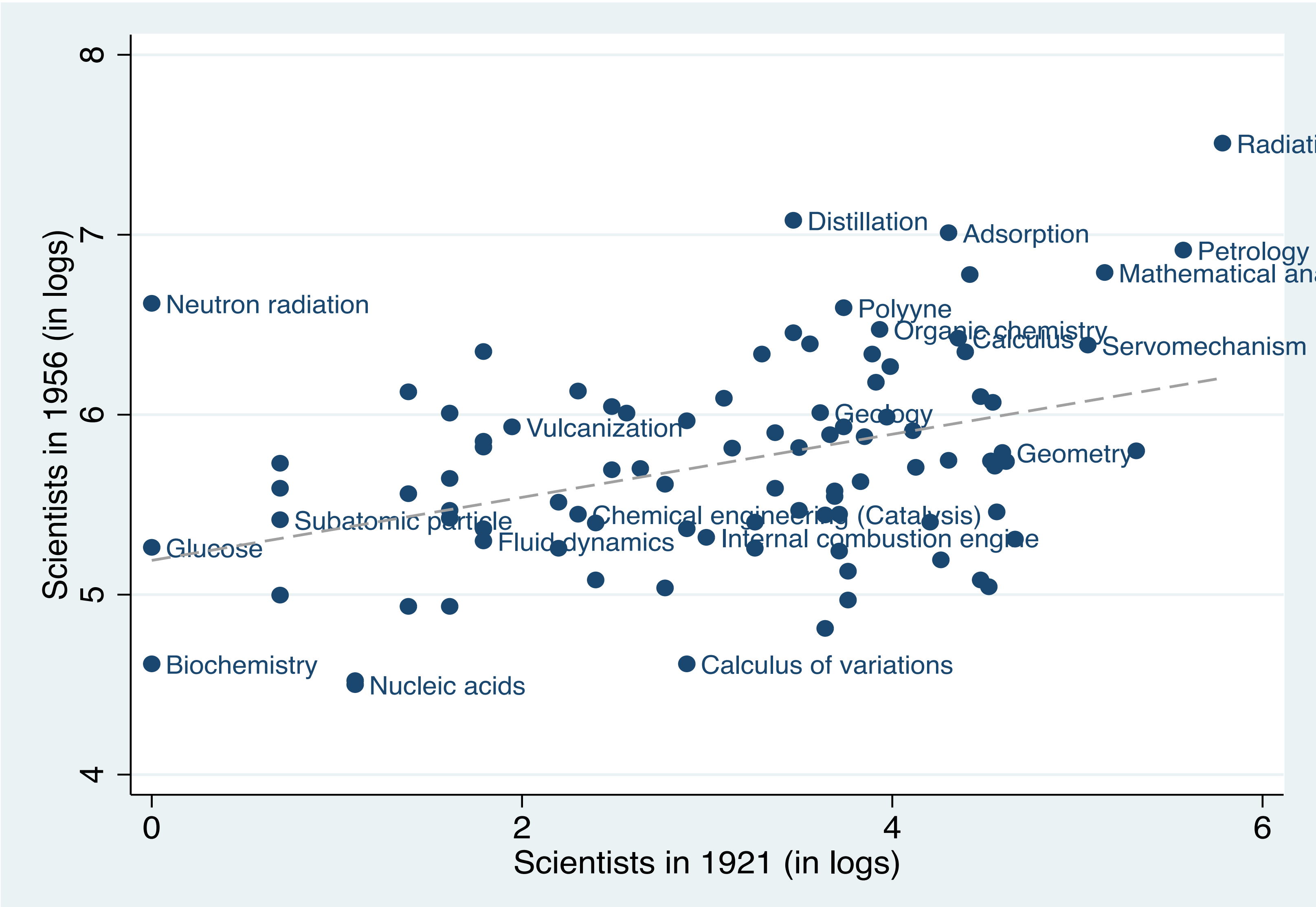
ESE fields == pre-quota (1921) fields of ESE-born American scientists

	Fields			
	ESE	Other	Difference	p-value
Share ESE-born scientists	0.035	0.000	0.035	0.000
Share WNE-born scientists	0.054	0.051	0.003	0.823
Age	44.72	44.41	0.313	0.854
Female	0.011	0.012	-0.001	0.832
Share star scientists	0.115	0.104	0.011	0.660

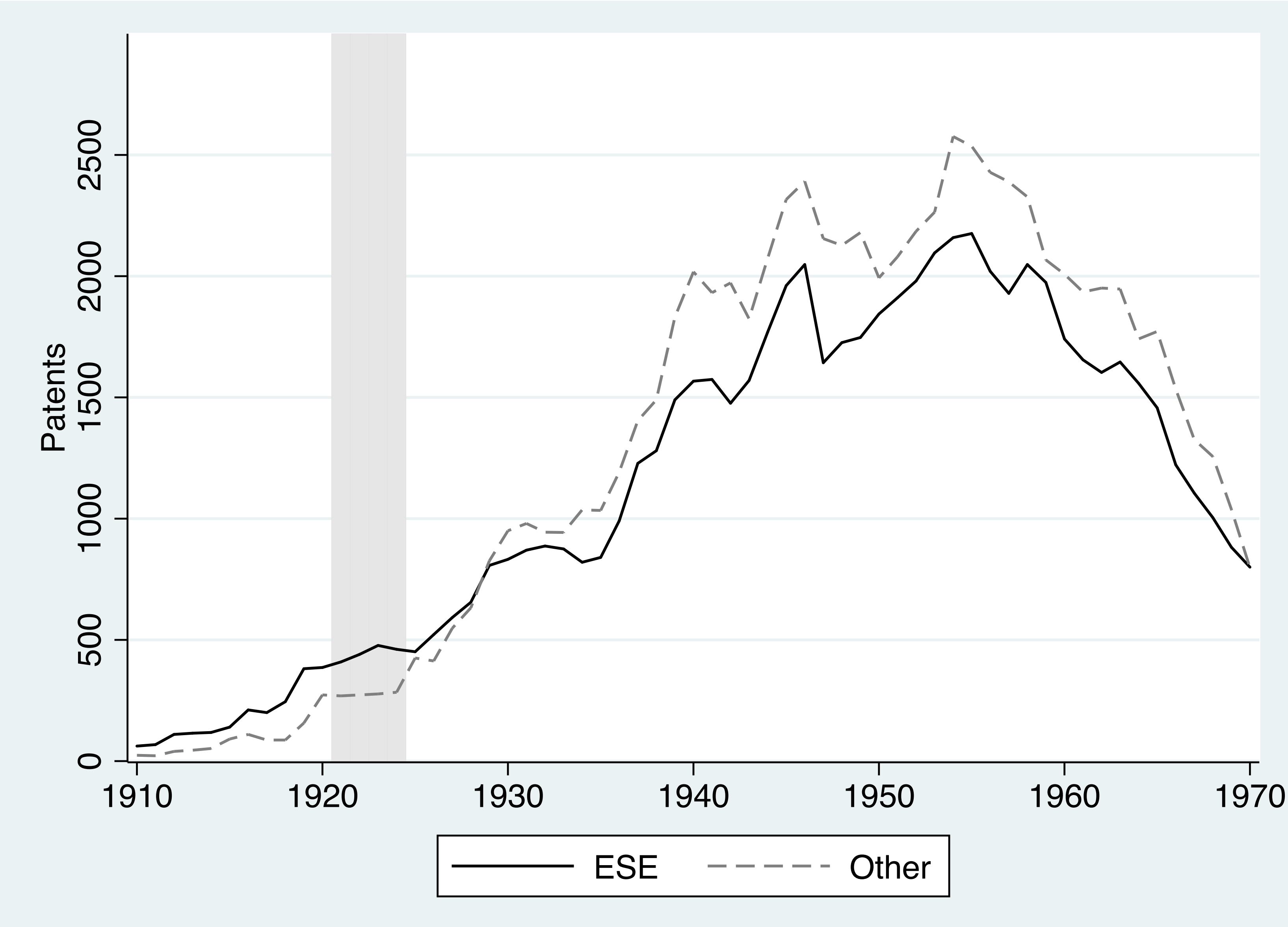
Before the quotas, ESE fields look like other fields, in terms of scientist's age, gender, and prominence (%stars)

