Women in Science
Lessons from the Baby Boom

Scott Kim, Wharton

Petra Moser, NYU, NBER and CEPR

Women are severely underrepresented in science

- Women comprise fewer senior staff and are promoted more slowly (National Academy of Sciences 2006)
- Women are more likely to leave STEM (Shaw and Stanton 2012)
  - 8 in 10 women and minority students who enroll in STEM drop out or switch out of STEM before finishing degree (Waldrop 2015)
- Structural Impediments
  - Discrimination at hire, glass ceiling in promotion, and inequity in salary and support (Settles et al. 1996; Sonnert and Holton 1996, Altonji and Blank 1999)
  - Lack of role models among faculty (Porter and Serra 2020) and in teaching materials (Stevenson and Zlotnik 2018)

Children are a possible cause

- Mothers spent more 46% more time on kids and 50% more on chores (American Time Use Survey 2019)
- Women do more housework and childcare even if they earn more (Besen-Cassino and Cassino 2014) and when their husbands are unemployed (van der Lippe, Treas, Norbutas 2018)

"Mommy can't take you to Katie's house. Mommy is busy cloning a slime mold."

Covid-19 widens gender gaps in work hours for mothers and fathers

- Feb-April 2020, mothers with young children reduced work hours 4-5x more than fathers
- 20-50% increase in gender gap of work hours (US population survey, Collins et al 2020)
- Survey of scientists in April 2020 shows that female scientists with young children experienced largest decline in time devoted to research (Meyers et al. 2020)

- What are the long run effects of these changes on participation and gender inequality?

How do children change productivity?

- Children contribute to gender gap in earnings (e.g., Bertrand, Goldin, and Katz 2010, Klevens, Landais, and Soogard 2019)
- But how do they affect output/ productivity?
  - Little systematic evidence to date
  - Especially when it comes to effects of children

We ask:

- How do children affect the timing of productivity?
- How do differences in timing of productivity impact tenure and participation?

Women in Science

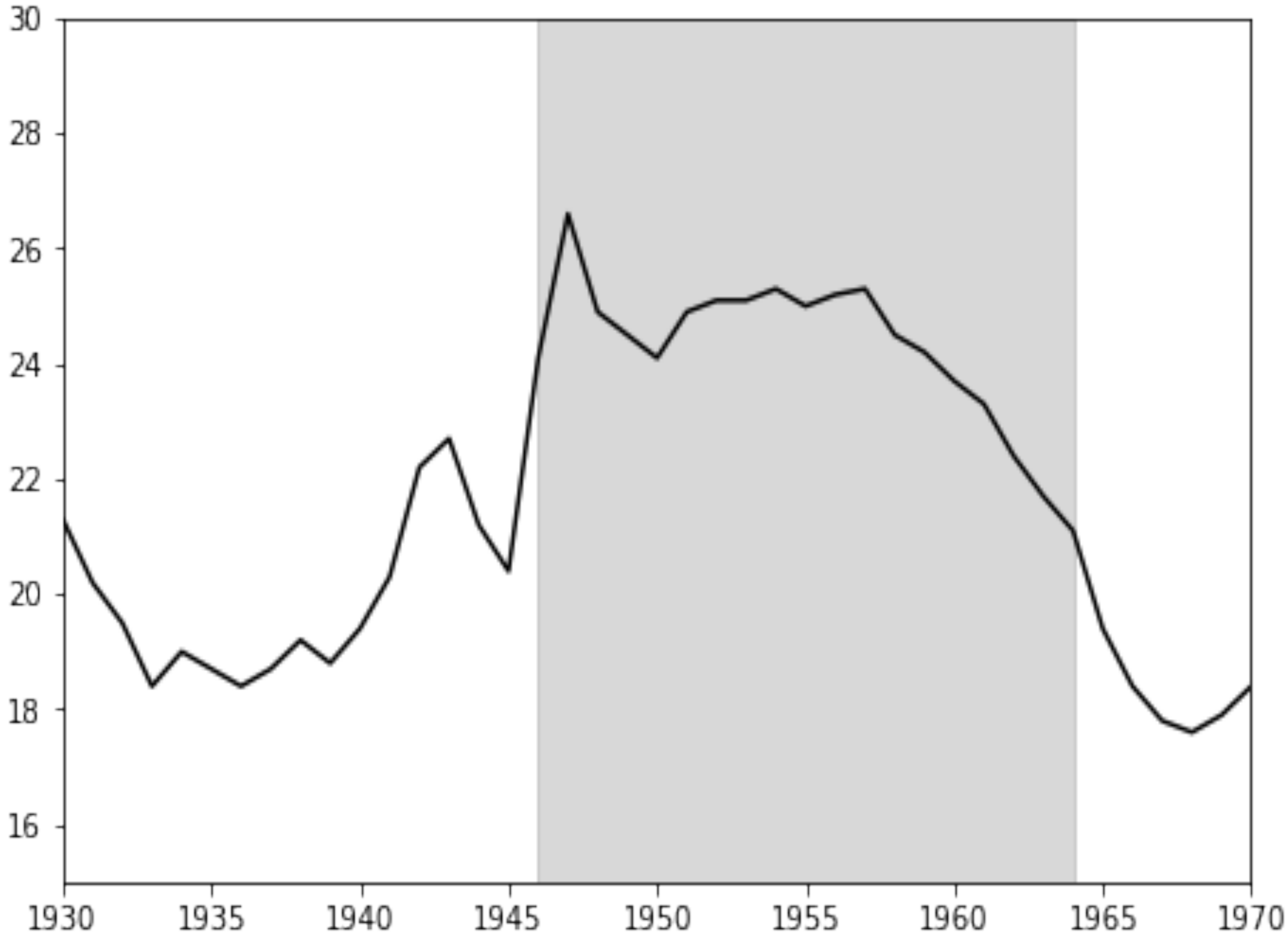
- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
- Effects on publications and tenure
  - Differences in publishing across the life cycle and across demographic groups
  - Event study estimates of the effects of children on tenure
  - Changes in publications before and after tenure
- Selection
- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

Baby Boom 1946-64

- 4.24 million births/year 1946-64
  - 76 million boomers in the U.S.
  - 6 million “boomies” in Canada
- Women give birth
  - at a younger age
  - immediately after marriage
  - Births spaced closely together
- “Family values” place burden of childcare squarely on women
  - *Archives of the Institute for Human Development* (Dyer, 1960)

A staff nurse greets some new arrivals at the Queen Charlotte Hospital in London, 1945.

Births increase from 22.7 per 1,000 in 1943 to 25.0 per year 1946-56



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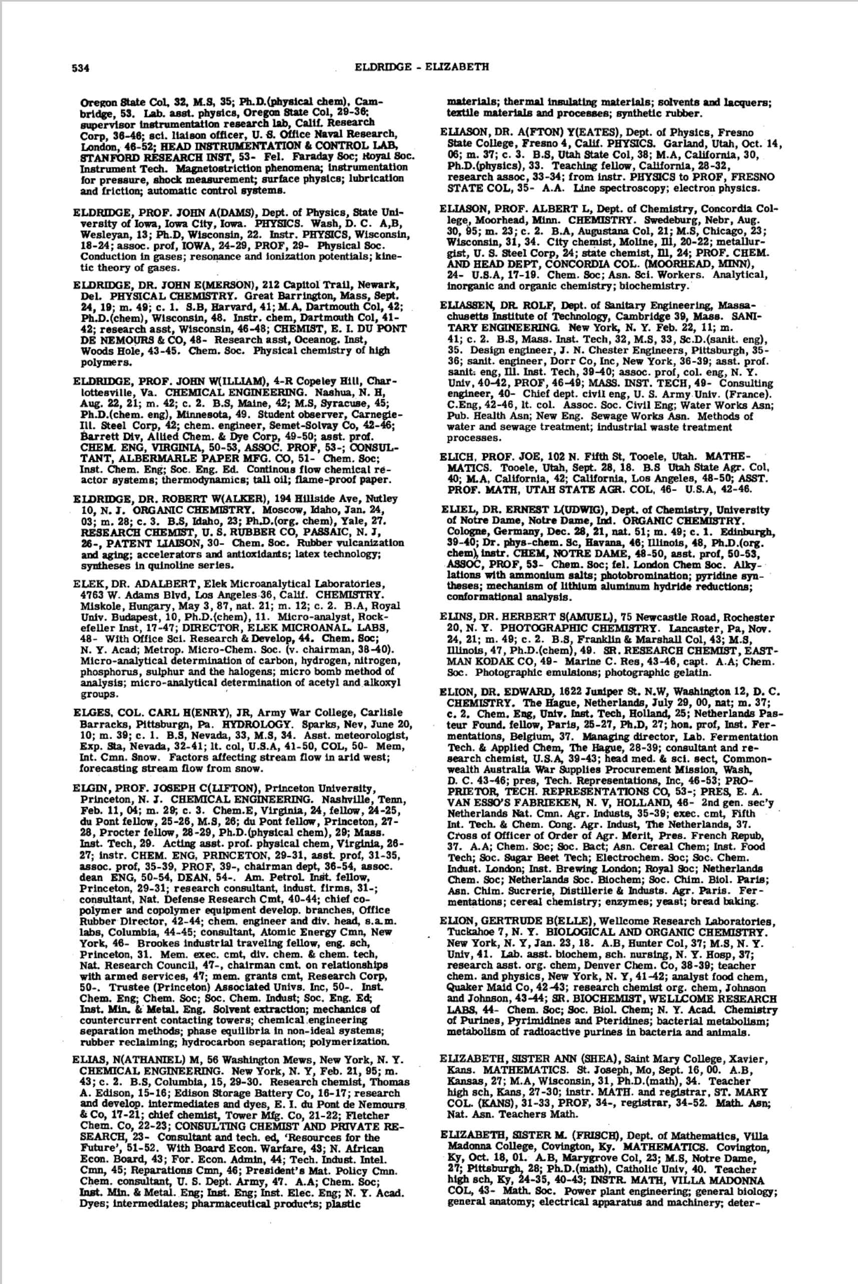
“American Men of Science. A Biographical Directory”



534 ELDRIDGE - ELIZABETH

Oregon State Col, 32, M.S, 35; Ph.D.(physical chem), Cambridge, 53. Lab. asst. physics, Oregon State Col, 29-36; supervisor instrumentation research lab, Calif. Research Corp, 36-46; sci. liaison officer, U. S. Office Naval Research, London, 46-52; HEAD INSTRUMENTATION & CONTROL LAB, STANFORD RESEARCH INST, 53- Fel. Faraday Soc; Royal Soc. Instrument Tech. Magnetostriction phenomena; instrumentation for pressure, shock measurement; surface physics; lubrication and friction; automatic control systems.

ELDRIDGE, PROF. JOHN A(DAMS), Dept. of Physics, State University of Iowa, Iowa City, Iowa. PHYSICS. Wash, D. C. A,B, Wesleyan, 13; Ph.D, Wisconsin, 22. Instr. PHYSICS, Wisconsin, 18-24; assoc. prof, IOWA, 24-29, PROF, 29- Physical Soc. Conduction in gases; resonance and ionization potentials; kinetic theory of gases.

ELDRIDGE, DR. JOHN E(MERSON), 212 Capitol Trail, Newark, Del. PHYSICAL CHEMISTRY. Great Barrington, Mass, Sept. 24, 19; m. 49; c. 1. S.B, Harvard, 41; M.A, Dartmouth Col, 42; Ph.D.(chem), Wisconsin, 48. Instr. chem, Dartmouth Col, 41-42; research asst, Wisconsin, 46-48; CHEMIST, E. I. DU PONT DE NEMOURS & CO, 48- Research asst, Oceanog. Inst, Woods Hole, 43-45. Chem. Soc. Physical chemistry of high polymers.

ELDRIDGE, PROF. JOHN W(ILLIAM), 4-R Copeley Hill, Charlottesville, Va. CHEMICAL ENGINEERING. Nashua, N. H, Aug. 22, 21; m. 42; c. 2. B.S, Maine, 42; M.S, Syracuse, 45; Ph.D.(chem. eng), Minnesota, 49. Student observer, Carnegie-Ill. Steel Corp, 42; chem. engineer, Semet-Solvay Co, 42-46; Barrett Div, Allied Chem. & Dye Corp, 49-50; asst. prof. CHEM. ENG, VIRGINIA, 50-53, ASSOC. PROF, 53-; CONSULTANT, ALBERMARLE PAPER MFG. CO, 51- Chem. Soc; Inst. Chem. Eng; Soc. Eng. Ed. Continous flow chemical reactor systems; thermodynamics; tall oil; flame-proof paper.

ELDRIDGE, DR. ROBERT W(ALKER), 194 Hillside Ave, Nutley 10, N. J. ORGANIC CHEMISTRY. Moscow, Idaho, Jan. 24, 03; m. 28; c. 3. B.S, Idaho, 23; Ph.D.(org. chem), Yale, 27. RESEARCH CHEMIST, U. S. RUBBER CO, PASSAIC, N. J, 26-, PATENT LIAISON, 30- Chem. Soc. Rubber vulcanization and aging; accelerators and antioxidants; latex technology; syntheses in quinoline series.

ELEK, DR. ADALBERT, Elek Microanalytical Laboratories, 4763 W. Adams Blvd, Los Angeles 36, Calif. CHEMISTRY. Miskole, Hungary, May 3, 87, nat. 21; m. 12; c. 2. B.A, Royal Univ. Budapest, 10, Ph.D.(chem), 11. Micro-analyst, Rockefeller Inst, 17-47; DIRECTOR, ELEK MICROANAL. LABS, 48- With Office Sci. Research & Develop, 44. Chem. Soc; N. Y. Acad; Metrop. Micro-Chem. Soc. (v. chairman, 38-40). Micro-analytical determination of carbon, hydrogen, nitrogen, phosphorus, sulphur and the halogens; micro bomb method of analysis; micro-analytical determination of acetyl and alkoxyl groups.

ELGES, COL. CARL H(ENRY), JR, Army War College, Carlisle Barracks, Pittsburgh, Pa. HYDROLOGY. Sparks, Nev, June 20, 10; m. 39; c. 1. B.S, Nevada, 33, M.S, 34. Asst. meteorologist, Exp. Sta, Nevada, 32-41; lt. col, U.S.A, 41-50, COL, 50- Mem, Int. Cmn. Snow. Factors affecting stream flow in arid west; forecasting stream flow from snow.

ELGIN, PROF. JOSEPH C(LIFTON), Princeton University, Princeton, N. J. CHEMICAL ENGINEERING. Nashville, Tenn, Feb. 11, 04; m. 29; c. 3. Chem.E, Virginia, 24, fellow, 24-25, du Pont fellow, 25-26, M.S, 26; du Pont fellow, Princeton, 27-28, Procter fellow, 28-29, Ph.D.(physical chem), 29; Mass. Inst. Tech, 29. Acting asst. prof. physical chem, Virginia, 26-27; instr. CHEM. ENG, PRINCETON, 29-31, asst. prof, 31-35, assoc. prof, 35-39, PROF, 39-, chairman dept, 36-54, assoc. dean ENG, 50-54, DEAN, 54-. Am. Petrol. Inst. fellow, Princeton, 29-31; research consultant, indust. firms, 31-; consultant, Nat. Defense Research Cmt, 40-44; chief copolymer and copolymer equipment develop. branches, Office Rubber Director, 42-44; chem. engineer and div. head, s.a.m. labs, Columbia, 44-45; consultant, Atomic Energy Cmn, New York, 46- Brookes industrial traveling fellow, eng. sch, Princeton, 31. Mem. exec. cmt, div. chem. & chem. tech, Nat. Research Council, 47-, chairman cmt. on relationships with armed services, 47; mem. grants cmt, Research Corp, 50-. Trustee (Princeton) Associated Univs. Inc, 50-. Inst. Chem. Eng; Chem. Soc; Soc. Chem. Indust; Soc. Eng. Ed; Inst. Min. & Metal. Eng. Solvent extraction; mechanics of countercurrent contacting towers; chemical engineering separation methods; phase equilibria in non-ideal systems; rubber reclaiming; hydrocarbon separation; polymerization.

ELIAS, N(ATHANIEL) M, 56 Washington Mews, New York, N. Y. CHEMICAL ENGINEERING. New York, N. Y, Feb. 21, 95; m. 43; c. 2. B.S, Columbia, 15, 29-30. Research chemist, Thomas A. Edison, 15-16; Edison Storage Battery Co, 16-17; research and develop. intermediates and dyes, E. I. du Pont de Nemours & Co, 17-21; chief chemist, Tower Mfg. Co, 21-22; Fletcher Chem. Co, 22-23; CONSULTING CHEMIST AND PRIVATE RESEARCH, 23- Consultant and tech. ed, ‘Resources for the Future’, 51-52. With Board Econ. Warfare, 43; N. African Econ. Board, 43; For. Econ. Admin, 44; Tech. Indust. Intel. Cmn, 45; Reparations Cmn, 46; President’s Mat. Policy Cmn. Chem. consultant, U. S. Dept. Army, 47. A.A; Chem. Soc; Inst. Min. & Metal. Eng; Inst. Eng; Inst. Elec. Eng; N. Y. Acad. Dyes; intermediates; pharmaceutical products; plastic materials; thermal insulating materials; solvents and lacquers; textile materials and processes; synthetic rubber.

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ELIASON, PROF. ALBERT L, Dept. of Chemistry, Concordia College, Moorhead, Minn. CHEMISTRY. Swedeburg, Nebr, Aug. 30, 95; m. 23; c. 2. B.A, Augustana Col, 21; M.S, Chicago, 23; Wisconsin, 31, 34. City chemist, Moline, Ill, 20-22; metallurgist, U. S. Steel Corp, 24; state chemist, Ill, 24; PROF. CHEM. AND HEAD DEPT, CONCORDIA COL. (MOORHEAD, MINN), 24- U.S.A, 17-19. Chem. Soc; Asn. Sci. Workers. Analytical, inorganic and organic chemistry; biochemistry.

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ELICH, PROF. JOE, 102 N. Fifth St, Tooele, Utah. MATHEMATICS. Tooele, Utah, Sept. 28, 18. B.S Utah State Agr. Col, 40; M.A, California, 42; California, Los Angeles, 48-50; ASST. PROF. MATH, UTAH STATE AGR. COL, 46- U.S.A, 42-46.

ELIEL, DR. ERNEST L(UDWIG), Dept. of Chemistry, University of Notre Dame, Notre Dame, Ind. ORGANIC CHEMISTRY. Cologne, Germany, Dec. 28, 21, nat. 51; m. 49; c. 1. Edinburgh, 39-40; Dr. phys-chem. Sc, Havana, 46; Illinois, 48, Ph.D.(org. chem), instr. CHEM, NOTRE DAME, 48-50, asst. prof, 50-53, ASSOC, PROF, 53- Chem. Soc; fel. London Chem Soc. Alkylations with ammonium salts; photobromination; pyridine syntheses; mechanism of lithium aluminum hydride reductions; conformational analysis.

ELINS, DR. HERBERT S(AMUEL), 75 Newcastle Road, Rochester 20, N. Y. PHOTOGRAPHIC CHEMISTRY. Lancaster, Pa, Nov. 24, 21; m. 49; c. 2. B.S, Franklin & Marshall Col, 43; M.S, Illinois, 47, Ph.D.(chem), 49. SR. RESEARCH CHEMIST, EASTMAN KODAK CO, 49- Marine C. Res, 43-46, capt. A.A; Chem. Soc. Photographic emulsions; photographic gelatin.