	Fields			
	ESE	Other	Difference	p-value
Share ESE-born scientists	0.035	0.000	0.035	0.000
Share WNE-born scientists	0.054	0.051	0.003	0.823
Age	44.72	44.41	0.313	0.854
Female	0.011	0.012	-0.001	0.832
Share star scientists	0.115	0.104	0.011	0.660

Strong persistence in size of field



After 1924, invention by US scientists declines in pre-quota fields of ESE scientists relative to other fields



Patenting increased less in ESE fields

How did the quotas affect invention by American scientists?

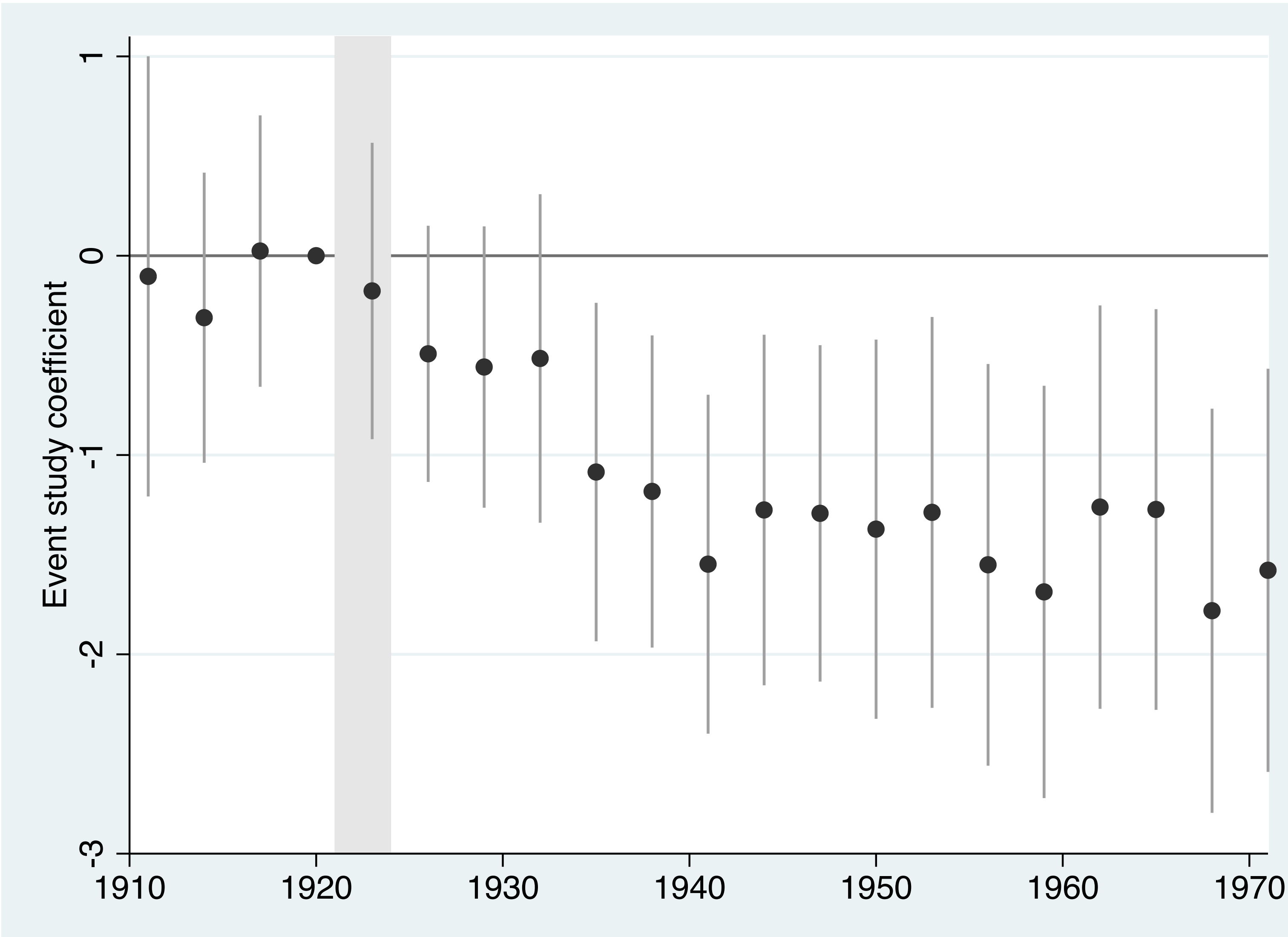
- Compare changes in invention after 1924 by American scientists in pre-quota fields of ESE scientists with changes in other fields

Estimate

$$\ln(y_{it}) = \beta_t \, ESE_i + \gamma_i + \delta_t + \epsilon_{ct}$$

y_{ict}	patents by American scientists in field i and year t.
ESE_i	indicates pre-quota fields of ESE scientists
γ_i and δ_t	field and year fixed effects

After the quotas, invention by US scientists declines in pre-quota ESE fields, and stays low through the 1960s



OLS estimates for β_t in the regression $\ln(y_{it}) = \beta_t\, ESE_i + \gamma_i + \delta_t + \epsilon_{ct}$

After 1924, Americans patent 68% less in pre-quota fields of ESE scientists compared with other fields

1-exp(-1.134) = 1-0.32 = 68%

	ln(patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESE x post	-1.134***	-1.089**	-1.183***	-1.231**	-1.277***	-1.346**	-1.280***	-1.278**
	(0.360)	(0.536)	(0.380)	(0.559)	(0.379)	(0.561)	(0.359)	(0.533)
	Baseline		Excl. 5% largest fields		Excl. fields w top 5% ESE share		Incl. new fields	
Percentage change	-0.68	-0.67	-0.70	-0.71	-0.72	-0.74	-0.72	-0.73
Mean patents before 1924	4.15	4.15	3.47	3.47	4.22	4.22	3.97	3.97
N (fields x years)	5795	5795	5490	5490	5551	5551	6100	6100
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field-specific pre-trends	No	Yes	No	Yes	No	Yes	No	Yes