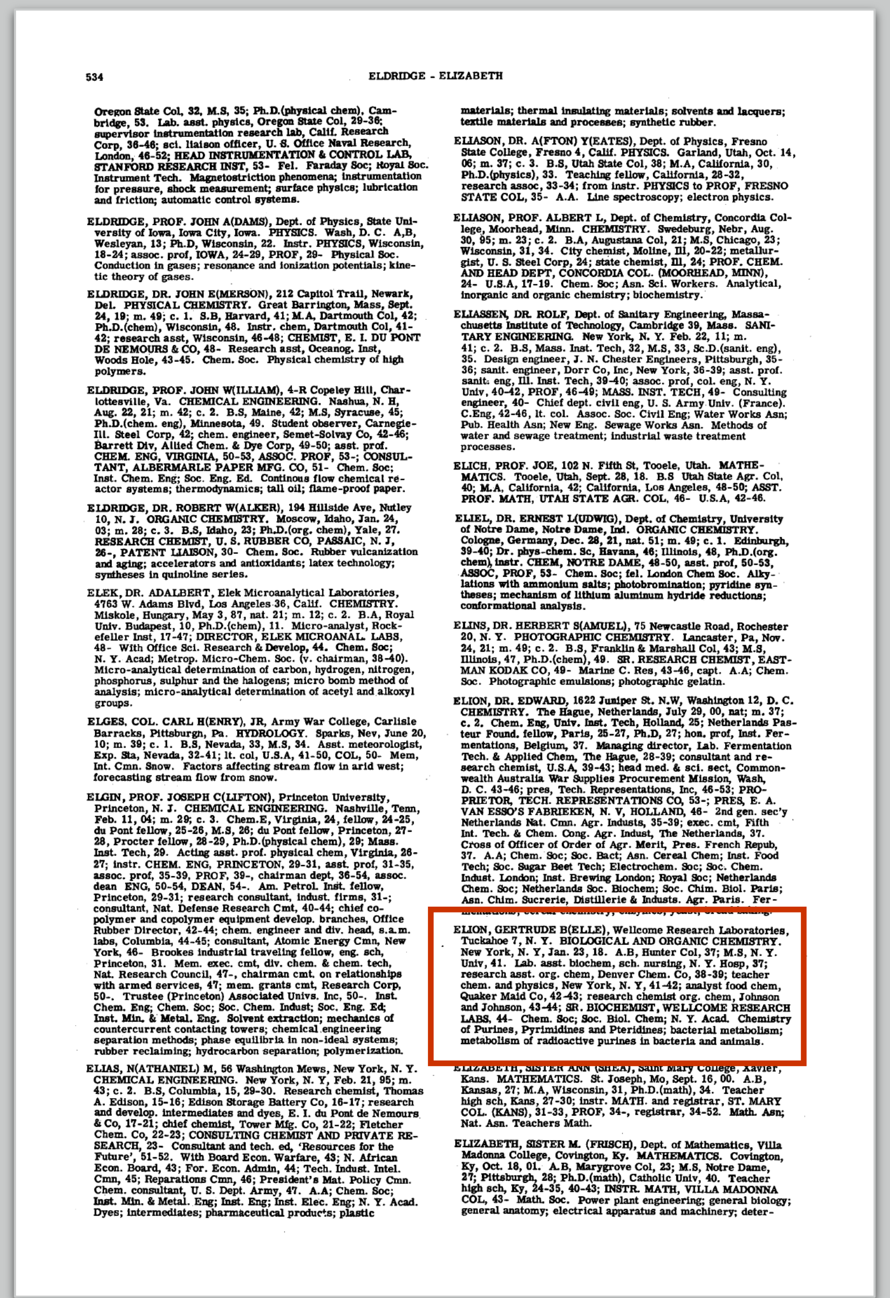
ELION, DR. EDWARD, 1622 Juniper St. N.W, Washington 12, D. C. CHEMISTRY. The Hague, Netherlands, July 29, 00, nat; m. 37; c. 2. Chem. Eng, Univ. Inst. Tech, Holland, 25; Netherlands Pasteur Found. fellow, Paris, 25-27, Ph.D, 27; hon. prof, Inst. Fermentations, Belgium, 37. Managing director, Lab. Fermentation Tech. & Applied Chem, The Hague, 28-39; consultant and research chemist, U.S.A, 39-43; head med. & sci. sect, Commonwealth Australia War Supplies Procurement Mission, Wash, D. C. 43-46; pres, Tech. Representations, Inc, 46-53; PROPRIETOR, TECH. REPRESENTATIONS CO, 53-; PRES, E. A. VAN ESSO’S FABRIEKEN, N. V, HOLLAND, 46- 2nd gen. sec’y Netherlands Nat. Cmn. Agr. Industs, 35-39; exec. cmt, Fifth Int. Tech. & Chem. Cong. Agr. Indust, The Netherlands, 37. Cross of Officer of Order of Agr. Merit, Pres. French Repub, 37. A.A; Chem. Soc; Soc. Bact; Asn. Cereal Chem; Inst. Food Tech; Soc. Sugar Beet Tech; Electrochem. Soc; Soc. Chem. Indust. London; Inst. Brewing London; Royal Soc; Netherlands Chem. Soc; Netherlands Soc. Biochem; Soc. Chim. Biol. Paris; Asn. Chim. Sucrerie, Distillerie & Industs. Agr. Paris. Fermentations; cereal chemistry; enzymes; yeast; bread baking.

ELION, GERTRUDE B(ELLE), Wellcome Research Laboratories, Tuckahoe 7, N. Y. BIOLOGICAL AND ORGANIC CHEMISTRY. New York, N. Y, Jan. 23, 18. A.B, Hunter Col, 37; M.S, N. Y. Univ, 41. Lab. asst. biochem, sch. nursing, N. Y. Hosp, 37; research asst. org. chem, Denver Chem. Co, 38-39; teacher chem. and physics, New York, N. Y, 41-42; analyst food chem, Quaker Maid Co, 42-43; research chemist org. chem, Johnson and Johnson, 43-44; SR. BIOCHEMIST, WELLCOME RESEARCH LABS, 44- Chem. Soc; Soc. Biol. Chem; N. Y. Acad. Chemistry of Purines, Pyrimidines and Pteridines; bacterial metabolism; metabolism of radioactive purines in bacteria and animals.

ELIZABETH, SISTER ANN (SHEA), Saint Mary College, Xavier, Kans. MATHEMATICS. St. Joseph, Mo, Sept. 16, 00. A.B, Kansas, 27; M.A, Wisconsin, 31, Ph.D.(math), 34. Teacher high sch, Kans, 27-30; instr. MATH. and registrar, ST. MARY COL. (KANS), 31-33, PROF, 34-, registrar, 34-52. Math. Asn; Nat. Asn. Teachers Math.

ELIZABETH, SISTER M. (FRISCH), Dept. of Mathematics, Villa Madonna College, Covington, Ky. MATHEMATICS. Covington, Ky, Oct. 18, 01. A.B, Marygrove Col, 23; M.S, Notre Dame, 27; Pittsburgh, 28; Ph.D.(math), Catholic Univ, 40. Teacher high sch, Ky, 24-35, 40-43; INSTR. MATH, VILLA MADONNA COL, 43- Math. Soc. Power plant engineering; general biology; general anatomy; electrical apparatus and machinery; deter-

- “...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)
- James McKeen Cattell
  - First US professor of psychology
  - Editor of Science for nearly 50 years
- Members of scientific societies
- Male and female scientists in Canada and United States



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ELINS, DR. HERBERT S(AMUEL), 75 Newcastle Road, Rochester 20, N. Y. PHOTOGRAPHIC CHEMISTRY. Lancaster, Pa, Nov. 24, 21; m. 49; c. 2. B.S, Franklin & Marshall Col, 43; M.S, Illinois, 47, Ph.D.(chem), 49. SR. RESEARCH CHEMIST, EASTMAN KODAK CO, 49- Marine C. Res, 43-46, capt. A.A; Chem. Soc. Photographic emulsions; photographic gelatin.

ELION, DR. EDWARD, 1622 Juniper St. N.W, Washington 12, D. C. CHEMISTRY. The Hague, Netherlands, July 29, 00, nat; m. 37; c. 2. Chem. Eng, Univ. Inst. Tech, Holland, 25; Netherlands Pasteur Found. fellow, Paris, 25-27, Ph.D, 27; hon. prof, Inst. Fermentations, Belgium, 37. Managing director, Lab. Fermentation Tech. & Applied Chem, The Hague, 28-39; consultant and research chemist, U.S.A, 39-43; head med. & sci. sect, Commonwealth Australia War Supplies Procurement Mission, Wash, D. C. 43-46; pres, Tech. Representations, Inc, 46-53; PROPRIETOR, TECH. REPRESENTATIONS CO, 53-; PRES, E. A. VAN ESSO'S FABRIEKEN, N. V, HOLLAND, 46- 2nd gen. sec'y Netherlands Nat. Cmn. Agr. Industs, 35-39; exec. cmt, Fifth Int. Tech. & Chem. Cong. Agr. Indust, The Netherlands, 37. Cross of Officer of Order of Agr. Merit, Pres. French Repub, 37. A.A; Chem. Soc; Soc. Bact; Asn. Cereal Chem; Inst. Food Tech; Soc. Sugar Beet Tech; Electrochem. Soc; Soc. Chem. Indust. London; Inst. Brewing London; Royal Soc; Netherlands Chem. Soc; Netherlands Soc. Biochem; Soc. Chim. Biol. Paris; Asn. Chim. Sucrerie, Distillerie & Industs. Agr. Paris. Fermentations; cereal chemistry; enzymes; yeast; bread baking.

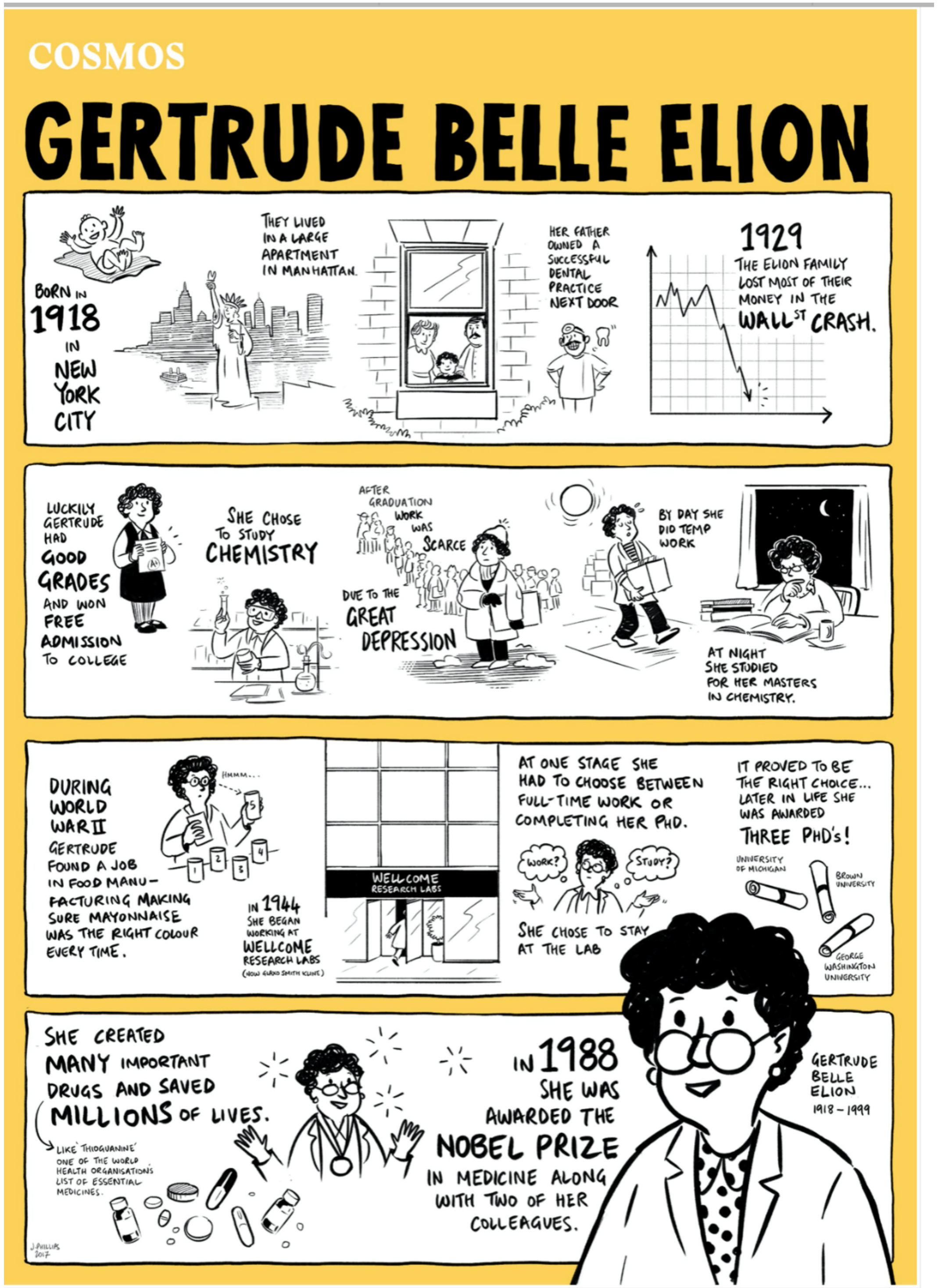
ELION, GERTRUDE B(ELLE), Wellcome Research Laboratories, Tuckahoe 7, N. Y. BIOLOGICAL AND ORGANIC CHEMISTRY. New York, N. Y, Jan. 23, 18. A.B, Hunter Col, 37; M.S, N. Y. Univ, 41. Lab. asst. biochem, sch. nursing, N. Y. Hosp, 37; research asst. org. chem, Denver Chem. Co, 38-39; teacher chem. and physics, New York, N. Y, 41-42; analyst food chem, Quaker Maid Co, 42-43; research chemist org. chem, Johnson and Johnson, 43-44; SR. BIOCHEMIST, WELLCOME RESEARCH LABS, 44- Chem. Soc; Soc. Biol. Chem; N. Y. Acad. Chemistry of Purines, Pyrimidines and Pteridines; bacterial metabolism; metabolism of radioactive purines in bacteria and animals.

ELIZABETH, SISTER ANN (SHEA), Saint Mary College, Xavier, Kans. MATHEMATICS. St. Joseph, Mo, Sept. 16, 00. A.B, Kansas, 27; M.A, Wisconsin, 31, Ph.D.(math), 34. Teacher high sch, Kans, 27-30; instr. MATH. and registrar, ST. MARY COL. (KANS), 31-33, PROF, 34-, registrar, 34-52. Math. Asn; Nat. Asn. Teachers Math.

ELIZABETH, SISTER M. (FRISCH), Dept. of Mathematics, Villa Madonna College, Covington, Ky. MATHEMATICS. Covington, Ky, Oct. 18, 01. A.B, Marygrove Col, 23; M.S, Notre Dame, 27; Pittsburgh, 28; Ph.D.(math), Catholic Univ, 40. Teacher high sch, Ky, 24-35, 40-43; INSTR. MATH, VILLA MADONNA COL, 43- Math. Soc. Power plant engineering; general biology; general anatomy; electrical apparatus and machinery; deter-

"American Men of Science. A Biographical Directory"

- "...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)
- James McKeen Cattell
  - First US professor of psychology
  - Editor of Science for nearly 50 years
- Members of scientific societies
- Male and female scientists in Canada and United States



Nobel in Physiology or Medicine 1988

- with George H. Hitchings and Sir James Black for methods of rational drug design
- focused on understanding drug target rather than proceeding through trial-and-error

Elion's work led to

- creation of AIDS drug AZT
- development of first immunosuppressive drug, azathioprine, used to fight rejection in organ transplants
- first successful antiviral drug, acyclovir (ACV) used in treatment of herpes

Full name (with middle name)

- Assign gender
- Match with US patents

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Gertrude Elion as student at Hunter College, which she attended from 1933 to 1937 (Courtesy of Gertrude B. Elion Foundation)

Full name (with middle name)

- Assign gender
- Match with US patents

Birthplace and date

- Age
- Birth cohort
- We use age to match scientists with patents and publications

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Full name (with middle name)
- Assign gender
- Match with US patents

Birthplace and date
- Age
- Birth cohort

Discipline and research topics

ELION, GERTRUDE B(ELLE), Wellcome Research Laboratories, Tuckahoe 7, N. Y. BIOLOGICAL AND ORGANIC CHEMISTRY. New York, N. Y, Jan. 23, 18. A.B, Hunter Col, 37; M.S, N. Y. Univ, 41. Lab. asst. biochem, sch. nursing, N. Y. Hosp, 37; research asst. org. chem, Denver Chem. Co, 38-39; teacher chem. and physics, New York, N. Y, 41-42; analyst food chem, Quaker Maid Co, 42-43; research chemist org. chem, Johnson and Johnson, 43-44; SR. BIOCHEMIST, WELLCOME RESEARCH LABS, 44- Chem. Soc; Soc. Biol. Chem; N. Y. Acad. Chemistry of Purines, Pyrimidines and Pteridines; bacterial metabolism; metabolism of radioactive purines in bacteria and animals.

Example: Helene Wallace Toolan

BS 1929, PhD 1946, Assistant Professor 1953

TOOLAN, PROF. HELENE WALLACE, 151 W. 86th St, New York 24, N.Y. EXPERIMENTAL PATHOLOGY. Chicago, Ill, Feb. 7, 12; m. 30; c. 3; m. 45. B.S, Chicago, 29; Ph.D.(path), Cornell, 46. Research asst, med. col, CORNELL, 46-50, ASST. PROF, SLOAN-KETTERING DIV, 53-; asst, SLOAN-KETTERING INST, 50-53, ASSOC, 53-. A.A; Soc. Path. & Bact; Asn. Cancer Research; Soc. Exp. Biol; Harvey Soc. Heterologous transplantation of human tissues, both normal and malignant; immunology.

Year of undergraduate degree 1929 (age 17)

Helene Toolan, 80, Cancer Researcher And Institute Head

By WOLFGANG SAXON

Dr. Helene Wallace Toolan, a cancer researcher, died on Sunday at Southwestern Vermont Hospital Center in Bennington. She was 80 years old and lived in Old Bennington, Vt.

She died of congestive heart failure after a long illness, her family said.

Dr. Toolan, a native of Chicago, graduated with honors from the University of Chicago at the age of 17 and received a Ph.D. in pathology from Cornell Medical Center. She was on the staff of the Sloan-Kettering Institute for Cancer Research in New York from 1950 until 1964.

Dr. Toolan did basic research on the transplantation of human tumors and tissues into laboratory animals. In 1955 she received the Sloan Award for her work.

Linked Cancers to Virus

She also studied the relationship between viruses and human cancer cells, leading a team of researchers that succeeded in linking viruses to eight types of human cancer in 1960. Previously only leukemia, a cancer affecting the blood, had been linked to a virus.

In 1964 Dr. Toolan moved to Bennington to direct the newly established Putnam Memorial Institute for Medical Research. In 1987 the institute was renamed the Helene W. Toolan Institute for Medical Research. She became director emeritus and senior scientist of the institute in 1978 and director emeritus and trustee in 1985.

Dr. Toolan was also an avid gardener, horticulturist and ornithologist, and participated in a project to beautify downtown Bennington in the early 1970's. The Garden Club of America gave her its Horticulural Award in 1982.

Her first husband, Dr. Edward Wallace, died in 1943. She later married Dr. James M. Toolan, who survives her. Also surviving are two sons, Robin Wallace of Gainesville, Fla., and Alan Wallace of Las Vegas, Nev.; four grandchildren, and two great-grandchildren.

NY Times, Obituary, Dec. 3, 1992

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Married in 1930 (age 18), 3 children

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PhD in 1946 (age 34, 17 years after undergrad)

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Year of undergraduate degree 1929 (age 17)

Married in 1930 (age 18), 3 children

PhD in 1946 (age 34, 17 years after undergrad)

Assistant professor 1953
At age 41, 7 years after PhD
Academic scientist ("asst. prof")

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NY Times, Obituary, Dec. 3, 1992

We link each scientists with their patents and publications

- Dr. Giuliana C. Tesoro
  - Born in Venice 1921
  - Jewish, not allowed to attend University in Italy under Fascist Racial Laws
  - Moved to Switzerland first and to US in 1939
  - Yale PhD in organic chemistry in 1943
- Married Victor Tesoro in 1943
  - Following her marriage, Tesoro worked part-time in summer job for Calco Chemical Company 43-44
  - Took a job as research chemist with Onyx Oil 1944, promoted to Head of Organic Synthesis Dept. 1946
- 2 children by 1956
- 89 US patents
  - Including patent for flame-retardant fiber

Year of marriage & number of children

TESORO, DR. GIULIANA C, 278 Clinton Ave, Dobbs Ferry, N. Y. ORGANIC CHEMISTRY. Venice, Italy, June 1, 21, nat. 46; m. 43; c. 2. Ph.D.(org. chem), Yale, 43. Research chemist, Calco Chem. Co, N. J, 43-44; ONYX OIL & CHEM. CO, 44-46, HEAD ORG. SYNTHESIS DEPT, 46- Chem. Soc; N. Y. Acad. Synthesis of pharmaceuticals, textile chemicals, germicides and insecticides; synthesis and rearrangement of glycols in the hydrogenated naphthalene series.

Controls for variation in output across fields

Two empirical challenges:

- Propensity to patent varies across fields (Moser 2012)
- Women may select into fields with low productivity

Solution:

- Control for field fixed effects
- Investigate selection into fields

Discipline

TESORO, DR. GIULIANA C, 278 Clinton Ave, Dobbs Ferry, N. Y. ORGANIC CHEMISTRY. Venice, Italy, June 1, 21, nat. 46; m. 43; c. 2. Ph.D.(org. chem), Yale, 43. Research chemist, Calco Chem. Co, N. J, 43-44; ONYX OIL & CHEM. CO, 44-46, HEAD ORG. SYNTHESIS DEPT, 46- Chem. Soc; N. Y. Acad. Synthesis of pharmaceuticals, textile chemicals, germicides and insecticides; synthesis and rearrangement of glycols in the hydrogenated naphthalene series.

Research topics

k-means assigns Tesoro to “benzene”

Apply *k*-means clustering to disciplines and research topics to assign each scientist to one unique field (Moser and San 2020)

VOLKOFF, PROF. G(EORGE) M(ICHAEL), Dept. of Physics, University of British Columbia, Vancouver 8, B. C. Can. PHYSICS. 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, research 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. Theoretical 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")
- Control for average output of scientists in the same field (through field FE)
- Examine selection into fields

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

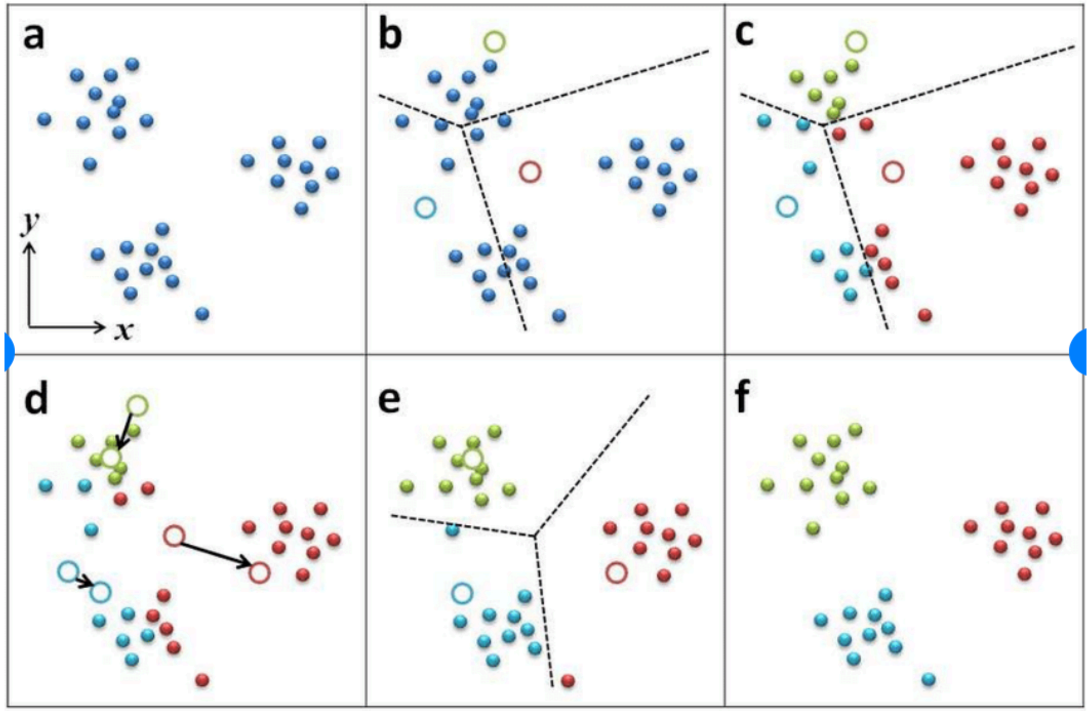
$idf(w) = \log\frac{1+n}{1+df(w)} + 1$

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.

Example: Volkoff falls into cluster 39:

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

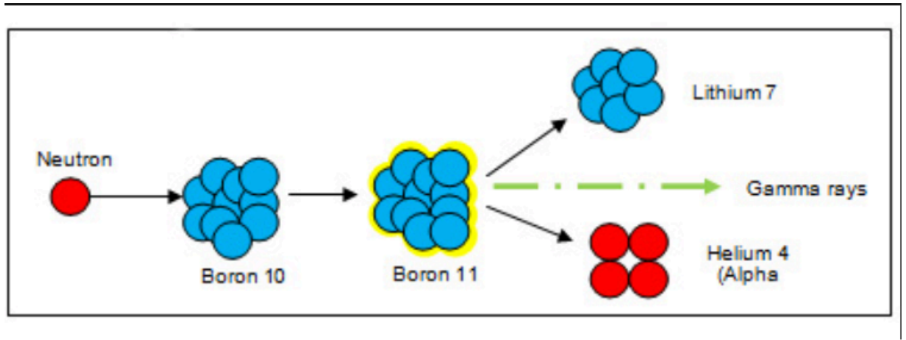
Cluster 39 has 749 scientists incl. Volkoff

cluster	9	19	29	39	49
title	Servomechanism	Chemical engineering	Organic chemistry	Neutron radiation	Internal combustion engine
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

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	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

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
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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 chemistr
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"

Who is included in the MoS?

- Members of scientific organizations
- Focused on researchers
  - Moser and Parsa (2020) compare Harvard 1955 Directory of University Professors and Students with MoS (1956)
- Full professors are more likely to be included
  - 32% of full professors at Harvard are in MoS
  - 11% of associate and 9% of assistant professors

Who was a female scientist?

This sounds more trivial than it is. We compared 4 different ways

- Manual assignment
  - Data typists assign gender based on their perception of gender
  - Problem: Based on perception of names today
- Algorithm using frequencies of male and female names in US census 1940
  - Uses historical perception of names in 1940
  - Assign gender based on % female in census of 1940
- Attendance at women's college
  - Built a list of women's colleges, w dates when they admitted men
- US Social Security Administration data, 1880-2011
  - Frequencies of male and female first names

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  - Frequencies of male and female first names
  - Python module "gender-detector"

Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
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  - Differences in publishing across the life cycle and across demographic groups
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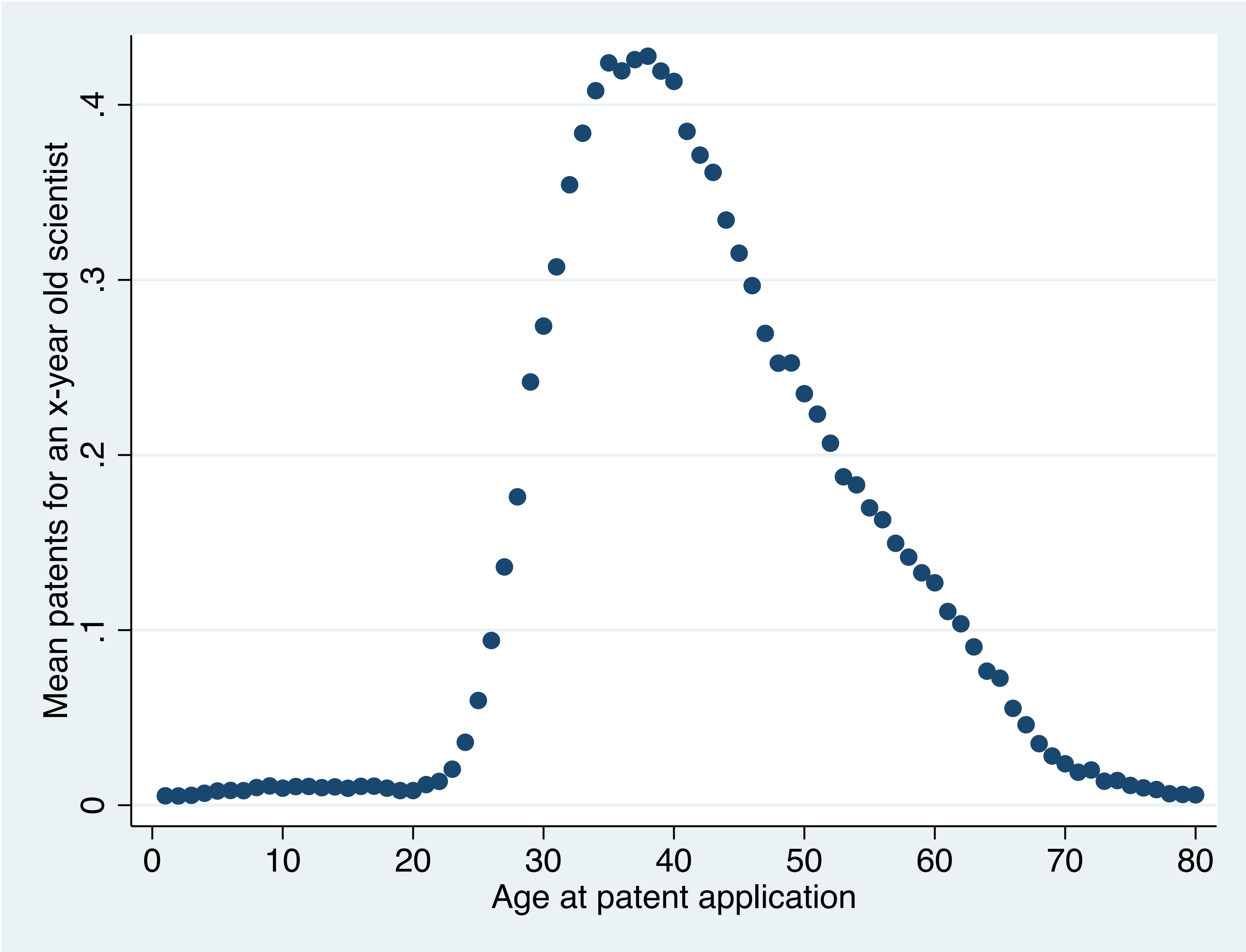
  - A lost generation of baby boom mothers
- Conclusions

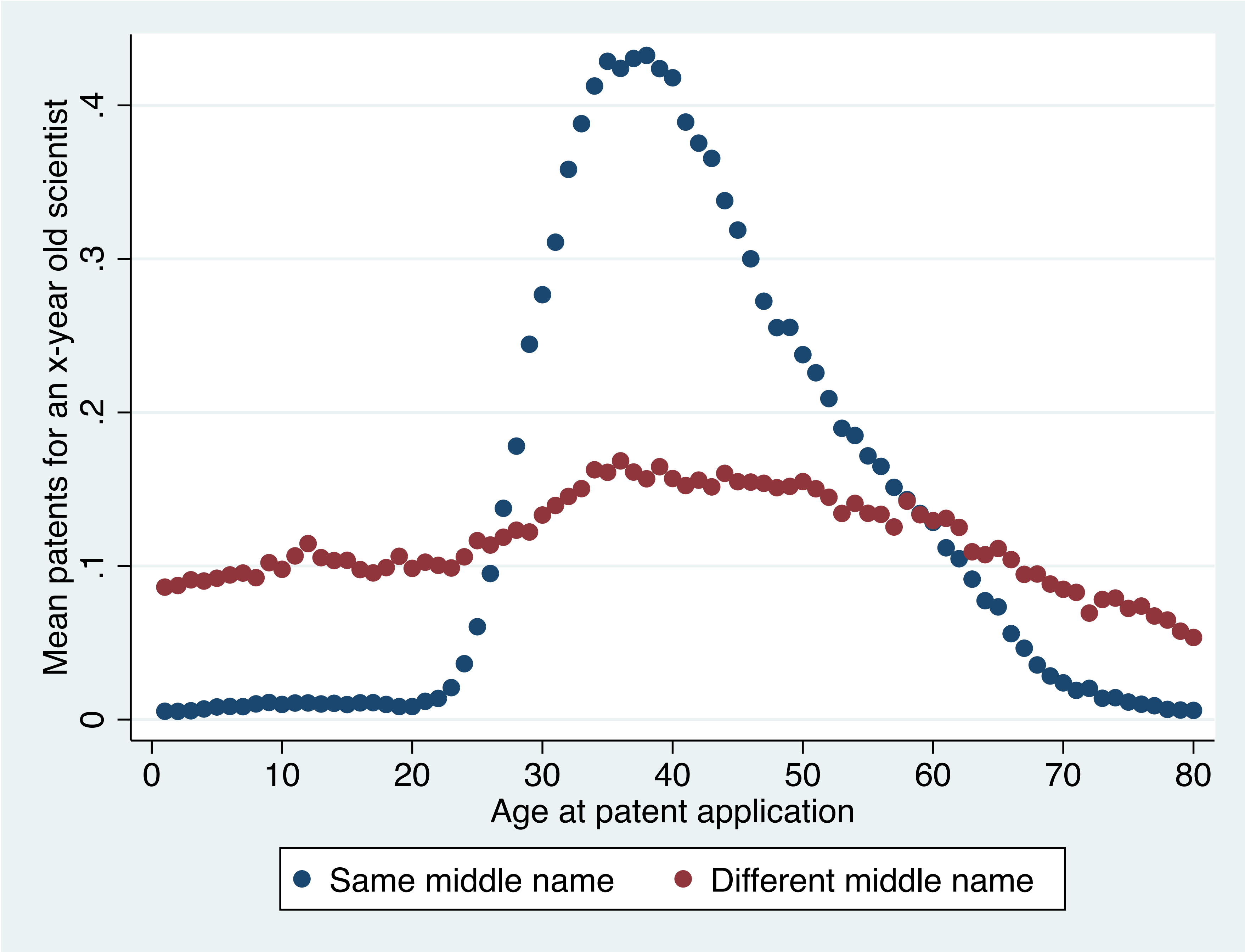
Patents

- Systematic measure for changes in productivity over time
- Match scientists with patents
  - Match using first, middle, and last names
    - Levenstein distance measure, allowing 1 letter to be different
  - Use age to reduce false positives
    - Patent applications when the scientists was a kid (0-18 years)
  - Best match quality in the physical sciences
    - Physical, biological, and social sciences
  - Frequent names get many false positives
    - Drop the top 20 percent of frequent names
- Propensity to patent varies across fields (Moser 2012)
  - Solution: Control for fields

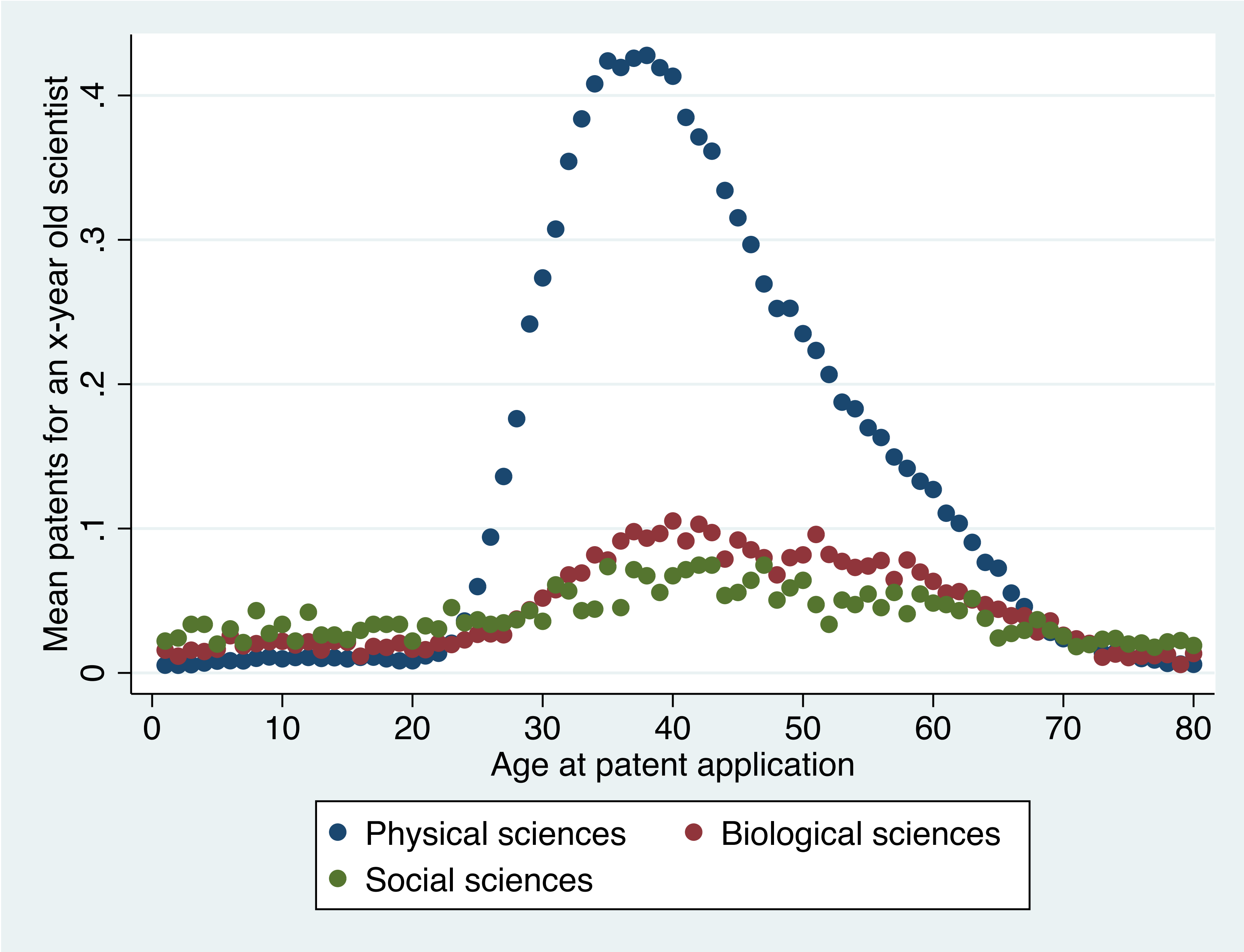
Patents applications when scientists are 0-18 years are likely false positives



Match on middle initial

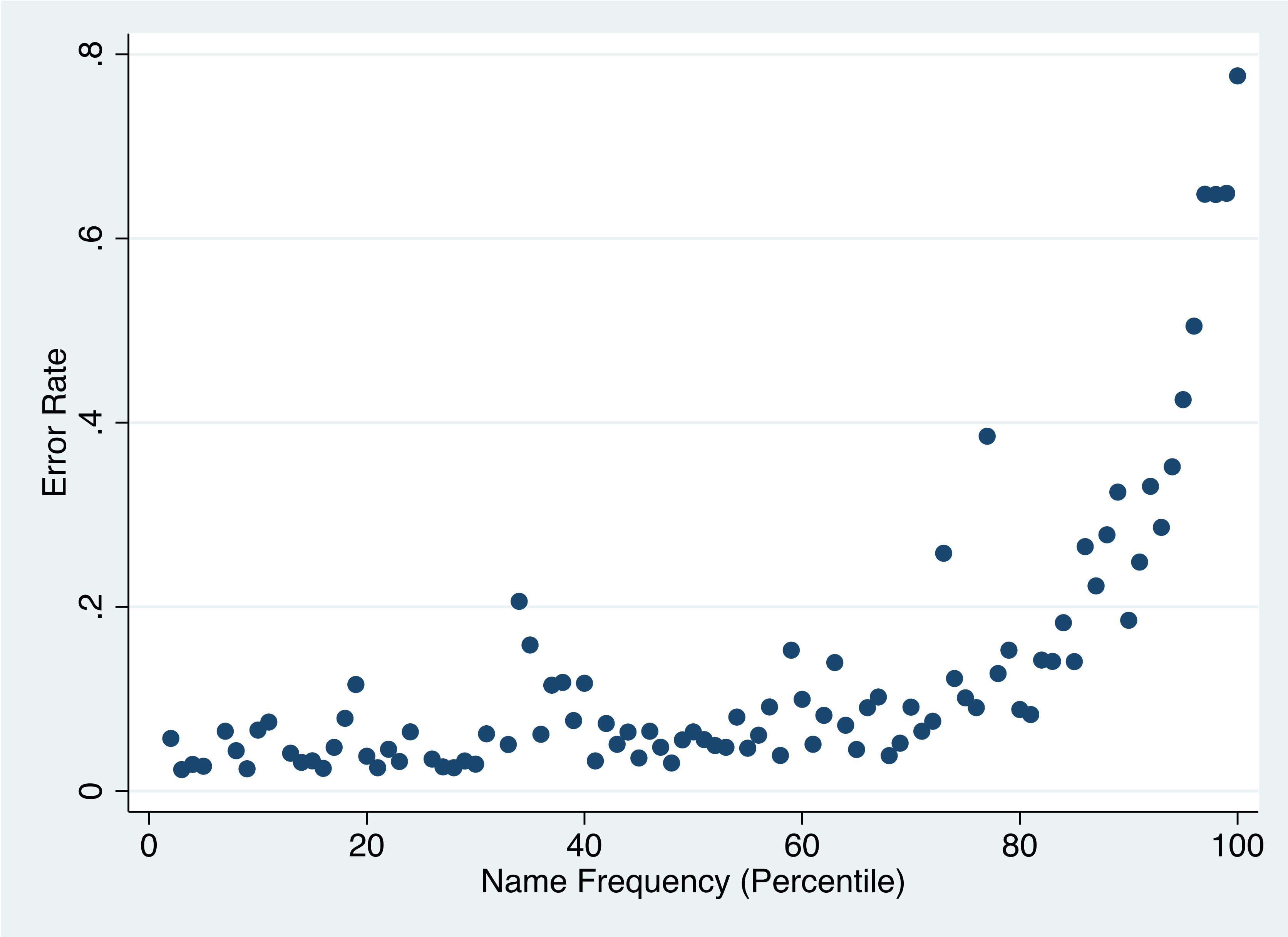


Analysis of patents focus on physical sciences (STEM): chemistry, physics, engineering, mathematics



From Moser and San (2020)

Low match quality for common names, esp above 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%