Robust to dropping outliers

Dropping largest clusters (column 3) and clusters with largest share of ESE scientists (column 5)

	ln(patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESE x post	-1.134***	-1.089**	-1.183***	-1.231**	-1.277***	-1.346**	-1.280***	-1.278**
	(0.360)	(0.536)	(0.380)	(0.559)	(0.379)	(0.561)	(0.359)	(0.533)
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Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field-specific pre-trends	No	Yes	No	Yes	No	Yes	No	Yes

Robust to including new clusters

Clusters of scientists in 1956 that had no scientists in 1921

	ln(patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESE x post	-1.134***	-1.089**	-1.183***	-1.231**	-1.277***	-1.346**	-1.280***	-1.278**
	(0.360)	(0.536)	(0.380)	(0.559)	(0.379)	(0.561)	(0.359)	(0.533)
	Baseline		Excl. 5% largest fields		Excl. fields w top 5% ESE share		Incl. new fields	
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Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field-specific pre-trends	No	Yes	No	Yes	No	Yes	No	Yes

Robust to including common names

Including scientists with names above the 80th percentile frequent names in the US census

	ln(patents)			
	(1)	(2)	(3)	(4)
ESE x post	-1.134***	-1.283***	-1.402***	-0.927***
	(0.360)	(0.345)	(0.276)	(0.220)
	Baseline	Incl. common names	Incl. different middle names	Incl. common names and different middle names
Percentage change	-0.68	-0.72	-0.75	-0.60
Mean patents before 1924	4.15	6.38	7.24	39.51
N (fields x years)	5,795	5,795	5,795	5,795
Year FE	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes

Standard errors are clustered at the level of research fields

Robust to our choice of *k*, the number of clusters (here fields)

	ln(patents)			
	(1)	(2)	(3)	(4)
ESE x post	-0.932**	-1.022***	-1.134***	-1.141***
	(0.429)	(0.382)	(0.360)	(0.341)
K clusters (here fields)	50	75	100	125
Percentage change	-0.61	-0.64	-0.68	-0.68
Mean patents before 1924	8.37	5.50	4.15	3.51
N (field x years)	2,867	4,392	5,795	6,832
Year FE	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes

Standard errors are clustered at the level of research fields

Robust to controlling for cluster-specific linear trends

Americans patent 67% less in pre-quota ESE clusters

	ln(patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESE x post	-1.134***	-1.089**	-1.183***	-1.231**	-1.277***	-1.346**	-1.280***	-1.278**
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Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field-specific pre-trends	No	Yes	No	Yes	No	Yes	No	Yes

Robustness
Baseline estimates ln(patents + 0.01)
Smaller numbers increase the size of the coefficients
Adding 0.01 is close to 0, yet conservative in estimation

	patents		ln(patents + ϵ)			
	(1)	(2)	(3)	(4)	(5)	(6)
ESE x post	-0.756***	-0.910***	-0.771***	-1.134***	-1.498***	-1.861***
	(0.272)	(0.237)	(0.278)	(0.360)	(0.454)	(0.555)
	Poisson	Negative Binomial	$\epsilon = 0.1$	$\epsilon = 0.01$	$\epsilon = 0.001$	$\epsilon = 0.0001$
Percentage change	-0.53	-0.60	-0.54	-0.68	-0.78	-0.84
Mean patents before 1924	4.15	4.15	4.15	4.15	4.15	4.15
N (fields x years)	5795	5795	5795	5795	5795	5795
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust to alternative estimation models, like QML Poisson

Americans patent 53% less in fields of ESE scientists after 1924

	patents		ln(patents + ϵ)			
	(1)	(2)	(3)	(4)	(5)	(6)
ESE x post	-0.756***	-0.910***	-0.771***	-1.134***	-1.498***	-1.861***
	(0.272)	(0.237)	(0.278)	(0.360)	(0.454)	(0.555)
	Poisson	Negative Binomial	$\epsilon = 0.1$	$\epsilon = 0.01$	$\epsilon = 0.001$	$\epsilon = 0.0001$
Percentage change	-0.53	-0.60	-0.54	-0.68	-0.78	-0.84
Mean patents before 1924	4.15	4.15	4.15	4.15	4.15	4.15
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Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes

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- Ethnicity-based immigration quotas in the 1920s
  - Intended to keep out low-skilled ”undesirable” immigrants from Eastern and Southern Europe (ESE)
- Biographical data on > 90,000 US scientists in 1921 and 1956
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After quotas, 46% fewer new scientists enter ESE fields in the physical sciences and 23% in all disciplines

	ln(new scientists)	
	Physical sciences	All disciplines
	(1)	(2)
ESE x post	-0.623***	-0.260**
	(0.204)	(0.130)
Percentage change	-0.46	-0.23
Mean new scientists per field and year 1910-24	5.65	12.47
N (fields x years)	3,800	3,600
Year FE	Yes	Yes
Field FE	Yes	Yes

Standard errors are clustered at the level of research fields

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After quotas, 40% fewer scientists work in ESE fields (extensive margin)

and scientists patent 33% less per scientist (intensive margin)

	Scientists		
	ln(scientists)	ln(patents/ scientist)	ln(patents)
	(1)	(2)	(3)
ESE x post	-0.515***	-0.394**	-0.923***
	(0.102)	(0.156)	(0.326)
Percentage change	-0.40	-0.33	-0.60
Mean outcome before 1924	66.32	0.05	3.83
N (fields x years)	4,275	4,275	4,275
Year FE	Yes	Yes	Yes
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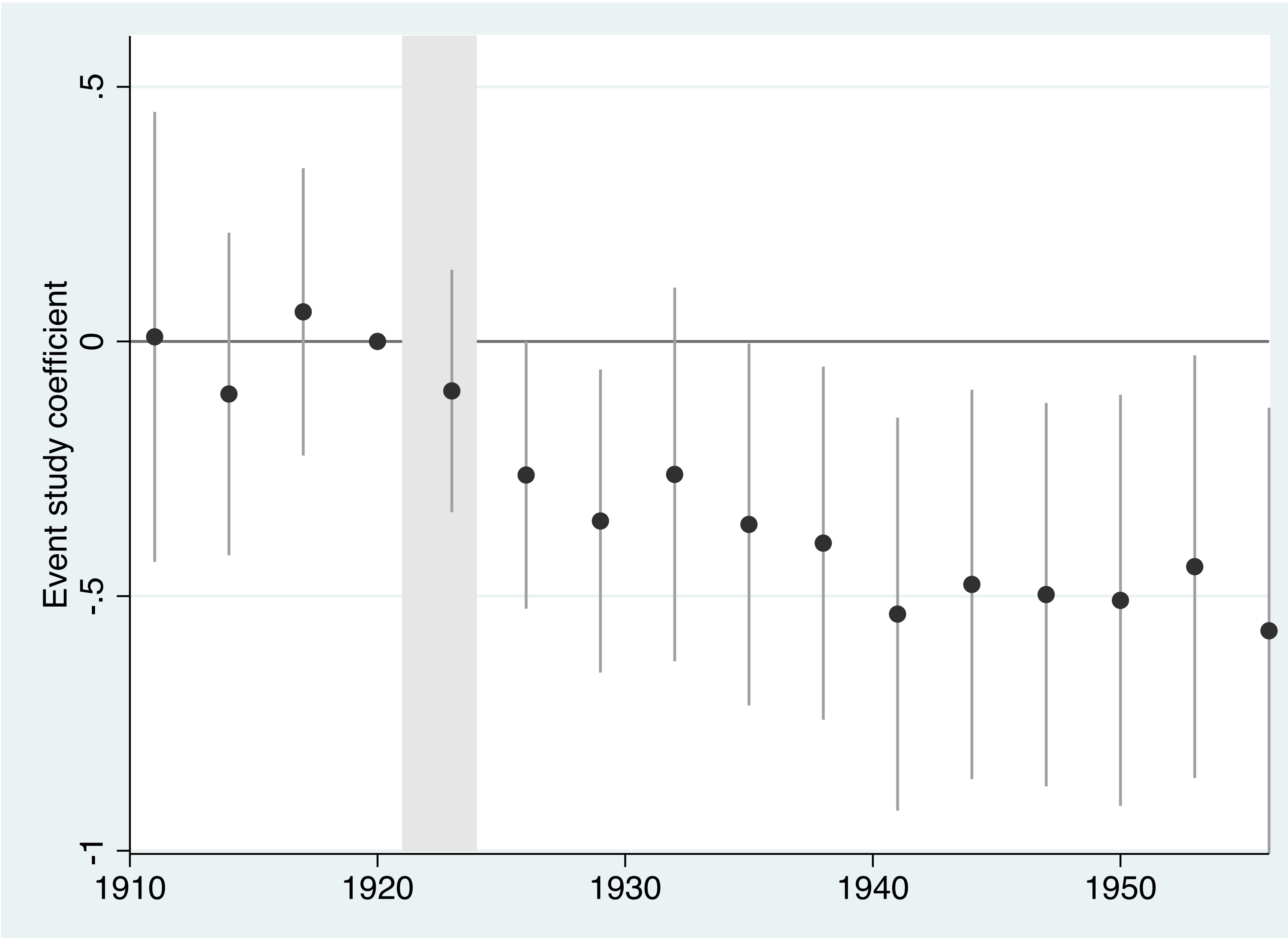
In ESE fields, US scientists produce fewer patents per scientist



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Native-born scientists produce 62% fewer inventions after 1924 in pre-quota fields of ESE scientists

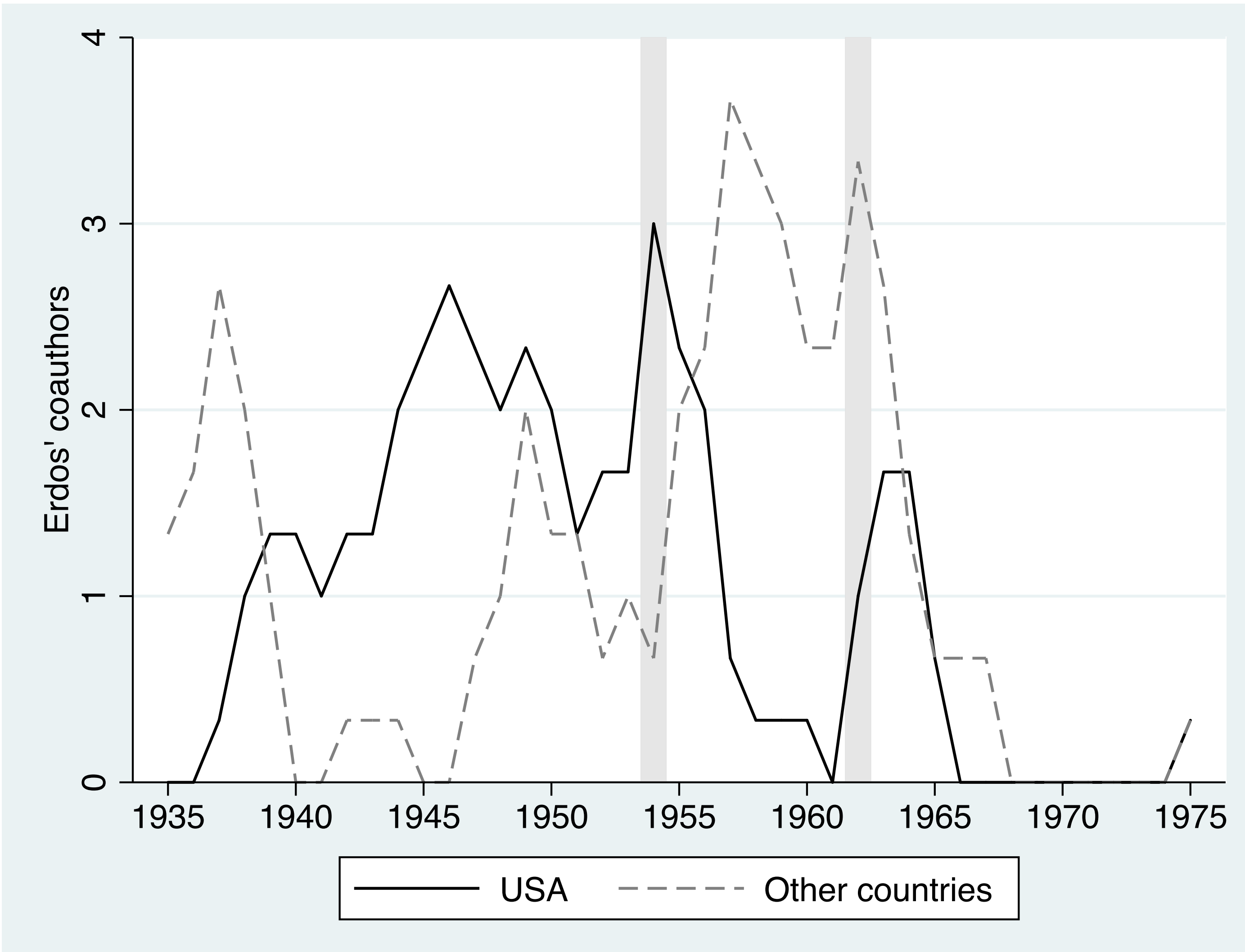
	ln(patents)			
	(1)	(2)	(3)	(4)
ESE x post	-0.971**	-1.020**	-1.094***	-1.111***
	(0.374)	(0.397)	(0.397)	(0.372)
	Baseline	Excl. 5% largest fields	Excl. fields w top 5% ESE share	Incl. new fields
Percentage change	-0.62	-0.64	-0.67	-0.67
Mean patents before 1924	3.61	3.04	3.68	3.45
N (fields x years)	5,795	5,490	5,551	6,100
Year FE	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes

Compared with journal publications, which are capacity-constrained, patents are unconstrained, allowing benefits of knowledge spillovers to outweigh costs of competition

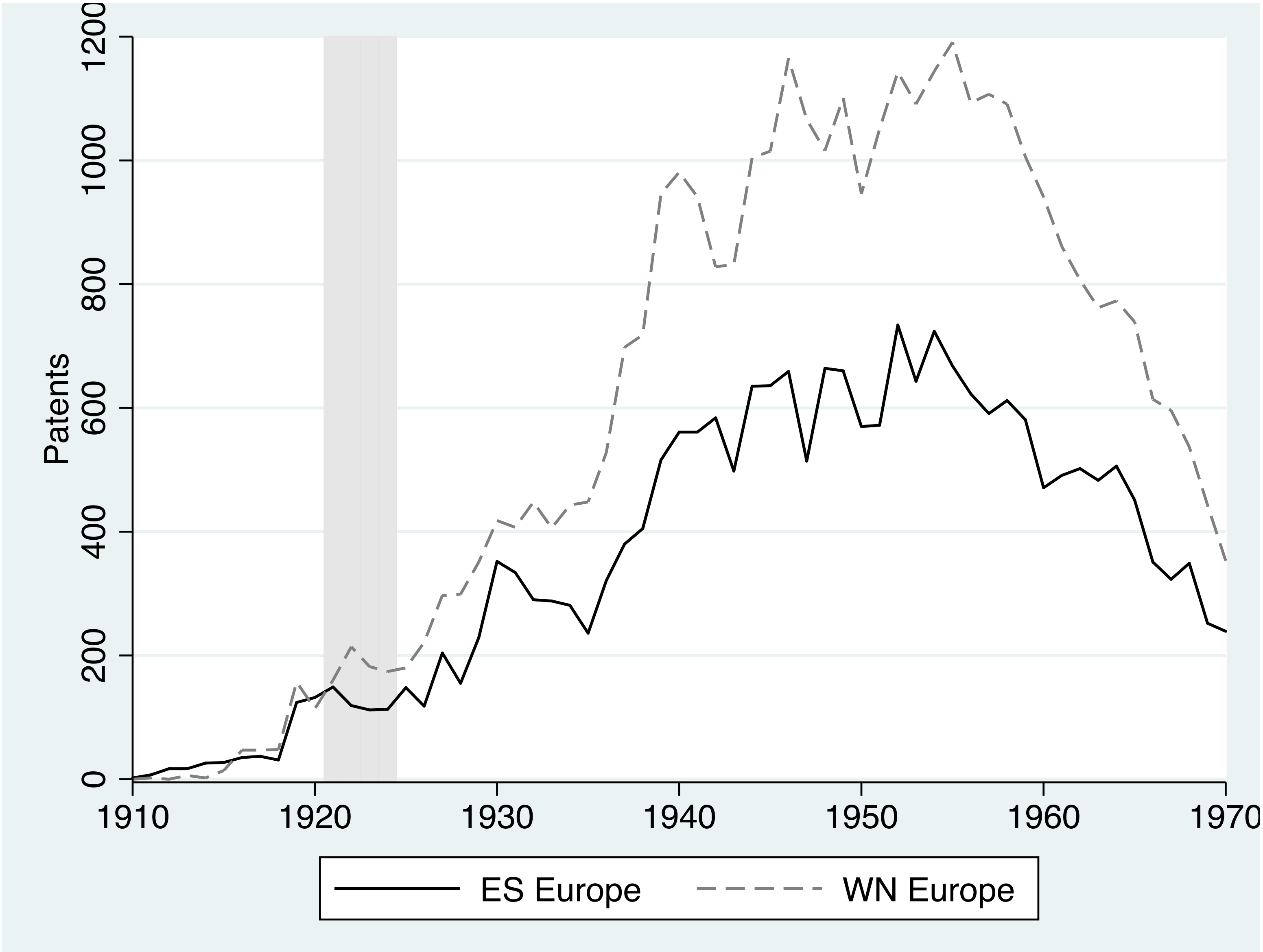
Case Study: Paul Erdős, the "founder of discrete mathematics"

- Erdős number
  - Count of co-authors that separate them from Erdős
  - Median Fields Medal recipients had an Erdős number of 3 (with a range from 2 to 6, in 2016)
  - In economics, the median Erdős number for a Nobel Laureate is 4 (with a range from 2 to 8)
- Professor at Notre Dame and a Hungarian citizen
  - Denied a re-entry visa by the US immigration services in 1954
  - Not granted re-entry until 1963.
- Use locations of co-authors to examine whether the quotas reduced professional links between US and ESE scientists

While Erdős' was denied re-entry, his collaborations shifted out of US.
Until 1954, 60% of Erdős' new co-authors were based in US
1954-63, 24% of Erdős' new co-authors were US scientists



Patents by co-inventors and co-inventors of co-inventors of ESE and WNE scientists



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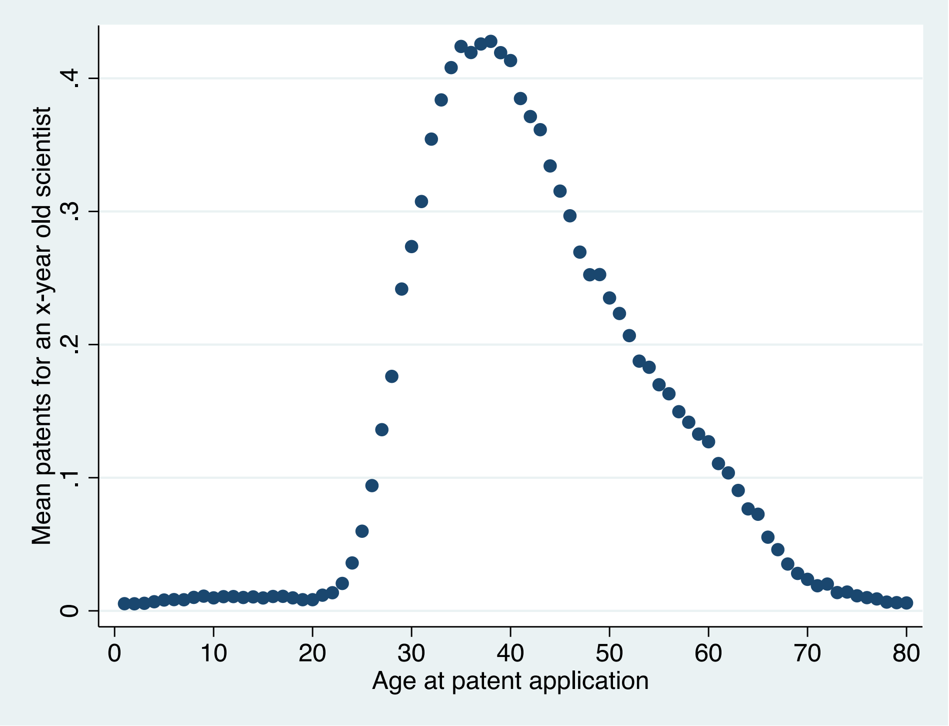
Aging research fields?