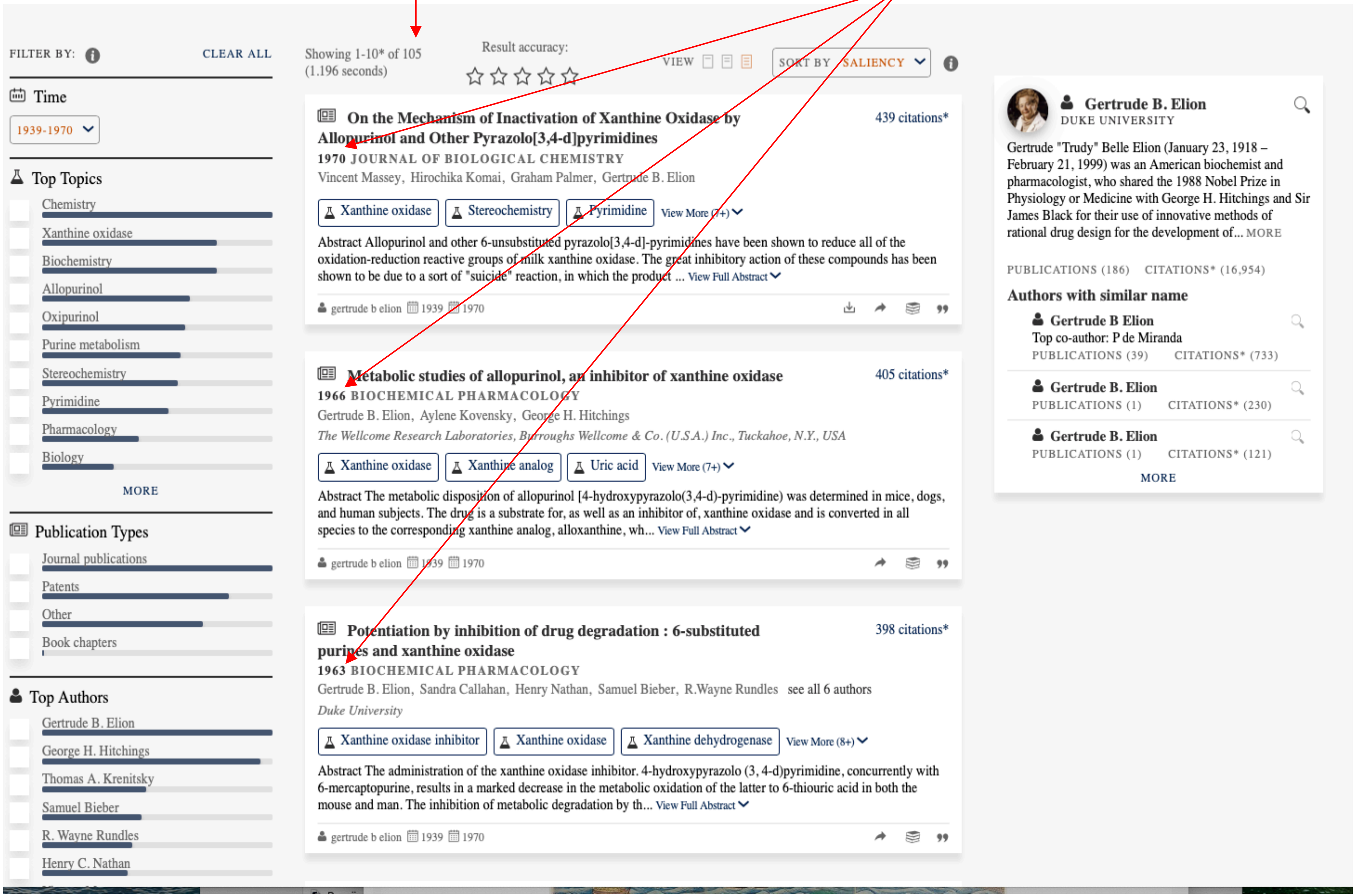
From Moser and San (2020)

Publications

- Microsoft Academic Graph (MAG)
  - Moser and Parsa (2020) ”Reducators: How Joseph McCarthy Changed the Course of American Science.”
  - Updated weekly. Our data from August 20, 2020
  - English-language publications and authors with 1+, 1900-60
- Match scientists in MoS (1956) with MAG authorid
  - Using first, last name, and middle initial
  - Manually clean duplicates
- Focus on journal publications
  - Excl book chapters and other publications
- All disciplines
  - STEM (physical sciences) + biological and social sciences

Gertrude B. Elion had 105 publications, including 75 journal publications

Years for all publications



754,851 journal publications by 46,102 scientists

- 66% of 70,230 US scientists have at least 1 publication
- 10.8 publications per scientist
  - std 23.7, median 2
- Scientists with most publications
  - Carl Djerassi, 864 publications
  - Jane Marion Oppenheimer, 240 publications

Image: Carl Djerassi with his assistant Arelina Gonzales in Mexico in 1851. Djerassi and Luis E. Miramontes synthesized Norethindron, the key ingredient of the birth-control pill

Citations as a control for differences in the quality of publications

- Measure differences in quality by the number of later publications that *cite* each publication as relevant input to their work.
- Citations data in the MAG include 18,537,851 citations to 790,180 publications. 23.5 per publication.
- Most highly cited paper:
  - Oliver Howe Lowery on “Protein measurement with the folin phenol reagent” (1951, 250,657 citations).
  - Marilyn Gist Farquhar on “Junctional complexes in various epithelia” (1962, 5,156 citations) joint work with George Palade (Nobel 1974)

Women in Science

- Historical background
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  - Matched with patents and publications
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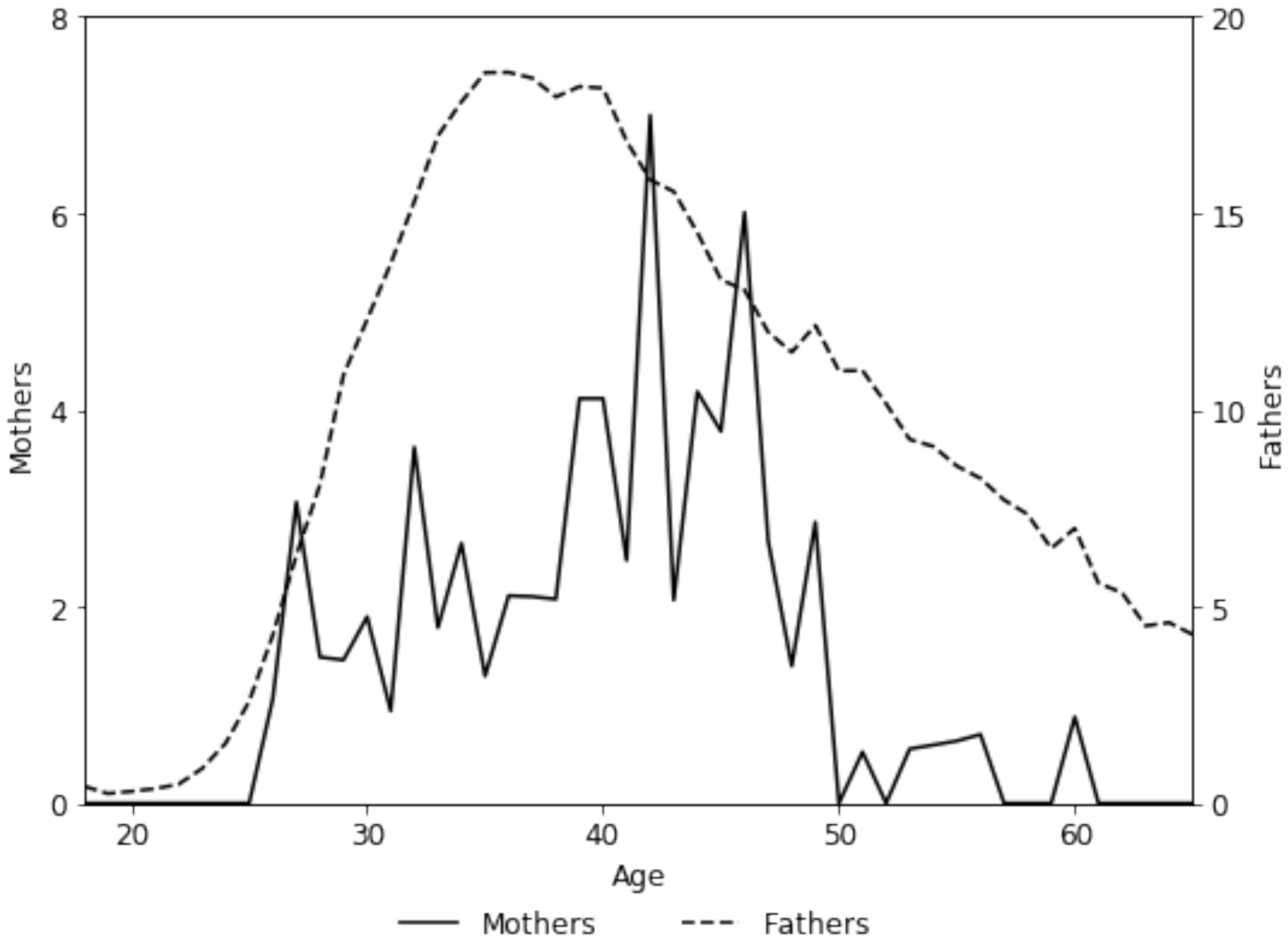
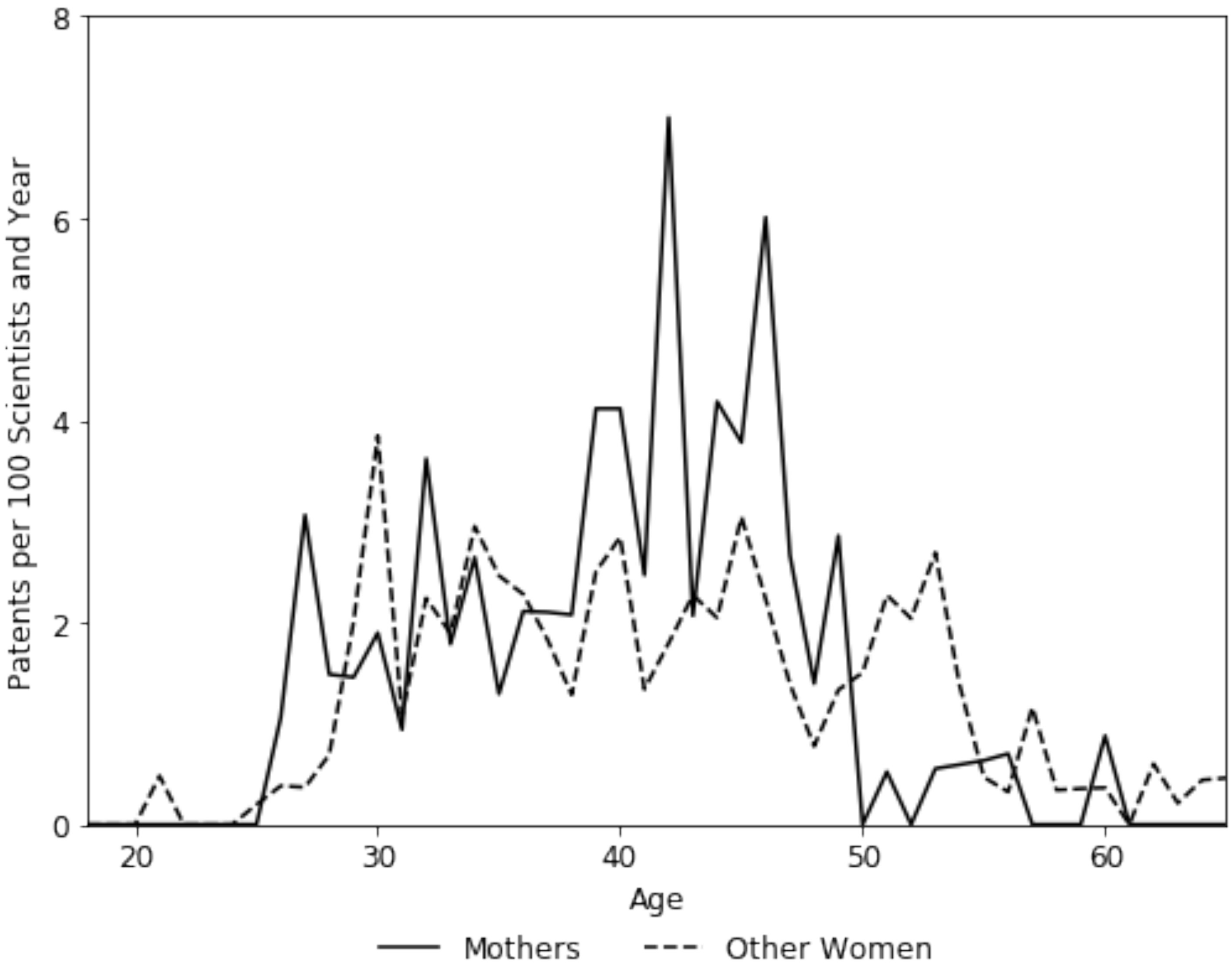
Mothers reach peak productivity at 42, 5 years later than fathers

Figure A2, Panel A: Mothers vs Fathers



Mothers became more productive than other women after age 38

Figure A2, Panel C: Mothers vs Other Women



No significant differences for women and men w/o kids

Figure A2, Panel B: Male vs. Female Scientists w/o Children

Differential changes in productivity across the life cycle

Estimate OLS separately for demographic groups *d:* mothers, fathers, women w/o kids, men w/o kids

$$y_{ia}^{d} = \beta_a^d Age_i + \delta_t + \pi_b + \mu_f + \epsilon_{it}$$

y_{ia}^{d}	patents by scientists i of demographic *d* at age *a*
δ_t	year fixed effects
π_b	birth year fixed effects
μ_f	field fixed effects
	20 is excluded age group

Mothers patent more after age 35

Figure 2: Age-Varying Estimates of Productivity Measured by Patents

Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
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- Conclusions

Mothers produce more patents than other women

but many less than fathers

TABLE 1 – SUMMARY STATISTICS ON MARRIAGE, PARENTING, AND INVENTION

	All women	All men	Women		Men	
			with children	w/o children	with children	w/o children
Demographics:						
N	4,032	66,198	892	3,140	48,987	17,211
Share married (in %)	38.8	84.2	93.3	23.4	95.6	51.9
Age at marriage	28.8	27.6	27.1	30.8	27.2	29.8
	(6.55)	(5.21)	(5.01)	(7.48)	(4.78)	(6.60)
Share parents (in %)	22.1	74.0	100	0	100	0
Children per scientist	0.41	1.69	1.88	0	2.28	0
	(0.88)	(1.35)	(0.89)		(1.05)	
Scientific Productivity:						
Patents per scientist	0.51	3.58	0.65	0.47	3.82	2.83
	(3.58)	(11.74)	(5.80)	(2.67)	(12.43)	(9.30)
Publications per scientist	5.14	7.14	5.39	5.06	7.23	6.89
	(10.38)	(15.96)	(11.67)	(9.98)	(16.36)	(14.75)
Citations per publication	260.94	155.20	709.27	125.35	137.92	206.82
	(3,364.16)	(2,152.10)	(5,650.29)	(2,232.58)	(2,000.40)	(2,568.73)

Mothers are more productive than other women, but much less productive than fathers

TABLE 1 – SUMMARY STATISTICS ON MARRIAGE, PARENTING, AND INVENTION

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Fathers are more productive than other men

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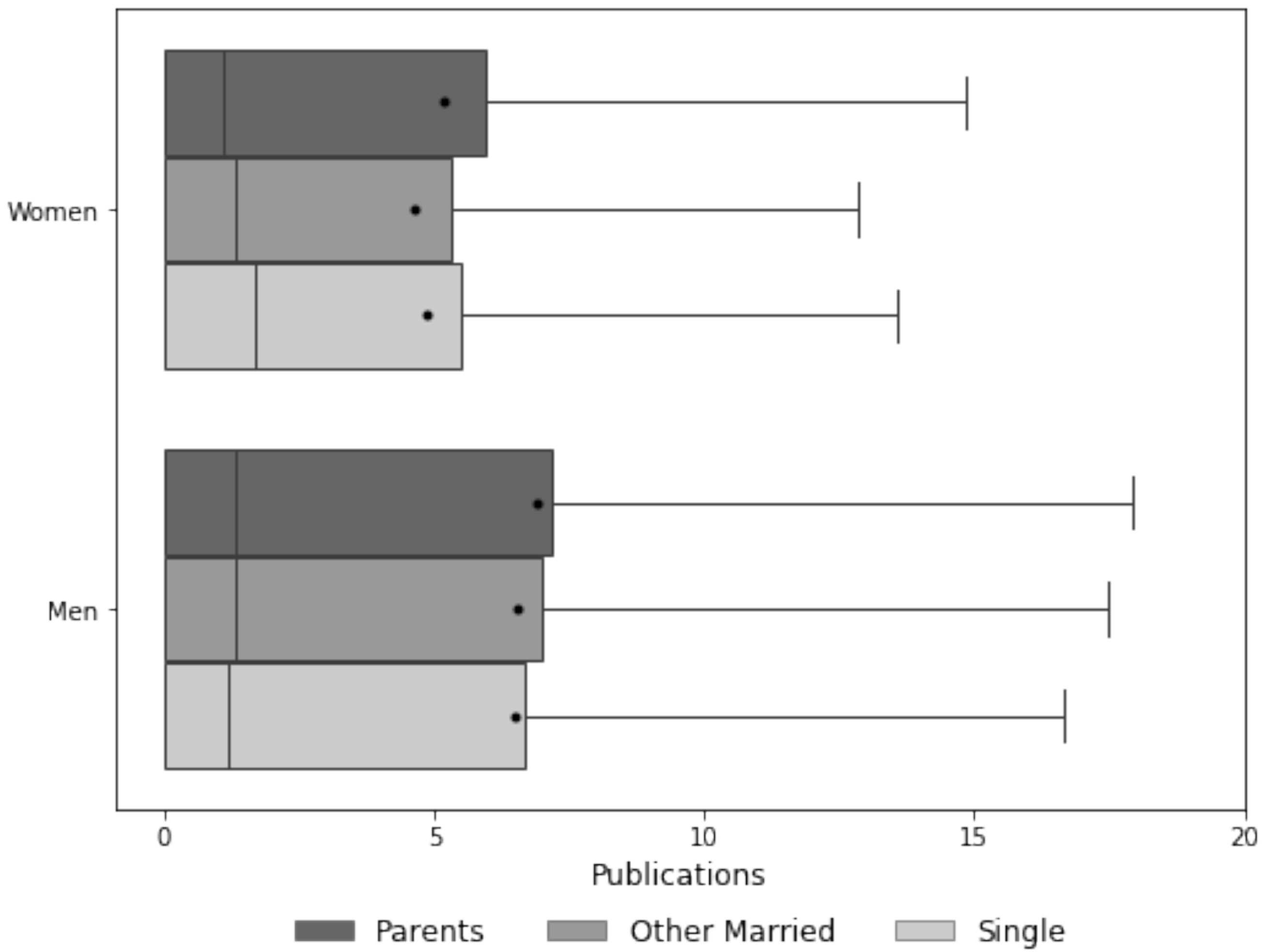
Parents (and especially mothers) publish more than other scientists



Papers by mothers are more highly cited than papers by women without children

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Papers by mothers are as highly cited as papers by fathers and other men

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per scientist	(0.88)	(1.35)	(0.89)		(1.05)	
Patents	0.51	3.58	0.65	0.47	3.82	2.83
per scientist	(3.58)	(11.74)	(5.80)	(2.67)	(12.43)	(9.30)
Publications	8.35	11.65	8.73	8.25	11.91	10.90
per scientist	(15.48)	(25.51)	(17.02)	(15.02)	(26.30)	(23.07)
Citations per publication	18.68	23.86	23.17	17.30	23.84	23.92

Differences in inventive output across demographic groups

Estimate OLS

$$y_{it} = \beta_1 Parent_i + \beta_2 Female_i + \beta_3 Female * Parent_i$$
$$+ \delta_t + \pi_b + \mu_f + \epsilon_{it}$$

y_{ia}^{d} patents per 100 scientists i in year t

δ_t year fixed effects

π_b birth year fixed effects

μ_f field fixed effects

Women patent 67% less compared with men (-5.9/8.8)

Mothers patent 77% less compared with fathers (-5.9-0.9/8.8)

Mothers patent 9% more than other women (1.8-0.9/8.8)

TABLE 2 – PRODUCTIVITY MEASURED BY PATENTS

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Female	-5.870***	-5.627***	-5.245***	-2.432***	-2.503***	-2.189***
	(0.173)	(0.174)	(0.156)	(0.067)	(0.067)	(0.061)
Parent	1.772***	1.898***	1.675***	1.186***	1.098***	1.089***
	(0.135)	(0.138)	(0.125)	(0.068)	(0.068)	(0.063)
Female*Parent	-0.912**	-1.090***	-1.293***	-0.847***	-0.795**	-0.924***
	(0.389)	(0.391)	(0.366)	(0.125)	(0.125)	(0.116)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes
Age FE	No	Yes	No	No	Yes	No
Field FE	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.606	4.579

*** denotes significance at the 1-percent level, ** at the 5-percent level, and * at the 10-percent level

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Age FE	No	Yes	No	No	Yes	No
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This may be due selection, if only exceptionally productive mothers "survive"

Robust to controlling for scientists' age (instead of birth year)

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Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.606	4.579

*** denotes significance at the 1-percent level, ** at the 5-percent level, and * at the 10-percent level

Robust to including older scientists (up to age 80)

TABLE 2 – PRODUCTIVITY MEASURED BY PATENTS

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Female	-5.870***	-5.627***	-5.245***	-2.432***	-2.503***	-2.189***
	(0.173)	(0.174)	(0.156)	(0.067)	(0.067)	(0.061)
Parent	1.772***	1.898***	1.675***	1.186***	1.098***	1.089***
	(0.135)	(0.138)	(0.125)	(0.068)	(0.068)	(0.063)
Female*Parent	-0.912**	-1.090***	-1.293***	-0.847***	-0.795**	-0.924***
	(0.389)	(0.391)	(0.366)	(0.125)	(0.125)	(0.116)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes
Age FE	No	Yes	No	No	Yes	No
Field FE	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.606	4.579