- With quotas, fewer young scientists move to United States
- Patent data suggest that scientists became less productive after 40

- Can aging explain the observed decline in invention?



Controlling for aging reduces estimated decline from 68 to 65%

	ln(patents)				
	(1)	(2)	(3)	(4)	(5)
ESE x post	1.145***	-1.045***	-1.073***	-0.985***	-1.014***
	(0.371)	(0.363)	(0.384)	(0.367)	(0.377)
Share above 40 x post		-0.011			-0.016
		(0.007)			(0.013)
Share above 65 x post			-0.006		-0.009
			(0.015)		(0.017)
Average age x post				-0.034	0.029
				(0.027)	(0.055)
Percentage change	-0.68	-0.65	-0.66	-0.63	-0.64
Mean patents pre-1924	4.22	4.22	4.22	4.22	4.22
N (fields x years)	5,551	5,551	5,551	5,551	5,551
Year FE	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes

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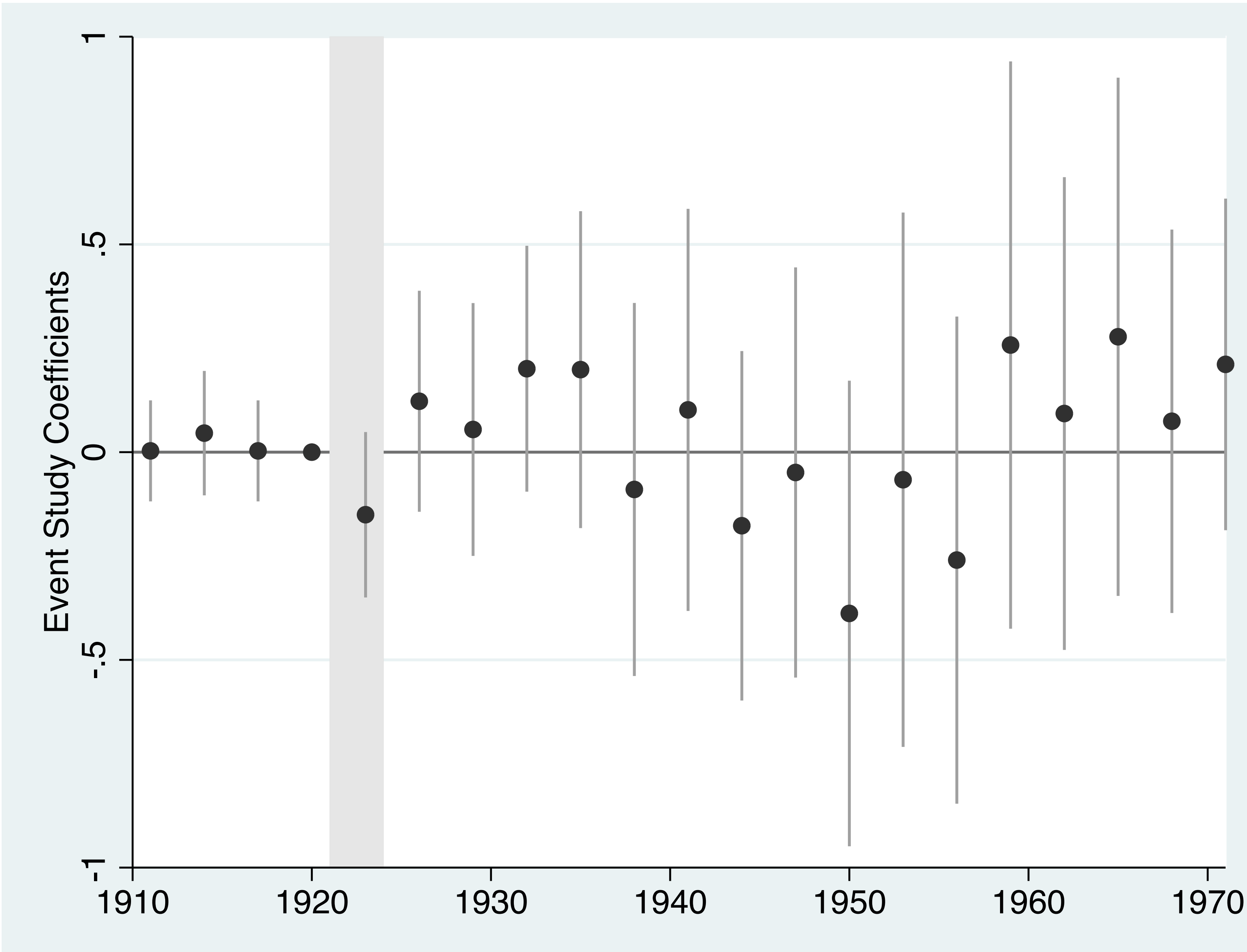
Selection into research fields?

- Did ESE-born scientists select into fields that became less productive after 1924?
- No comparable policy change in Canada
  - Continued to be welcoming to (non-Jewish) Eastern Europeans
- Estimate Placebo for Canada

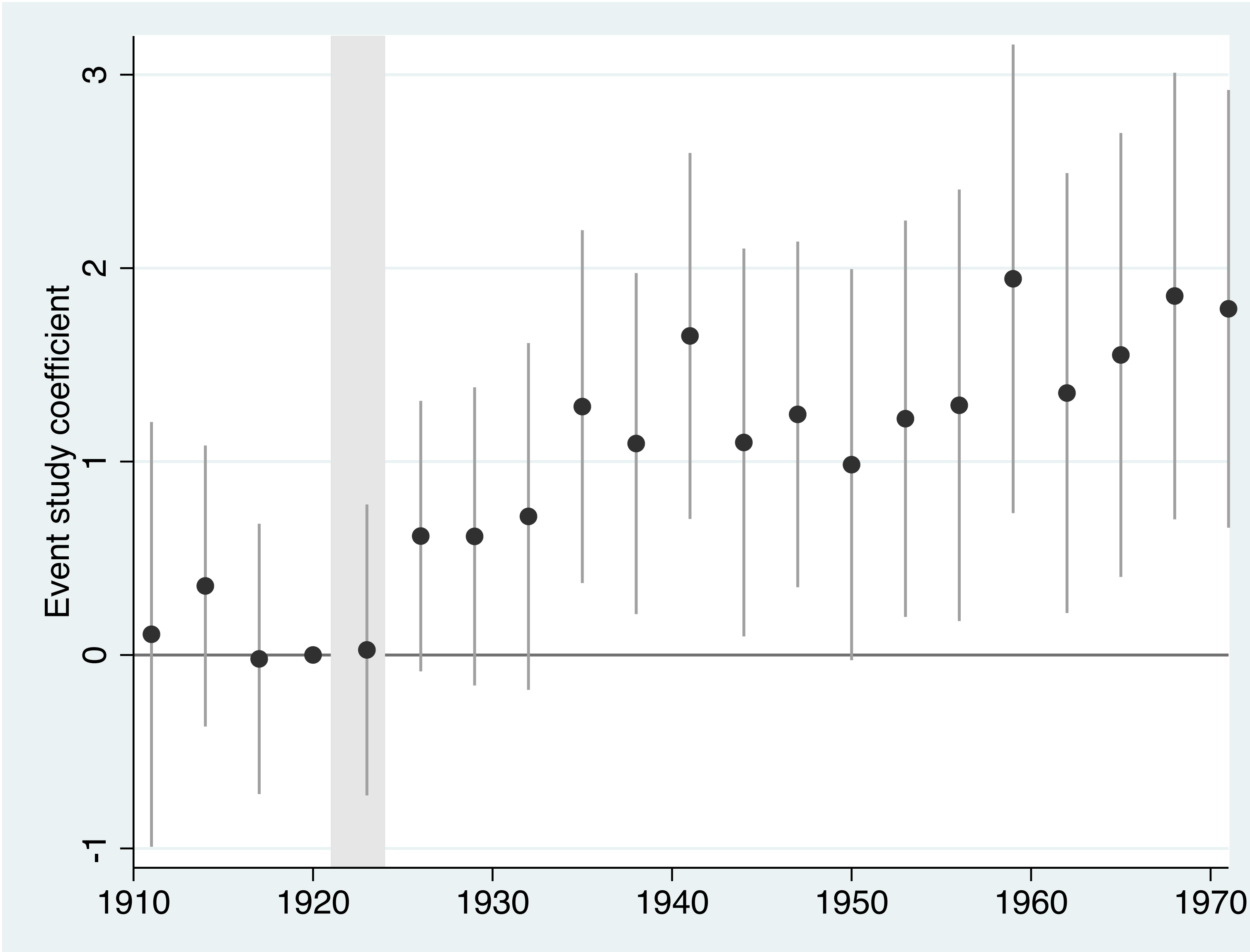
No comparable decline in patenting for Canadian-born (Placebo: Canada did not impose immigration quotas)