*** denotes significance at the 1-percent level, ** at the 5-percent level, and * at the 10-percent level

Differences are smaller in other disciplines (biological and social sciences)
Women patent 52% less (-2.4/4.6), compared with 67% less in physical sciences

TABLE 2 – PRODUCTIVITY MEASURED BY PATENTS

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
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Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes
Age FE	No	Yes	No	No	Yes	No
Field FE	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80
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Pre-baby boom mean	8.811	8.811	8.752	4.606	4.606	4.579

*** denotes significance at the 1-percent level, ** at the 5-percent level, and * at the 10-percent level

Estimates for parenting are nearly identical:
Mothers patent 71% less compared with fathers (77% for STEM)
Mothers patent 7% more than women without children (9% for STEM)

TABLE 2 – PRODUCTIVITY MEASURED BY PATENTS

	Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
Female	-5.870***	-5.627***	-5.245***	-2.432***	-2.503***	-2.189***
	(0.173)	(0.174)	(0.156)	(0.067)	(0.067)	(0.061)
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	(0.389)	(0.391)	(0.366)	(0.125)	(0.125)	(0.116)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes
Age FE	No	Yes	No	No	Yes	No
Field FE	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.606	4.579

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The first child carries the largest productivity penalty for mothers

(consistent with Danish registry data on earnings today, Klevens, Landais, Soogard 2019)

TABLE A2 – EFFECTS OF HAVING MORE CHILDREN ON THE PRODUCTIVITY OF MALE AND FEMALE SCIENTISTS

	Patents per 100 scientists per year				
	(1)	(2)	(3)	(4)	(5)
Female	-5.870***	-5.628***	-5.245***	-4.108***	-3.730***
	(0.173)	(0.174)	(0.156)	(0.068)	(0.061)
1 Child	1.669***	1.822***	1.558***	1.624***	1.494***
	(0.185)	(0.186)	(0.171)	(0.098)	(0.090)
2 Children	1.838***	1.950***	1.717***	1.687***	1.565***
	(0.160)	(0.165)	(0.149)	(0.082)	(0.076)
3+ Children	1.781***	1.886***	1.712***	1.496***	1.410***
	(0.168)	(0.166)	(0.157)	(0.085)	(0.079)
Female*1 Child	-2.284***	-2.589***	-2.664***	-1.724***	-1.758***
	(0.374)	(0.386)	(0.347)	(0.132)	(0.122)
Female*2 Children	0.535	0.490	0.127	-1.267***	-1.319***
	(0.763)	(0.761)	(0.730)	(0.232)	(0.218)
Female*3+ Children	-1.316***	-1.582***	-1.539***	-1.902***	-2.027***
	(0.331)	(0.349)	(0.306)	(0.107)	(0.010)
Year FE	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	No	Yes	Yes	Yes
Age FE	No	Yes	No	No	No
Field FE	Yes	Yes	Yes	No	No
Disciplines	Physical sciences	Physical sciences	Physical sciences	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.579

For men, productivity increases with each child

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	(0.160)	(0.165)	(0.149)	(0.082)	(0.076)
3+ Children	1.781***	1.886***	1.712***	1.496***	1.410***
	(0.168)	(0.166)	(0.157)	(0.085)	(0.079)
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	(0.331)	(0.349)	(0.306)	(0.107)	(0.010)
Year FE	Yes	Yes	Yes	Yes	Yes
Birth Year FE	Yes	No	Yes	Yes	Yes
Age FE	No	Yes	No	No	No
Field FE	Yes	Yes	Yes	No	No
Disciplines	Physical sciences	Physical sciences	Physical sciences	All	All
Scientists' age	18-65	18-65	18-80	18-65	18-80
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,591,524
Pre-baby boom mean	8.811	8.811	8.752	4.606	4.579

Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
- Effects on publications and tenure
  - Differences in publishing across the life cycle and across demographic groups
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- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

Event study to investigate impact of marriage (first child)

- Goal: Understand impact of children on scientific output
  - Ideal experiment would randomize fertility
- Event study of marriage (first child)
  - Parents typically had first child quickly after marriage (Weiss 2020)
  - While choice to have children is not exogenous, event of marriage (first child) generates sharp change in productivity
  - Arguably orthogonal to unobserved determinants of productivity that evolve more smoothly over time
  - Trace out long-run trajectory of productivity after marriage

Differential changes in productivity after marriage

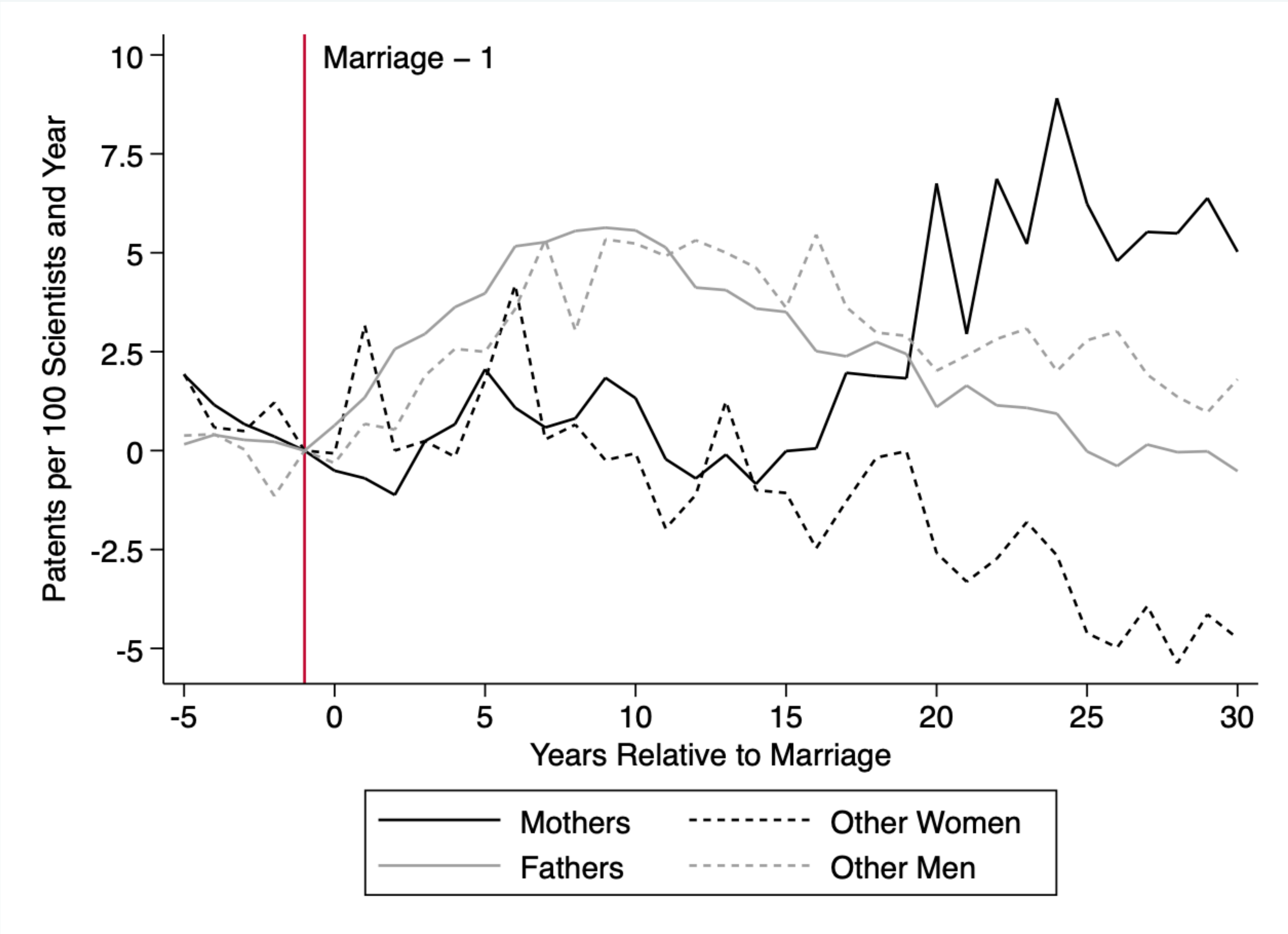
Estimate differential changes in productivity after marriage for mothers, fathers, women without kids, and men without kids

$$y_{is}^{d} = \beta_{s}^{d} EventTime_{i} + \delta_{t} + \alpha_{a} + \mu_{f} + \epsilon_{it}$$

y_{is}^{d}	patents by scientists i in demographic d and year s after marriage
δ_t	year fixed effects
α_a	age fixed effects
μ_f	field fixed effects
	Marriage -1 is excluded period

Mothers' productivity increases dramatically 15 years after year of marriage

Figure 3: Event Study Estimates of Changes in Patenting After Marriage



Why are mothers more productive late in life and marriage?

- 15 years into the marriage, even the younger kids require less work
- In 2019 mothers spent
  - 2.75 h/day caring for children under age 6
  - 1.17 h/day when youngest child 6-12 (BLS 2020)

Average hours per day spent caring for and helping household children as their main activity, 2019 annual averages (from BLS 2020)

Activity	Parents, youngest child 6-12 years	Fathers, youngest child 6-12 years	Mothers, youngest child 6-12 years	Parents, child under age 6	Fathers, child under age 6	Mothers, child under age 6
Total, caring for and helping household children	0.93	0.65	1.17	2.14	1.42	2.75
Physical care for household children	0.24	0.12	0.33	0.91	0.51	1.25
Reading to and with household children	0.03	0.02	0.04	0.08	0.06	0.10
Playing with household children, not sports	0.11	0.12	0.11	0.64	0.56	0.71
Activities related to household children's education	0.11	0.09	0.14	0.12	0.05	0.17

Or pent-up research potential?

- Are mothers more productive because they have “time” to think about research while they work?
- Not as likely
- Labor markets penalize interruptions in employment, esp. at the beginning of a person’s career
  - E.g., large and persistent effects on employment and wages when workers suffer unemployment early stages in their careers (Oreoupoulous, von Wachter, Heicz 2012, Jarosch 2015)
- Skills atrophy
  - McDowell (1982) documents differences among fields in costs of interrupted careers and finds higher decay rates for physics and chemistry than in other fields (like History and English)
  - Skill obsolescence among older workers increases with the pace of technological change (MacDonald and Weisbach 2004, “has-been” model)

Women in Science

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  - Matched with patents and publications
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  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
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  - Differences in publishing across the life cycle and across demographic groups
  - Event study estimates of the effects of children on tenure
  - Changes in publications before and after tenure
- Selection
- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

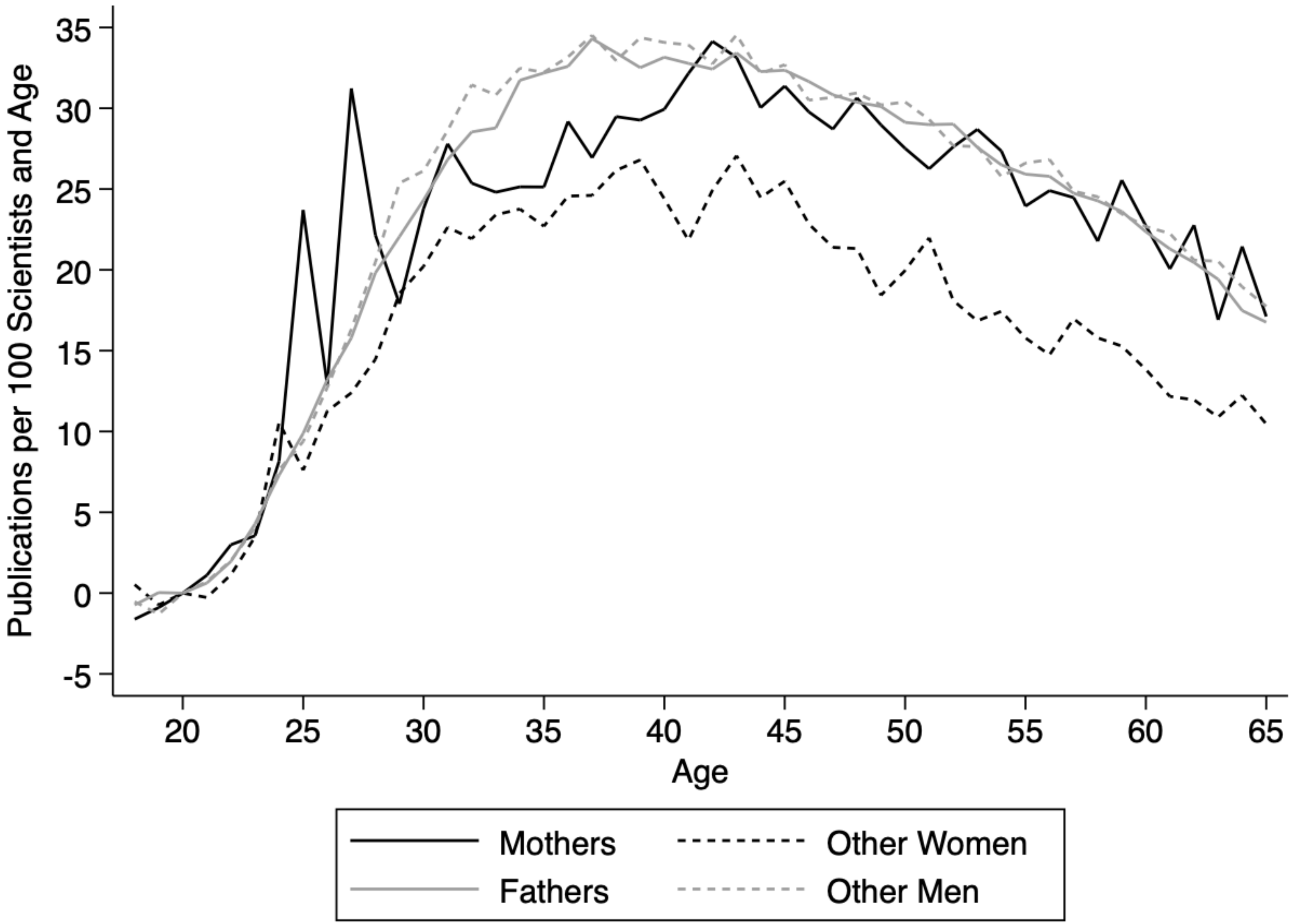
Differential changes in productivity across the life cycle

Estimate OLS separately for demographic groups *d:* mothers, fathers, women w/o kids, men w/o kids

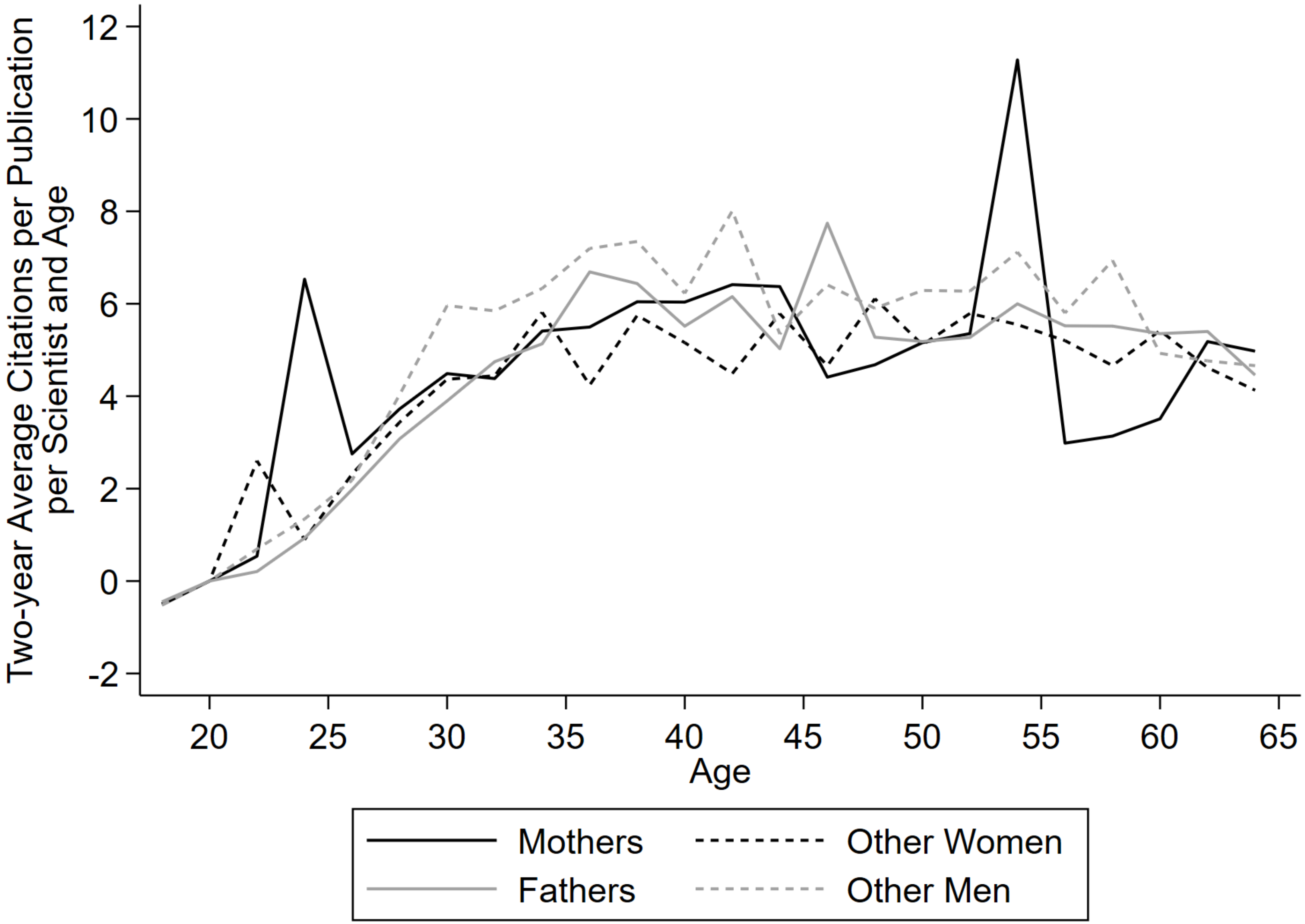
$$y_{ia}^{d} = \beta_a^d Age_i + \delta_t + \pi_b + \mu_f + \epsilon_{it}$$

y_{ia}^{d}	publications by scientists i of demographic *d* at age *a*
δ_t	year fixed effects
π_b	birth year fixed effects
μ_f	field fixed effects
	20 is excluded age group

Mothers' publications decline after median age of marriage and recover after age 35



Publications by mothers are of similar quality (measured by citations) to those of other scientists



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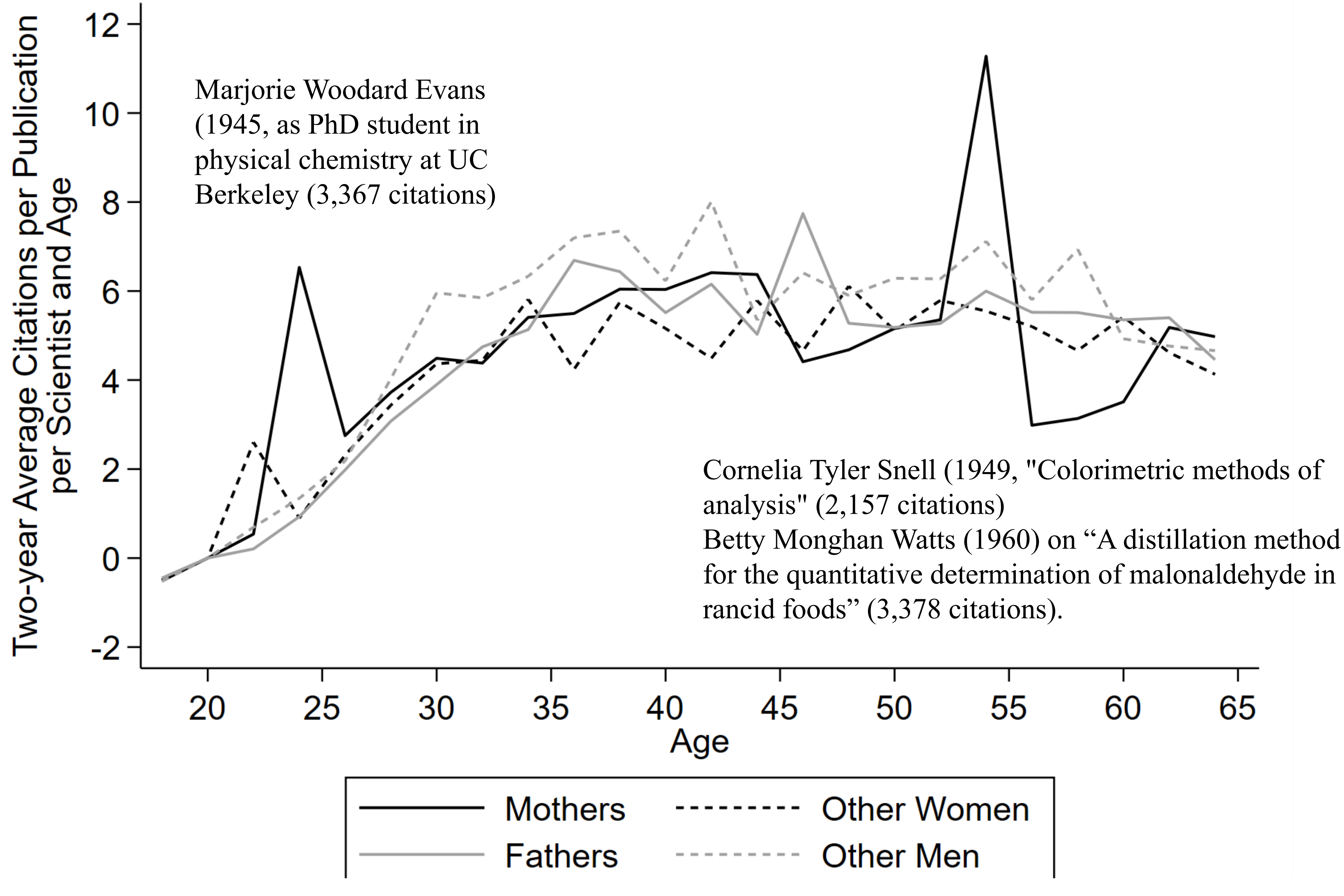

Differences in publishing productivity across demographic groups

Estimate OLS

$$y_{it} = \beta_1 Parent_i + \beta_2 Female_i + \beta_3 Female * Parent_i$$
$$+\delta_t + \pi_b + \mu_f + \epsilon_{it}$$

y_{ia}^{d} publications per 100 scientists i in year t

δ_t year fixed effects

π_b birth year fixed effects

μ_f field fixed effects

Women publish 75% less compared with men (-8.4/11.2)
Mothers publish 85% less compared with fathers (-8.4-1.1/11.2)
Mothers publish roughly the same as other women (1.0-1.1/11.2)

TABLE 3 – PRODUCTIVITY MEASURED BY PUBLICATIONS AND CITATIONS

	Publications (1-6)						Citations (7-8)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	-8.355***	-8.646***	-8.176***	-9.959***	-9.945***	-9.613***	-9.077***	-9.072***
	(0.258)	(0.256)	(0.235)	(0.197)	(0.196)	(0.181)	(2.215)	(2.318)
Parent	1.028***	0.491***	1.160***	0.829***	-0.609***	0.977***	14.091***	14.411***
	(0.138)	(0.133)	(0.131)	(0.114)	(0.111)	(0.107)	(4.234)	(4.196)
Female*Parent	-1.108**	-0.811*	-0.982**	-0.353	-0.321	-0.442	-9.248***	-10.742***
	(0.474)	(0.470)	(0.454)	(0.411)	(0.410)	(0.387)	(3.354)	(3.879)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes	Yes	No
Age FE	No	Yes	No	No	Yes	No	No	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All	STEM	STEM
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80	18-65	18-65
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524	1,204,592	1,204,592
Pre-baby boom mean	11.189	11.189	11.208	15.832	15.832	15.862	21.275	21.275

*** denotes significance at the 1-percent level, ** at the 5-percent level, and * at the 10-percent level

Women receive 43% fewer citations than men (-9.1/21.3)
Mothers receive 86% fever citations than fathers (-9.1-9.2/21.3)
Mothers receive 23% more citations than other women (14.1-9.2/21.3)

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Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes	Yes	No
Age FE	No	Yes	No	No	Yes	No	No	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All	STEM	STEM
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80	18-65	18-65
N (scientists x years)	1,204,592	1,204,592	1,298,053	2,391,179	2,391,179	2,591,524	1,204,592	1,204,592
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Mothers in STEM publish roughly same as other women, but patent slightly (8%) more than other women

- Patents more likely in industry, publications in academia
- Selection
  - Mothers may be less able to accommodate long hours of laboratory work required in industry
  - Only the most productive mothers survive and patent in STEM
- Productivity
  - Motherhood may reduce publishing productivity of mothers in academia more than in science, if mothers are less likely to get tenure
- We examine both channels below

Gender differences in other disciplines are smaller than in STEM

Women publish 63% less (-10.0/15.8), compared with 75% less in STEM

Mothers publish 66% less compared with fathers (-10.0-0.4/15.8), 85% less in STEM

Mothers patent 3% more than other women (0.8-0.4/15.8), 1% in STEM

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Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year FE	Yes	No	Yes	Yes	No	Yes	Yes	No
Age FE	No	Yes	No	No	Yes	No	No	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Disciplines	STEM	STEM	STEM	All	All	All	STEM	STEM
Scientists' age	18-65	18-65	18-80	18-65	18-65	18-80	18-65	18-65
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Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
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- Selection
- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

Mothers who were academic scientists were 21% less likely to achieve tenure than fathers, 19% less likely than other women

TABLE 4 – SUMMARY STATISTICS ON PARTICIPATION AND CAREER PROGRESSIONS FOR ACADEMIC SCIENTISTS

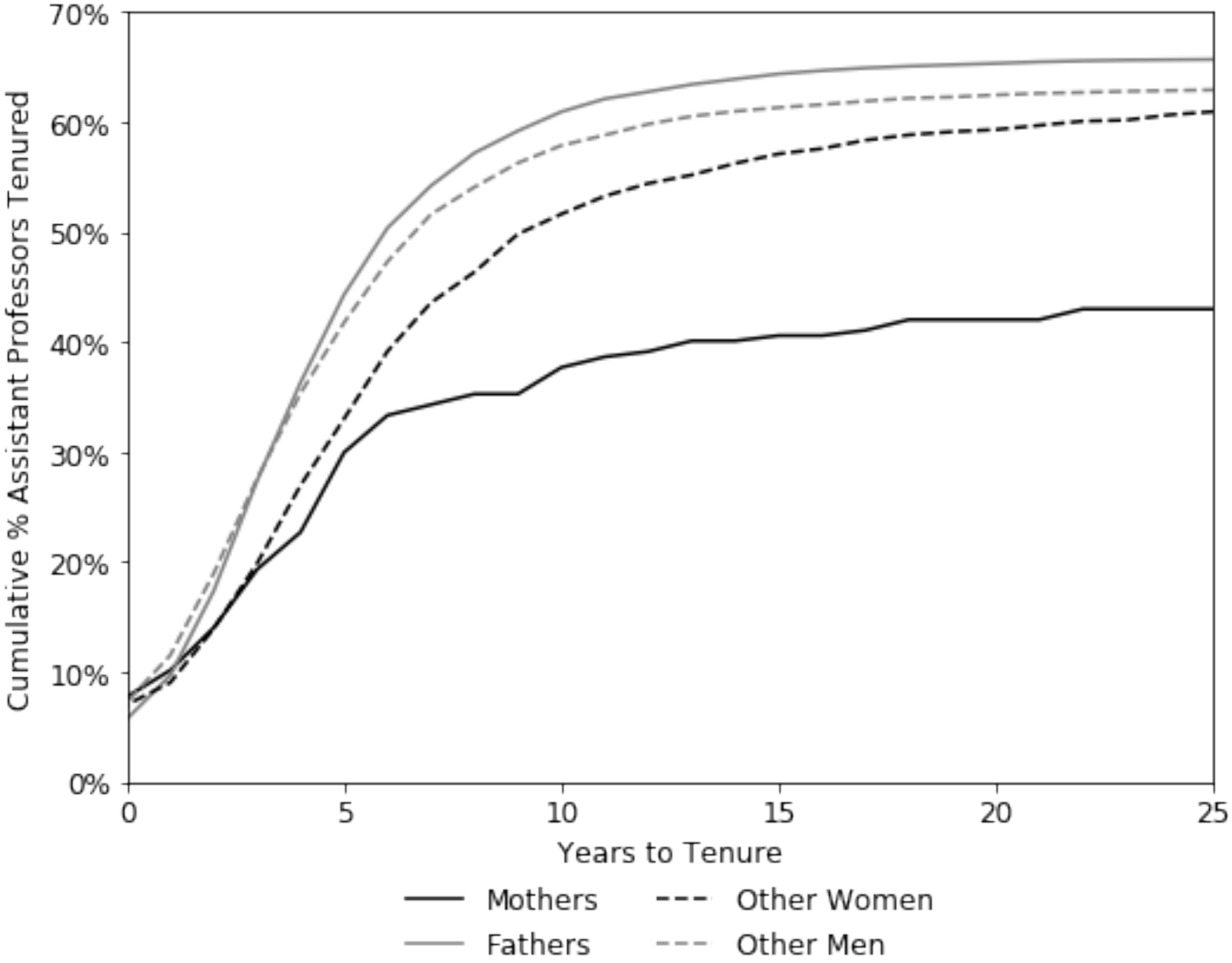
	All women	All men	Women		Men	
			with children	w/o children	with children	w/o children
N	4,032	66,198	892	3,140	48,987	17,211
Academic / all scientists	87.7%	74.6%	84.5%	88.6%	73.8%	77.1%
PhD / academic scientists	84.1%	77.5%	83.2%	84.4%	76.6%	79.8%
Tenure track / academic scientists	42.7%	45.5%	35.9%	44.6%	45.4%	45.9%
Tenured / academic scientists	41.7%	47.7%	26.8%	45.7%	47.8%	47.2%

27% of mothers promoted to tenure

- 19% less than 46% of women w/o kids
- 21% less than 48% of fathers

Differences in timing of productivity had important implications for promotions

Figure 5: Speed of Promotion to Tenure



Event study estimates for tenure after marriage

Estimate differential changes in probability of tenure after marriage for mothers, fathers, women without kids, and men without kids

$$y_{is}^{d} = \beta_{y}^{d} EventTime_{i} + \delta_{t} + \alpha_{a} + \epsilon_{it}$$

y_{is}^{d} indicator for tenured job held by scientist *i* in demographic *d* and year *s* after marriage

δ_t year fixed effects

α_a age fixed effects

marriage -1 is excluded period

For mothers, the probability of getting tenure declines with each year of marriage

Event Study Estimates of Tenure After Marriage

Event Study Estimates of Holding a Tenured Job After Marriage

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  - A lost generation of baby boom mothers
- Conclusions

Mothers who do not get tenure sustain high productivity into mid 50s

Figure A2, Panel A: Age-Varying Estimates of Productivity Measured by Publications

Mothers who achieve tenure experience a large boost in productivity after 40

Figure A2, Panel B: Age-Varying Estimates of Productivity Measured by Publications. Scientists who achieve tenure

Differential changes in productivity after tenure

Estimate differential changes in productivity after tenure for mothers, fathers, women without kids, and men without kids

$$y_{is}^{d} = \beta_{s}^{d} EventTime_{i} + \delta_{t} + \alpha_{a} + \mu_{f} + \epsilon_{it}$$

y_{is}^{d}	publications by scientists i in demographic d and year y after tenure
δ_t	year fixed effects
α_a	age fixed effects
μ_f	field fixed effects
	tenure -1 is excluded period

Figure 7: Event Study Estimates
of Changes in Publishing Productivity Relative to the Year of Tenure

Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
- Effects on publications and tenure
  - Differences in publishing across the life cycle and across demographic groups
  - Event study estimates of the effects of children on tenure
  - Changes in publications before and after tenure
- Selection
- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

Selection

- Examine selection into:
  - getting a PhD
  - becoming an assistant professor
  - marriage
  - parenting
  - fields
  - survival in science

Female scientists may be more or less likely to have PhDs

- Women who expect to spend less time in labor market, have weak incentive to invest in education valued by labor market
  - Women may be less likely to get PhD
- But, the presence of labor-market discrimination, women may have to be more qualified to get the same jobs
  - Women may be more likely to get PhD
  - Women who have PhDs may be more likely to survive in science

Formal and informal barriers made it difficult for women to earn PhDs

- Example, Joan Steitz, “Queen of RNA”
  - Interaction of the ribosome and messenger RNA, via complementary base pairing
  - Discovery of small nuclear ribonuclearproteins (snRNPs) whose function is essential to RNA transcription
  - Diagnosis and treatment of lupus
- At Harvard in the 1960s turned down by professor she asked to be her advisor: “but you are a woman, and you’ll get married, and you’ll have kids, and what good will a PhD have done?”
- Married classmate Tom Steitz, 1 child
  - 2009 Nobel Prize in Chemistry (w Venkatraman Ramakrishnan and Ada Yonath) "for studies of the structure and function of the ribosome”

Female academic scientists were *more* likely to have PhD

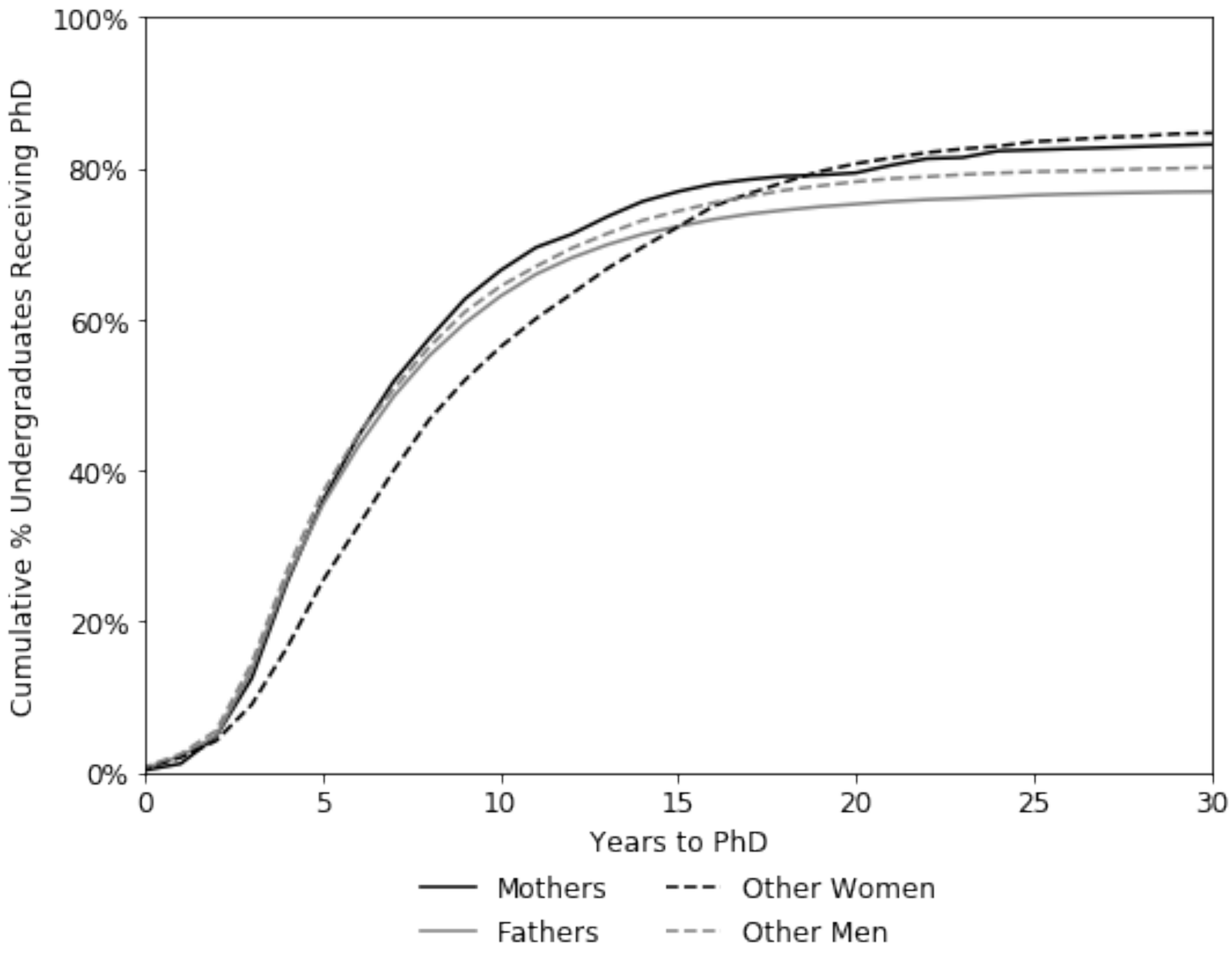
TABLE 4 – SUMMARY STATISTICS ON PARTICIPATION AND CAREER PROGRESSIONS FOR ACADEMIC SCIENTISTS

	All women	All men	Women		Men	
			with children	w/o children	with children	w/o children
N	4,032	66,198	892	3,140	48,987	17,211
Academic / all scientists	87.7%	74.6%	84.5%	88.6%	73.8%	77.1%
PhD / academic scientists	84.1%	77.5%	83.2%	84.4%	76.6%	79.8%
Tenure track / academic scientists	42.7%	45.5%	35.9%	44.6%	45.4%	45.9%
Tenured / academic scientists	41.7%	47.7%	26.8%	45.7%	47.8%	47.2%

84% of female academic scientists had PhD
78% of male academic scientists had PhD

Women in science in 1956 were more likely to have PhD.
85 in 100 female scientists have PhD, 78 male scientists

Years from Undergraduate to PhD



Mothers were less likely to become assistant professors
36% of mothers became assistant professors
compared with 45% of fathers and 45% of women w/o kids

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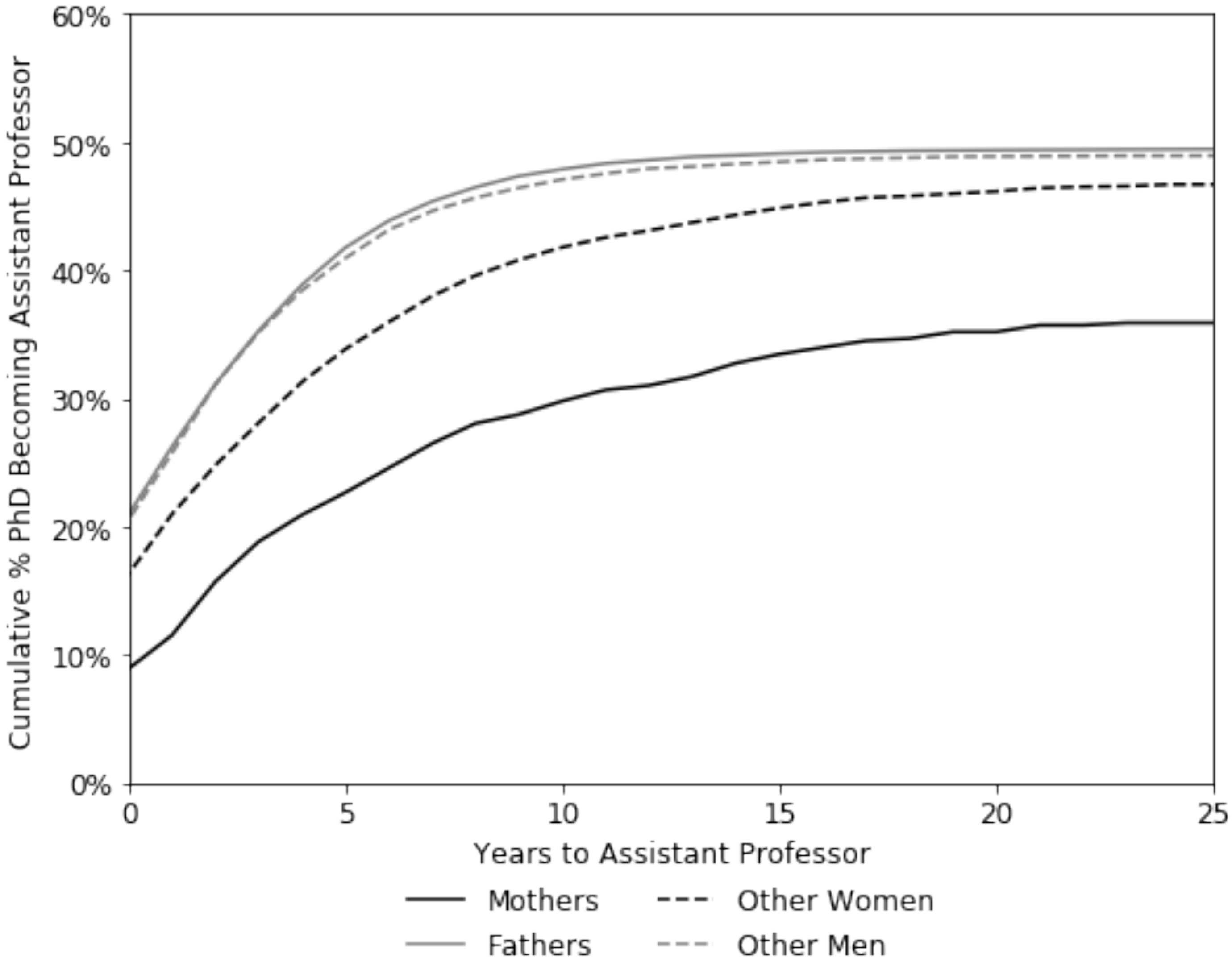
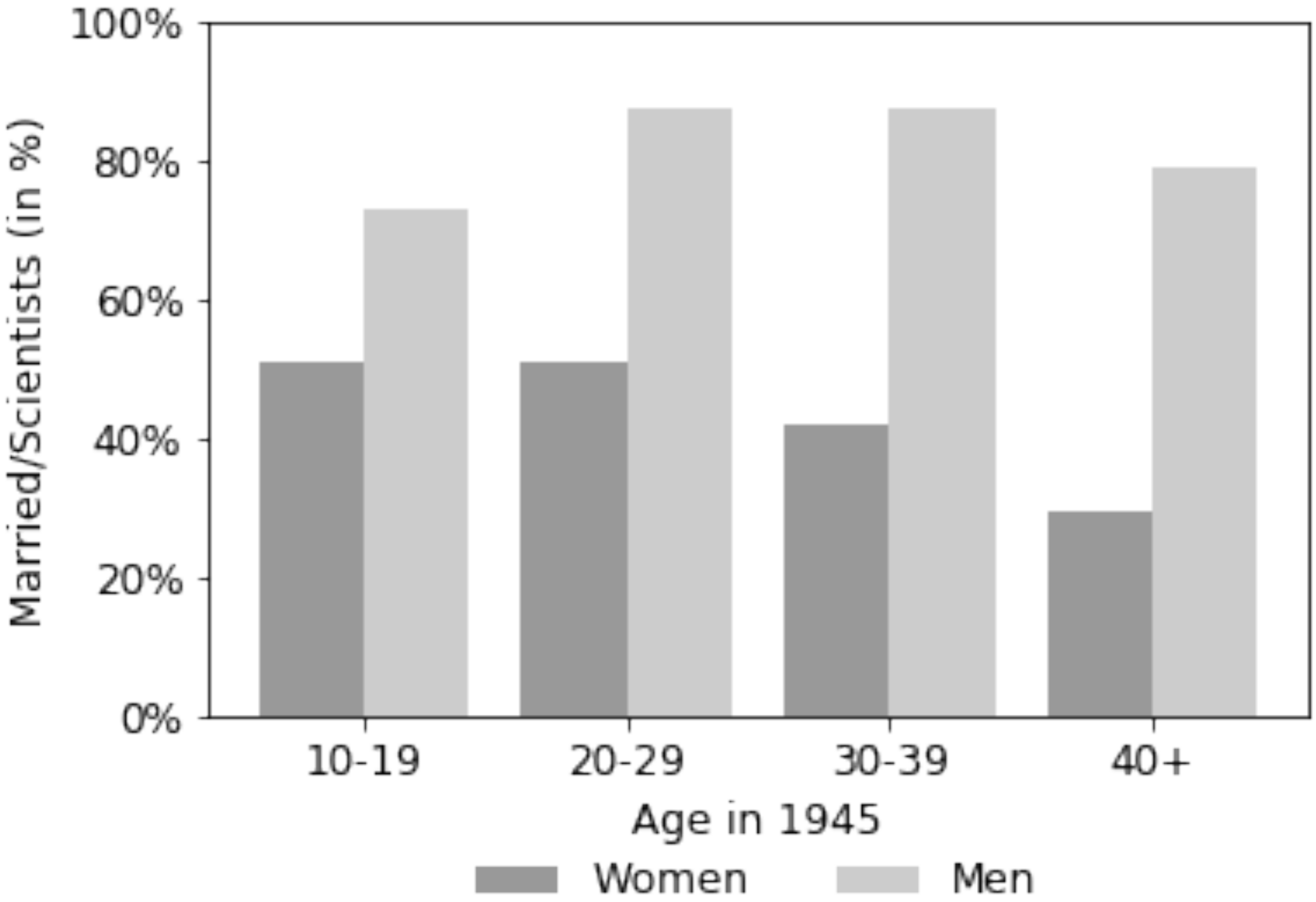
Mothers took 4.4 years to get first tenure track job compared with 1.3 for fathers and 2.8 for other women