No comparable decline in patenting for Canadian-born (Placebo: Canada did not impose immigration quotas)

	ln(patents)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ESE x post	0.049	-0.019	-0.103	-0.176	0.061	-0.025	0.081	0.021
	(0.151)	(0.171)	(0.131)	(0.148)	(0.158)	(0.180)	(0.148)	(0.167)
	Baseline		Excl. 5% largest fields		Excl. fields w top 5% ESE share		Incl. new fields	
Percentage change	0.05	-0.02	-0.10	-0.16	0.06	-0.02	0.08	0.02
Mean patents before 1924	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N (fields x years)	5795	5795	5490	5490	5551	5551	6100	6100
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field-specific pre-trends	No	Yes	No	Yes	No	Yes	No	Yes

After 1924, Canadians patent more than Americans in fields of ESE scientists compared with other fields



OLS estimate for β_t in $\ln(y_{ict}) = \beta_t \, ESE_i \, Canada_c + \gamma_{ic} + \delta_{it} + \theta_{ct} + \epsilon_{ict}$

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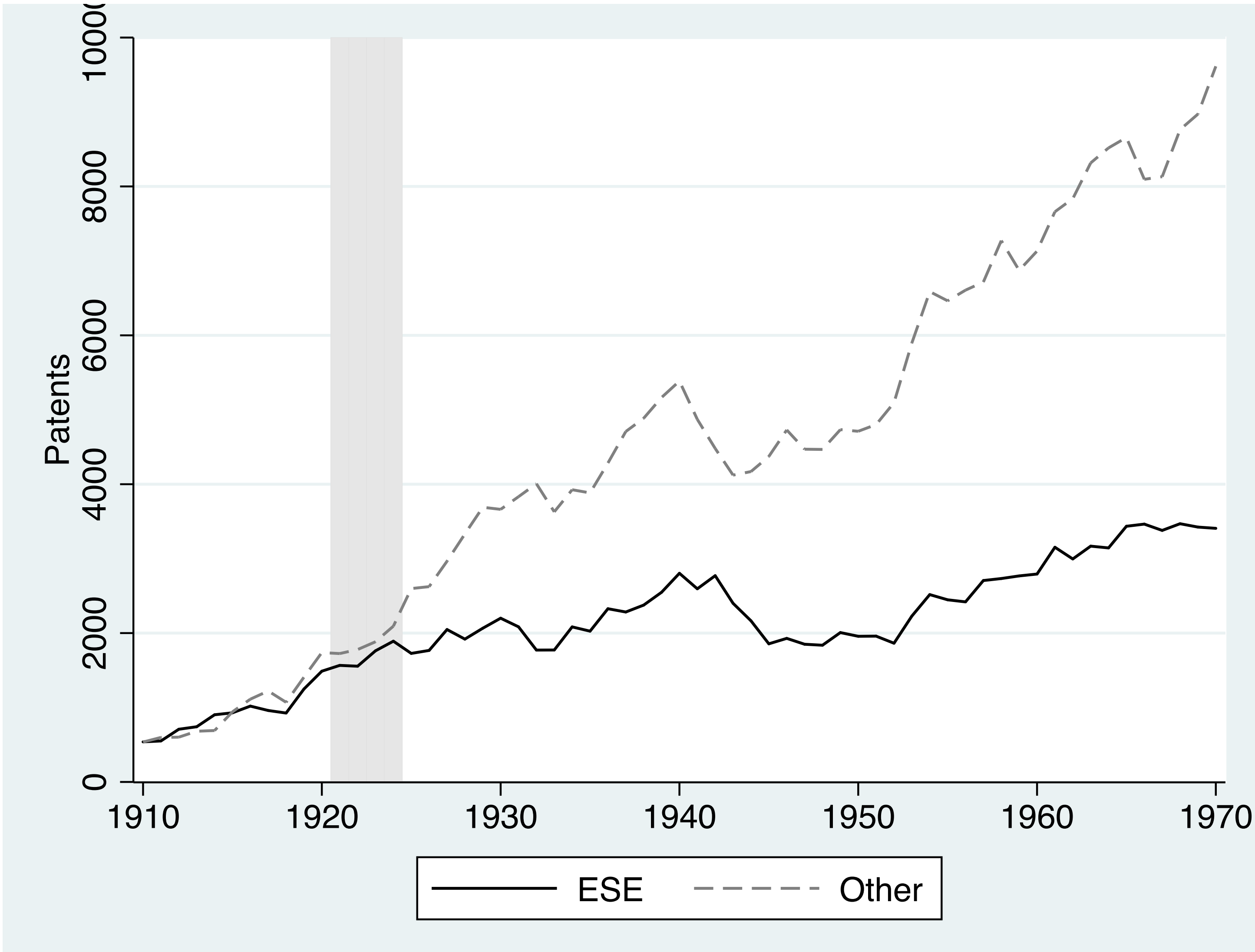
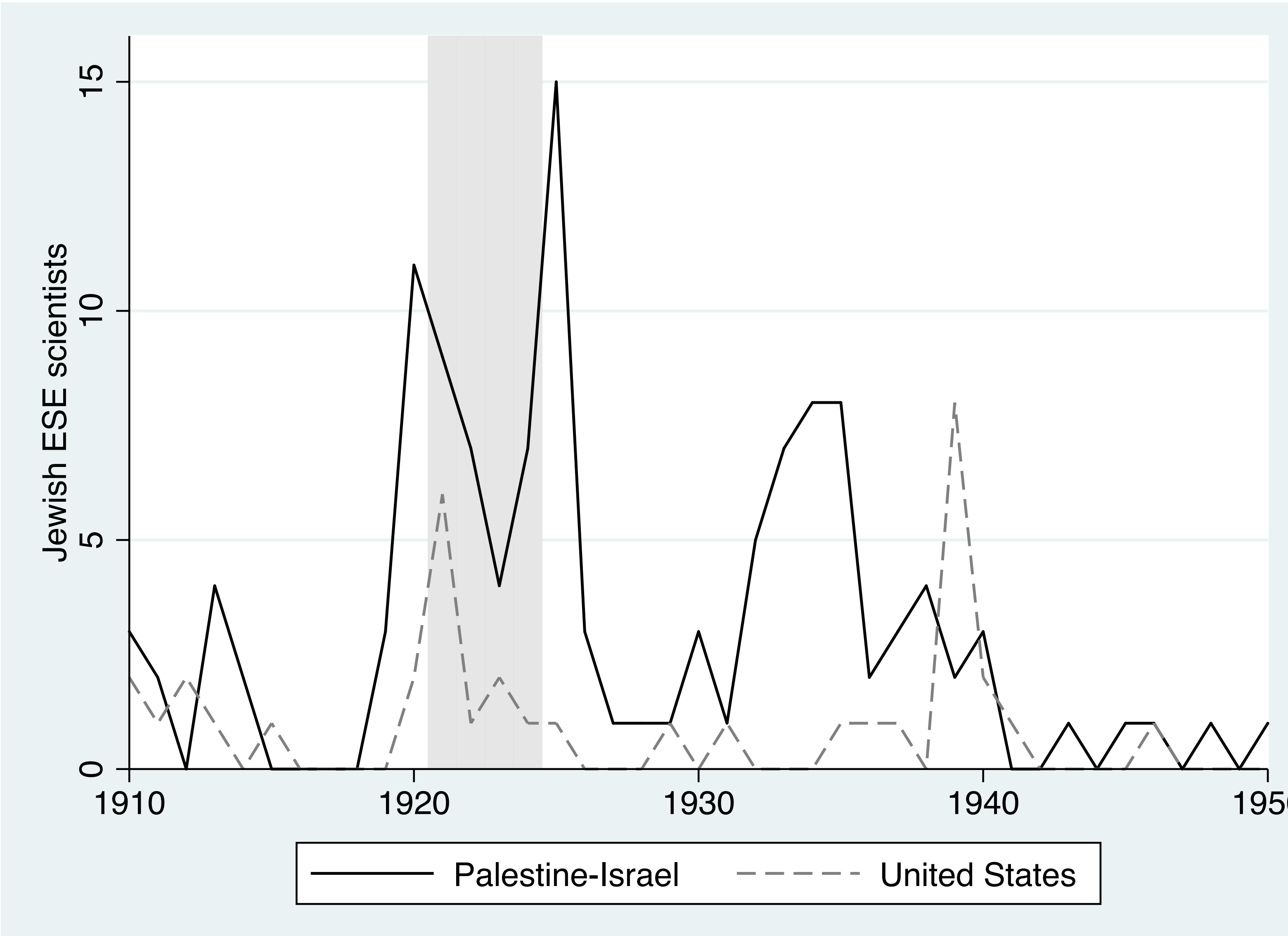
Firms employing ESE-born immigrants patent 53% less