Years from PhD to Assistant Professor



Female scientists were less than half as likely to marry
40% of female scientists married, compared with 80% of men

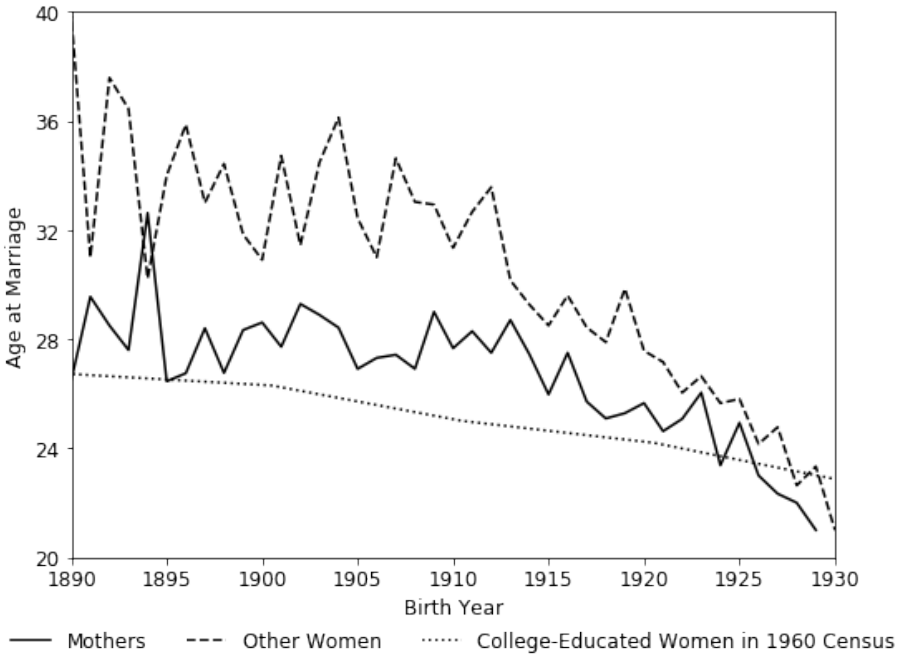
Figure A6, Panel A: Share of Married Scientists



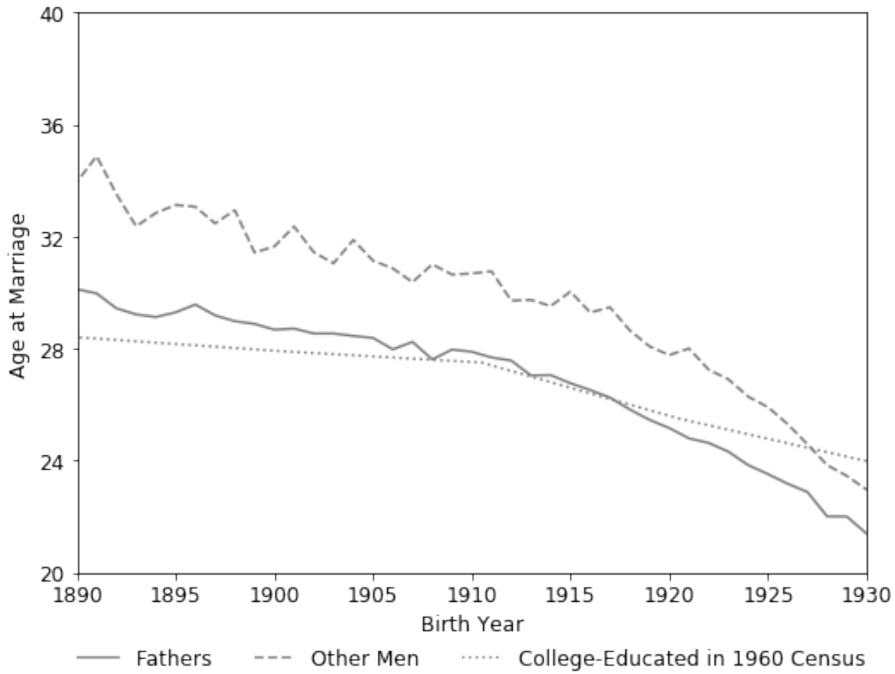
Female scientists married much later than other college-educated women. Male and female scientists married at median age of 27

Mean Age at Marriage by Birth Year

Women

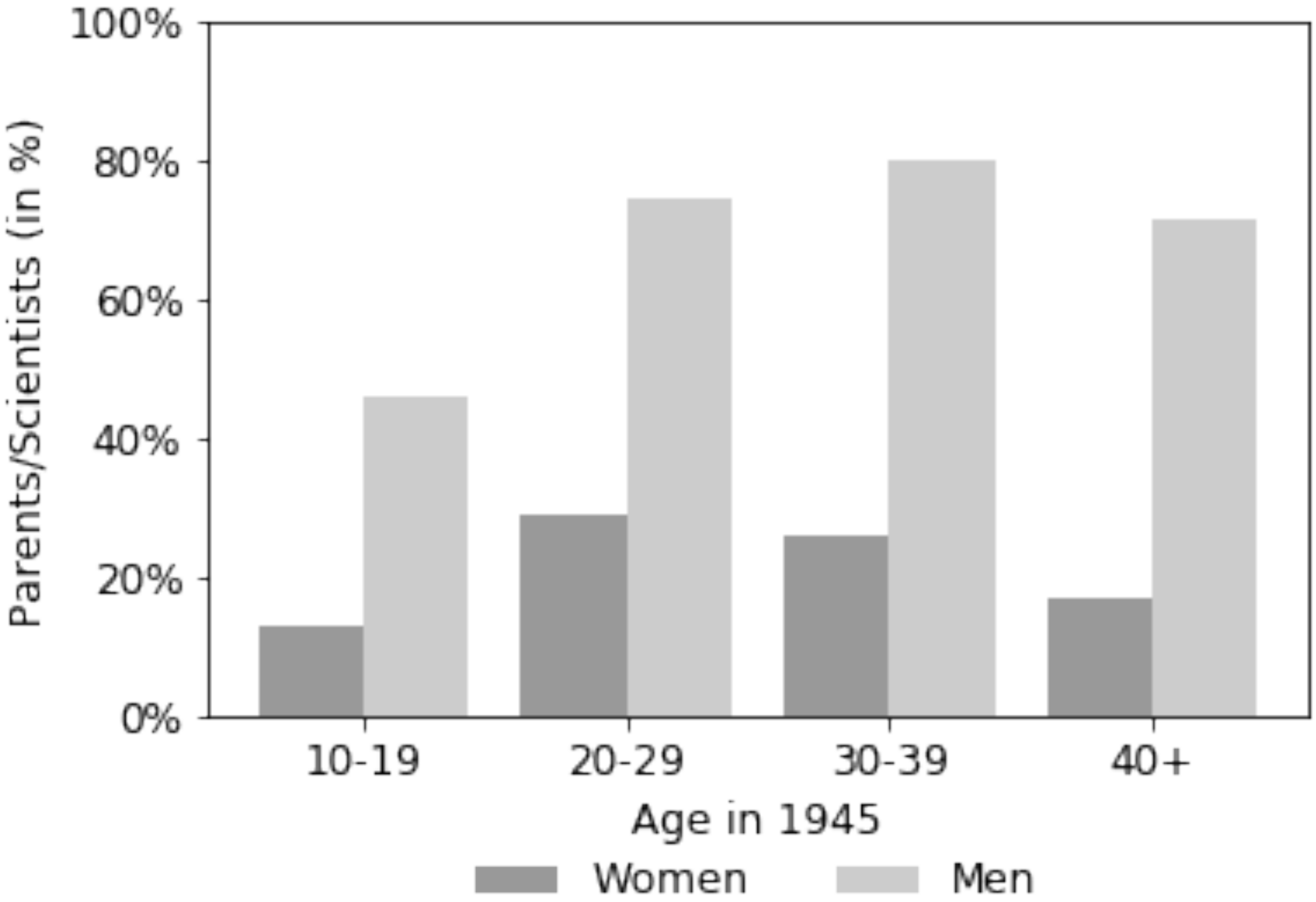


Men



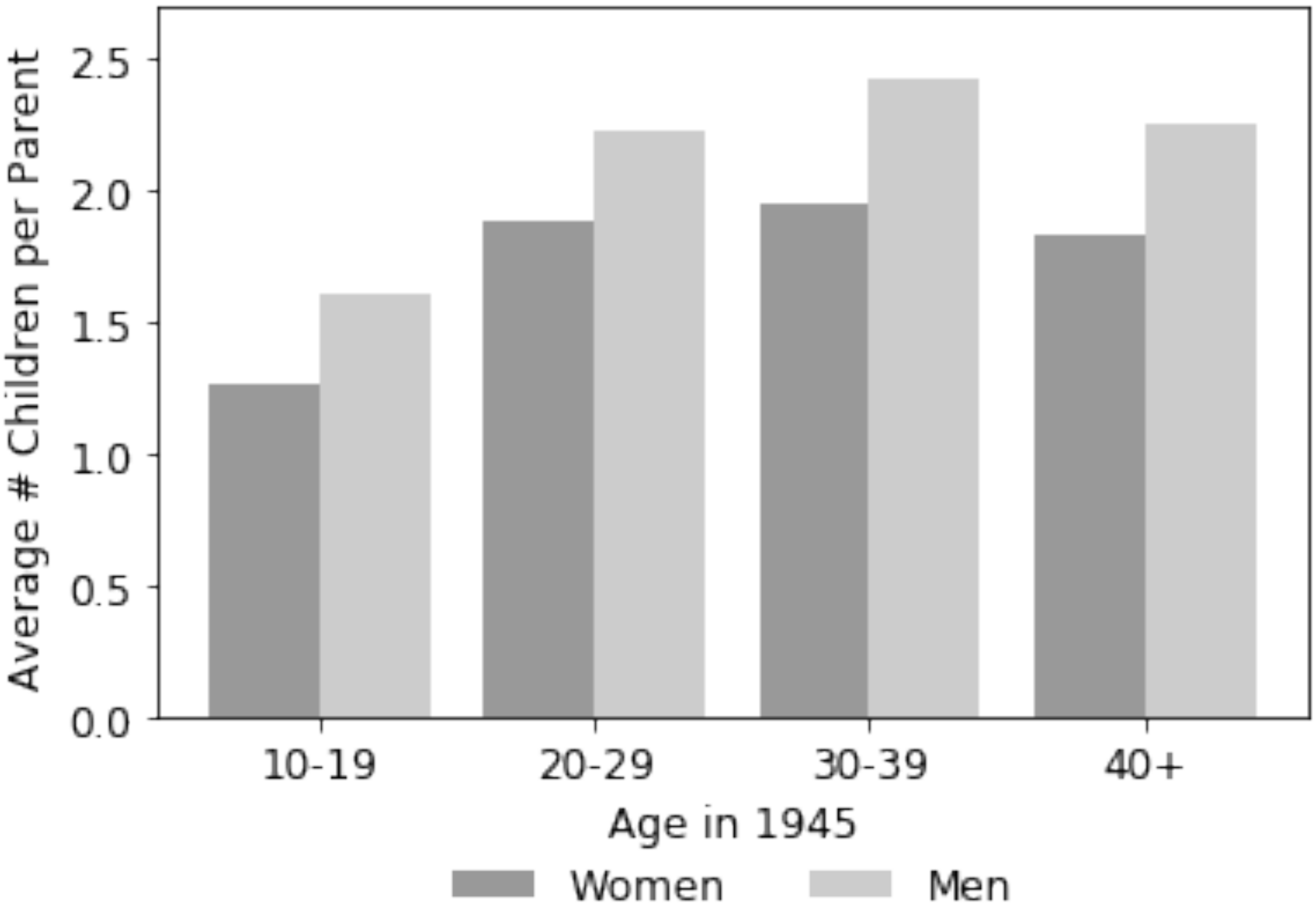
22% of female scientists had children, compared with 74% of men

Figure A6, Panel B: Share of Parents



Mothers had 1.9 children compared with 2.3 for fathers

Figure A6, Panel D: Number of Children per Parent



Mothers were positively selected

Mothers produce 2.5x as many patents compared with other married women by age 27
5.3x more compared with single women

TABLE A4 – INVENTION AND PUBLISHING BY PARENTS, AND OTHER MARRIED AND SINGLE SCIENTISTS

	All women	All men	Women			Men		
			Parents	Other married	Single	Parents	Other married	Single
Patents:								
By age 27	0.013	0.119	0.032	0.013	0.006	0.125	0.093	0.106
	(0.249)	(0.944)	(0.504)	(0.148)	(0.076)	(0.985)	(0.738)	(0.884)
Lifetime	0.51	3.58	0.65	0.52	0.45	3.82	3.23	2.32
	(3.58)	(11.74)	(5.80)	(2.81)	(2.62)	(12.43)	(10.55)	(7.35)
Publications:								
By age 27	0.24	0.45	0.31	0.22	0.22	0.44	0.47	0.43
	(1.41)	(2.06)	(2.12)	(0.81)	(1.21)	(2.11)	(1.92)	(1.90)
Lifetime	5.14	7.14	5.39	4.82	5.14	7.23	6.84	6.94
	(10.38)	(15.96)	(11.67)	(8.48)	(10.40)	(16.36)	(14.38)	(15.14)

Mothers were positively selected

Mothers publish 1.4x as much by age 27 compared with other women

TABLE A4 – INVENTION AND PUBLISHING BY PARENTS, AND OTHER MARRIED AND SINGLE SCIENTISTS

	All women	All men	Women			Men		
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Fathers are less positively selected than mothers

TABLE A4 – INVENTION AND PUBLISHING BY PARENTS, AND OTHER MARRIED AND SINGLE SCIENTISTS

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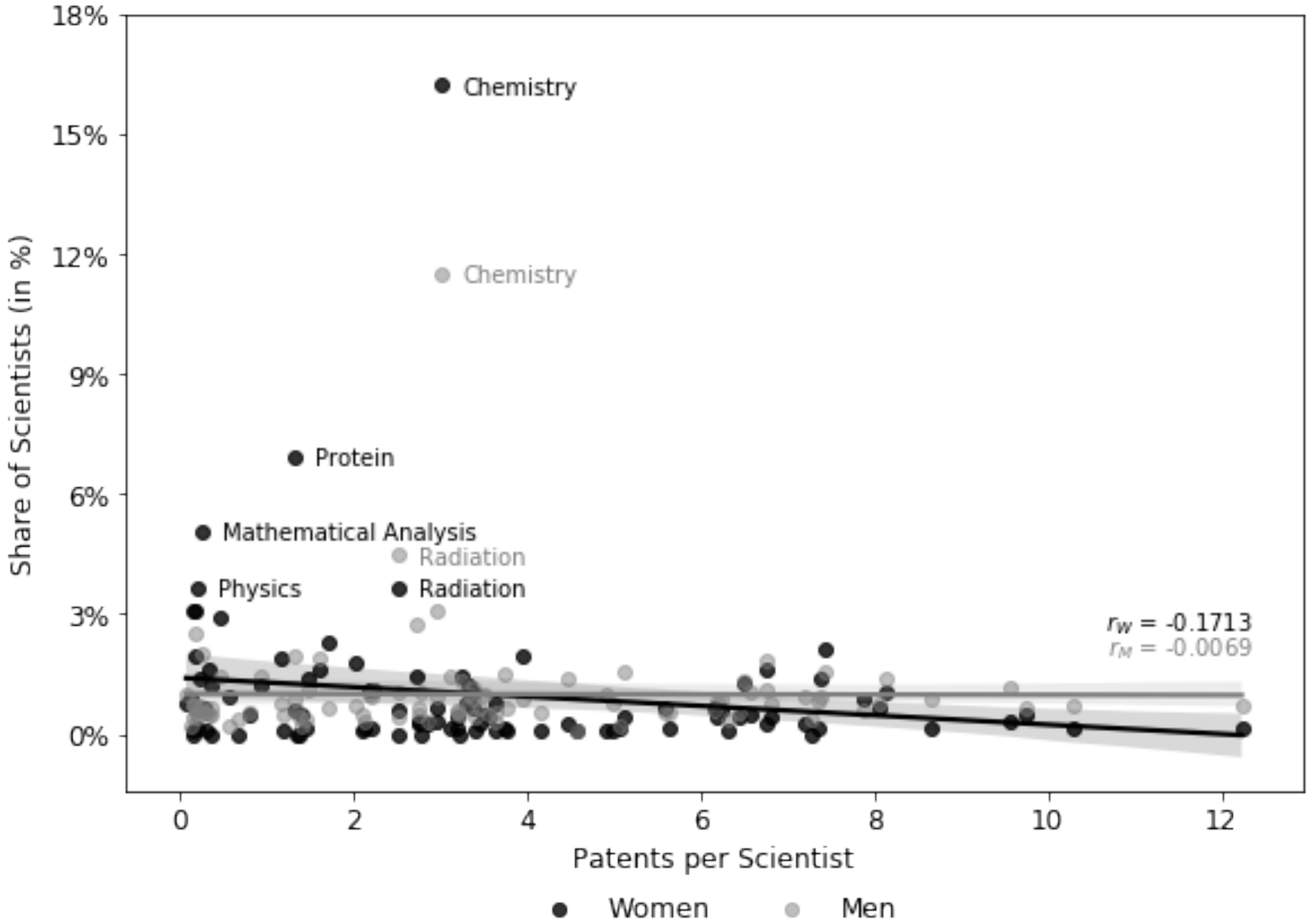
	(10.38)	(15.96)	(11.67)	(8.48)	(10.40)	(16.36)	(14.38)	(15.14)

Do women select into fields that are less patent-intensive?