In 1925, 15 ESE-born Jewish scientists moved to Palestine



Collected from *World Jewish Register, A Biographical* Compendium of Notable Jews in the Arts, Sciences, and Professions, 1955

An ESE-born immigrant to Palestine in 1925: Aharon Katzir (1914-72)

- Polish-born
- Came to Palestine in 1925
- Professor at Hebrew University in Jerusalem
- Pioneer of electrochemistry of biopolymers
- Founded polymer research department at Israel's Weizman Institute of Sciences
- Namesake for the Katchalsky crater on the moon

Giulio Racah (1909-65)
Founder of theoretical physics in Israel

- Professor of physics in Pisa
- Emigrated to Palestine in 1939, after the Fascists' Regio Decreto of November 18, 1938 excluded Jews from higher education
- Professor of Theoretical Physics at the Hebrew University
- Established theoretical physics as a discipline in Israel
- Developed mathematical methods, based on tensor operators and continuous groups
- These methods revolutionized spectroscopy and remain essential tools in atomic, nuclear, and particle physics today.

The Racah Institute of Physics at the Hebrew University Givat Ram campus in Jerusalem,, by OwenX - CC BY 3.0,

Conclusions

- 1,165 missing scientists
- Decline in US invention
  - US scientists produce 68% fewer patents in fields of ESE scientists after 1924 compared with other fields
- Mechanisms
  - *Fewer scientists* in pre-quota fields of ESE-born and fewer patents *per scientist*
  - 60% decline in invention by US-born. Quotas reduced collaborations
  - Small effects of aging
  - Not selection into research fields
- Effects on aggregate invention
  - Firms employing immigrants patent 53% less
  - Gains for other countries

Potentially broader effects through children of immigrants

FEYNMAN, DR. RICHARD PHILLIPS, California Institute of Technology, Pasadena, Calif. THEORETICAL PHYSICS. New York, N. Y, May 11, 18; m. 52. B.S, Mass. Inst. Tech, 39; Procter fellow, Princeton, 40-42, Ph.D.(theoret. physics), 42. Physicist, atomic energy project, Princeton, 41-42; Los Alamos project, N. Mex, 42-45; assoc. prof. PHYSICS, Cornell, 45-51; PROF, CALIF. INST. TECH, 51- Einstein Award, 54. Nat. Acad; A.A; Physical Soc. Quantum electrodynamics; principle of least action in quantum mechanics; liquid helium.

- Feynman's father was born in Belarus and moved to US when he was 5
- Feynman's mother was born in Poland
  - Both would have been kept out of the United States had they arrived after 1924
- Identify children of immigrants
  - Currently matching scientists in 1921 and 1956 with census records in 1880, 1900, 1910, 1920, 1930, 1940

Broader research agenda: What propelled US to lead 20th century science? And what held the US back?

- Inequality: How have differences in socioeconomic status influenced participation in American science? Does status influence success or perceptions of success? Who becomes a star in America?
- Education: What is the role of public primary, secondary and tertiary education in encouraging broad-based participation? How did the GI Bill affect science and innovation in the United States?
- Women: What are good locations for smart girls to be born? And what are good places for them to work? Did WWI and II draw women into science? And how were these women affected by the return of male scientists?
- War: How did the wars influence the rate and direction of innovation? How did military spending influence American science? Was were the costs of trauma on the Greatest Generation?
- Ideology: How did McCarthy’s hunt for “communists” affect American science?