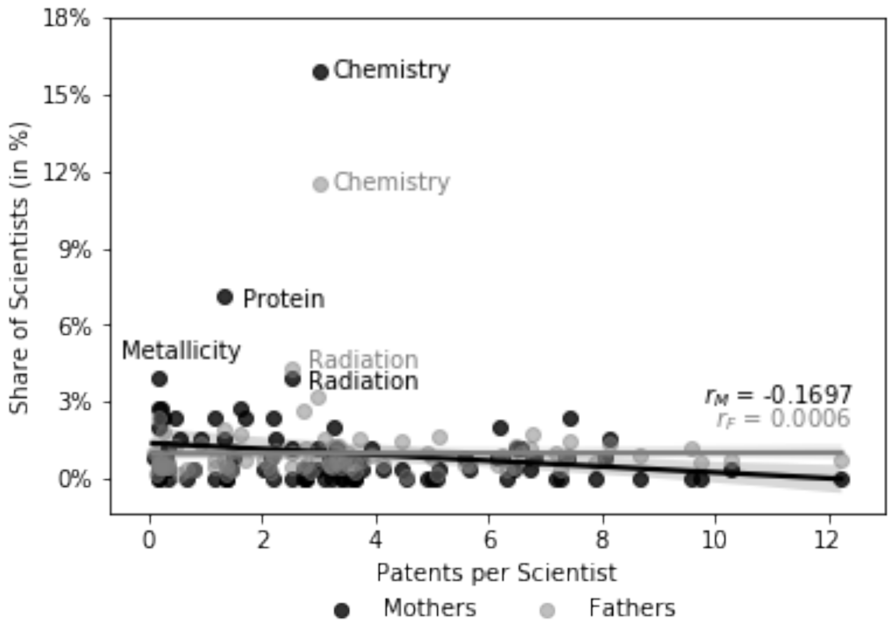
Female scientists are just slightly less likely to work in patent-intensive fields
Selection into fields cannot explain low patenting rates for female scientists.



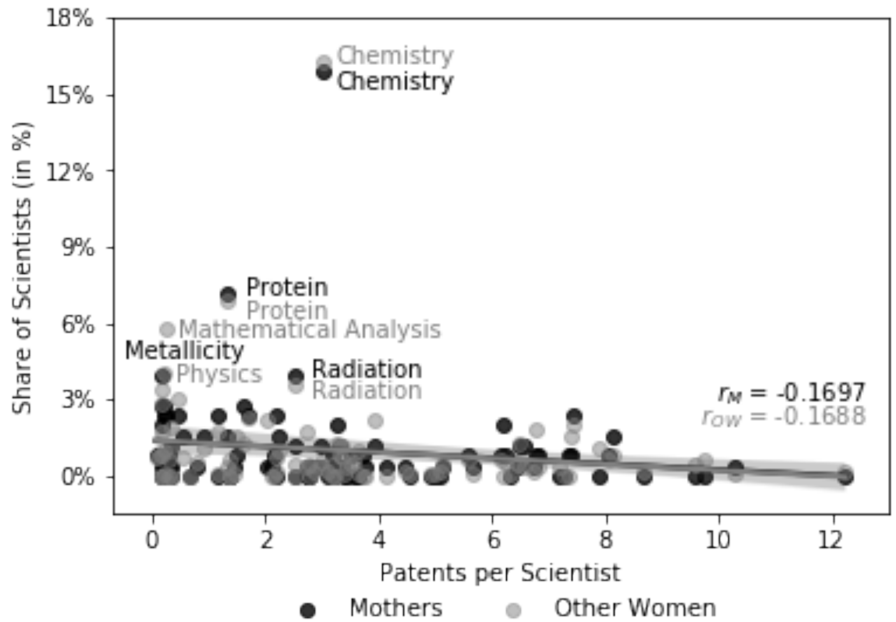
Parenting had no noticeable effect on selection into fields

Mothers are slightly less likely to work in fields with many patents than fathers. No significant differences between mothers and other women

Mothers vs. Fathers



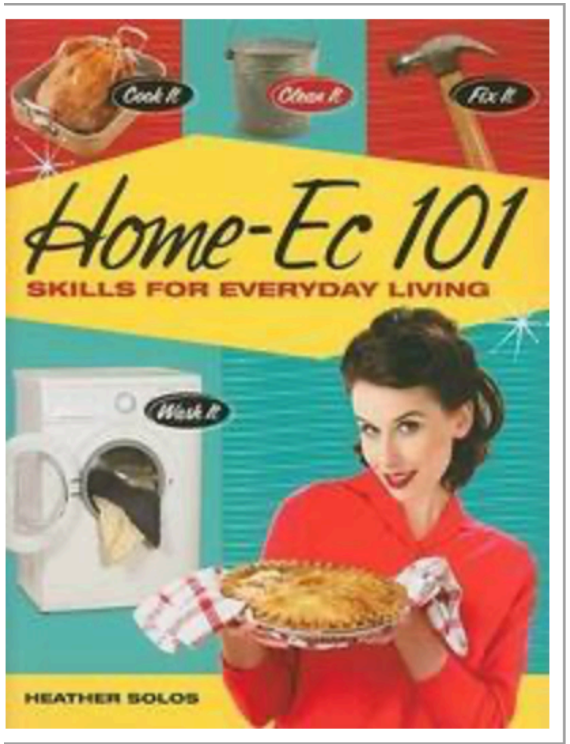
Mothers vs. Other Women

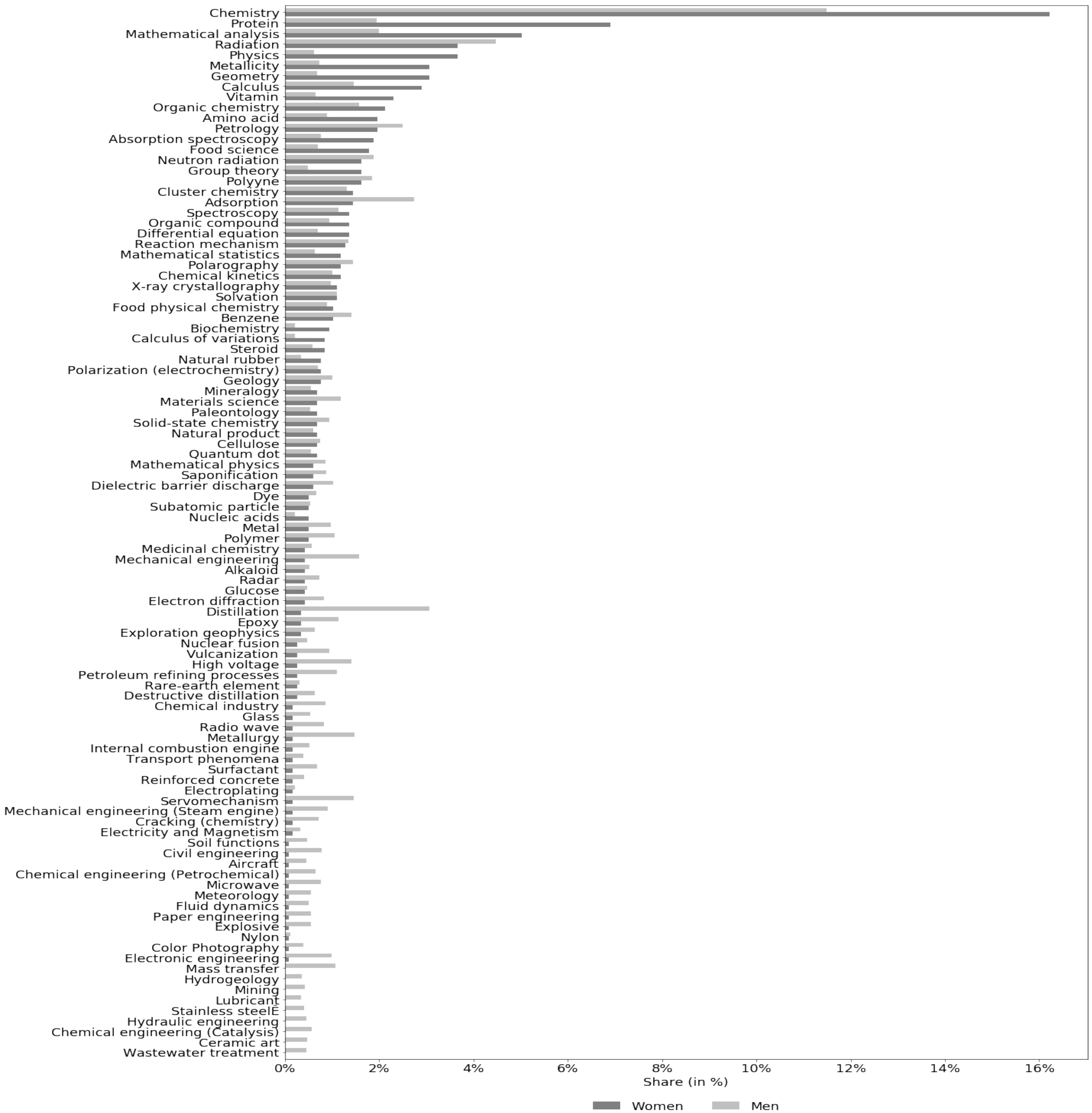


Selection into research fields

- Women may select into fields that are less competitive (e.g., Niedele and Vesterlund 2007) or more family-friendly (e.g. Goldin 2004, Goldin and Katz 2016)

- Trying to explain the underrepresentation of women Kevles, Daniel J (1971) writes
  - …professionally oriented women still aspired to the more “womanly” professions. Classes in high-school chemistry, which could open the door to careers in such fields as home economics, nutrition, or nursing, enrolled almost as many girls as boys; in physics courses, boys outnumbered girls three to one





Women more likely to work in chemistry and protein (more patents) mathematical analysis and physics (fewer patents)

Selection into survival
Who survived to enter the MoS (1956)?

- We have digitized faculty directories of Columbia University for 1943-45

CORNELIA LEE CAREY, 1929 . . . . . . *Associate Professor of Botany in Barnard College*
B.S., Columbia, 1919; A.M., 1921; Ph.D., 1923.
[From July 1, 1944.]
[Assistant Professor of Botany in Barnard College, to June 30, 1944.]

- And-matched faculty with academic scientists in MoS (1956)

CAREY, PROF. CORNELIA L(EE), Quissett Harbor, Falmouth, Mass. BOTANY. Montclair, N.J, Jan. 15, 91. B.S, Columbia, 19, A.M, 21, Ph.D.(bot), 23. Asst, BARNARD COL, COLUMBIA, 18-21; lectr, 22-23, instr, 23-29, asst. prof. BOT, 29-44, assoc. prof. 44-50, chmn. dept, 39-50; RETIRED. A.A; Bot. Soc; Soc. Plant Physiol; Soc. Bact; Torrey Bot. Club. Colloidal adsorption; soil and marine bacteriology.

- Were women less likely to survive?
- Were mothers or women in cohorts of baby boom mothers less likely to survive? Matching faculty directories with census of 1940 to add information on birth years and children

Female faculty half as likely to survive compared with men

Just 10% of female academic scientists from 1943-45 survived to enter MoS 1956, compared with 20% of men

TABLE 5 – SURVIVAL IN ACADEMIC SCIENCE

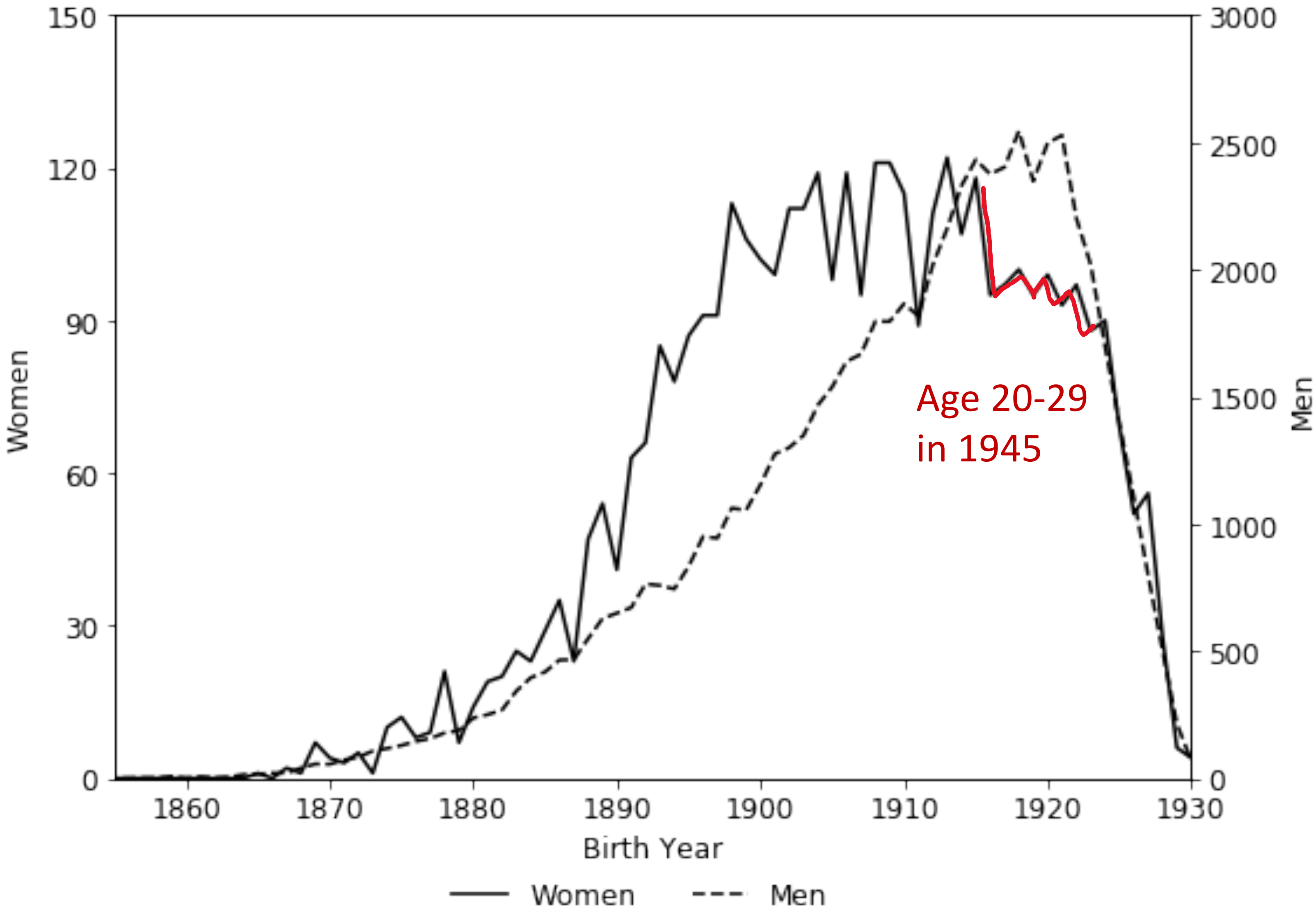
	All	All women	All men	Women		Men	
				with children	w/o children	with children	w/o children
Surviving faculty:							
N	872	79	793	20	59	584	209
Columbia	385	46	339	11	35	255	84
Stanford	166	7	159	3	4	123	36
UC Berkeley	240	16	224	5	11	158	66
UCLA	95	12	83	1	11	57	26
Demographics:							
Age in 1956	56.1	56.7	56.0	53.7	57.7	55.4	58.0
	(11.79)	(9.96)	(11.95)	(11.45)	(9.23)	(11.69)	(12.46)
Share married (in %)	77.9	43.0	81.3	90.0	27.1	91.6	52.6
Age at marriage	29.4	29.2	29.5	26.0	32.8	28.8	32.8
	(6.61)	(8.60)	(6.50)	(4.51)	(10.67)	(5.80)	(8.42)
Share parents (in %)	69.3	25.3	73.6	100	0	100	0
N children	1.63	0.49	1.74	1.95	0	2.36	0
	(1.38)	(0.95)	(1.37)	(0.83)		(1.03)	

Women in Science

- Historical background
- Data
  - Biographies of American scientists in 1956
  - Matched with patents and publications
- Productivity differences across demographic groups
  - Differences in inventive output across the life cycle
  - Differences in inventive output across demographic groups
  - Event studies of inventive output after marriage
- Effects on publications and tenure
  - Differences in publishing across the life cycle and across demographic groups
  - Event study estimates of the effects of children on tenure
  - Changes in publications before and after tenure
- Selection
- Aggregate effects on participation
  - A lost generation of baby boom mothers
- Conclusions

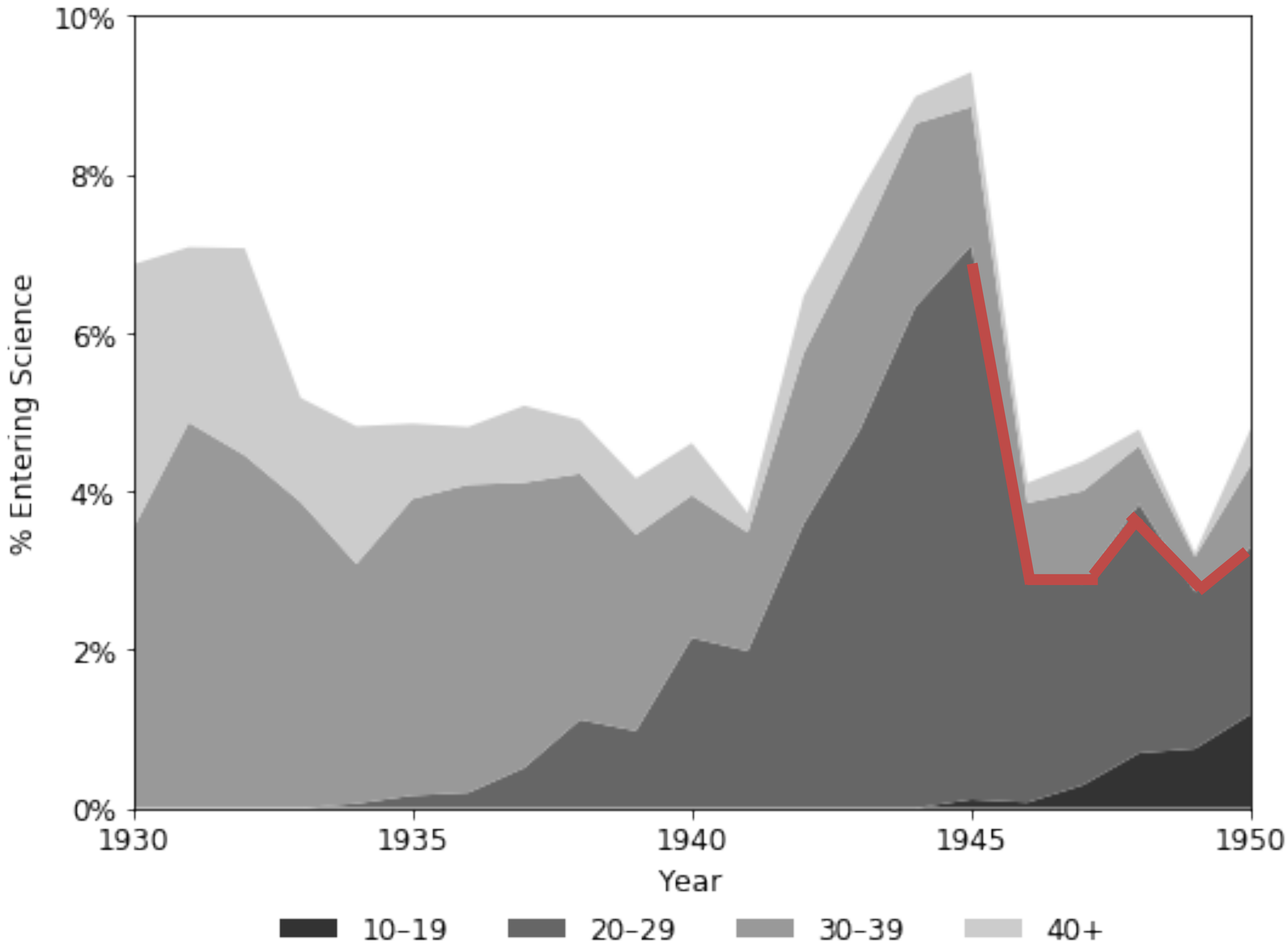
Participation by women declined by 16% from 110/year for women born 1900-15 to 92.3 for women born 1916-25

Figure 8: Women and Men Active in American Science in 1956, by Birth Year



Lost generation of baby boom mothers (b. 1916-25)

Share women among entrants into US science declined by 40% from 7% in 1940-45 to 4.3% per year in 1946-50



Conclusions

- Children reduced productivity of mothers but not fathers
  - Gender differences are stronger in STEM than in biological and social sciences
- Mothers have different time pattern of productivity than other scientists
  - Mothers became more productive after age 35
  - After marriage, mothers' productivity declined and recovered 15 years later
- Important implications for promotions
  - Mothers 21% less likely to get tenure compared with fathers
  - 19% less than other women
- Selection into marriage, parenting, and "survival" in science
  - Mothers were no less productive than other women
  - But female scientists married late and had fewer children
  - Women (mothers) were less likely to survive in science
- Dramatic decline in entry by women in their 20s in 1945
  - Disparate burden of parenting created a lost generation of female scientists among mothers of the baby boom

- Please send comments to pmoser@stern.nyu.edu and scottjmk@wharton.penn.edu

- Thank you!