# German Jewish Émigrés and U.S. Invention

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# Do high-skilled immigrants encourage domestic innovation?

- Immigrants write more highly-cited papers (Hunt 2011)
- They are successful at creating startups (Stephan and Levin 2001)

- Mixed evidence of immigrants' effects on domestic invention
  - Positive correlation at state level (Hunt and Gauthier-Loiselle 2010)
  - No significant effects at city level (Kerr and Lincoln, 2010)
  - Competition by Soviet immigrants after 1993 discouraged publication by U.S. mathematicians (Borjas and Doran, 2011)

- Empirical challenge:
  - More productive scientists tend to move to more innovative locations
  - Comparisons across locations overstate the benefits of immigrants

# After 1933, many highly-educated German Jews fled to the U.S.

- In 1933 Nazis dismissed all Jewish persons from public service
- Dismissals from Austria after the annexation in 1938
- 133,000 German Jews fled to U.S. from April 1933 to 1944
  - 20% were university graduates
  - 900 lawyers, 2,000 physicians, 1,500 writers
  - 2,400 academics
- Jewish refugees formed the core of the Manhattan project

# Did Jewish émigré chemists increase U.S. invention?

- Exploit exogenous historical event to address the selection of migrants
- Examine effects on precisely defined technologies
  - Patents by U.S. inventors across USPTO classes before and after 1933
  - Compare classes with patents by émigrés to the U.S. to classes with patents by other German university chemists
  - Instrument: classes with pre-1933 patents by all dismissed chemists
- Only measure effects on patented invention (Moser, 2005, 2011)
  - Higher propensity to patent in chemistry (Cohen *et al.*, 2002)
  - Also historically, beginning in the late 19th century (Moser 2011), making patents a relatively good measure of innovations for chemistry

# Anecdotal evidence suggests that émigrés "revolutionized" U.S. chemistry

- Among the émigrés were very prominent chemists:
  - Otto Meyerhof (NL), Otto Stern (NL), Otto Loewi (NL), Max Bergmann, Gustav Neuberg, Kasimir Fajans.

- *"Offered teaching posts not long after arriving, these men soon effected hardly less than a revolution in American academic chemistry…their work on the structures of proteins and amino acids, on metabolic pathways and genetics, almost immediately propelled the United States to world leadership in the chemistry of life."*

  (Sachar 1992, p. 749)

# But émigrés were hampered by visa policies, anti-semitism, cultural differences

- Visa Restrictions:
  - "Kafkaesque gridlock of seeking affidavits from relatives in America, visas from less-than-friendly United States consuls, special permits from other nations whose territory was to be crossed in transit." (Sachar ,1992)

- Anti-semitism in the United States:
  - DuPont rejected Carl Neuberg as "too Jewish"
  - Havard, Yale, and Princeton did not hire Jewish faculty until the late 1940s.
  - *"In the hungry 1930s, anti-Semitism was a fact of life among American university faculties as in other sectors of the economy. Physicists and chemists had the best chance of securing appointments"*

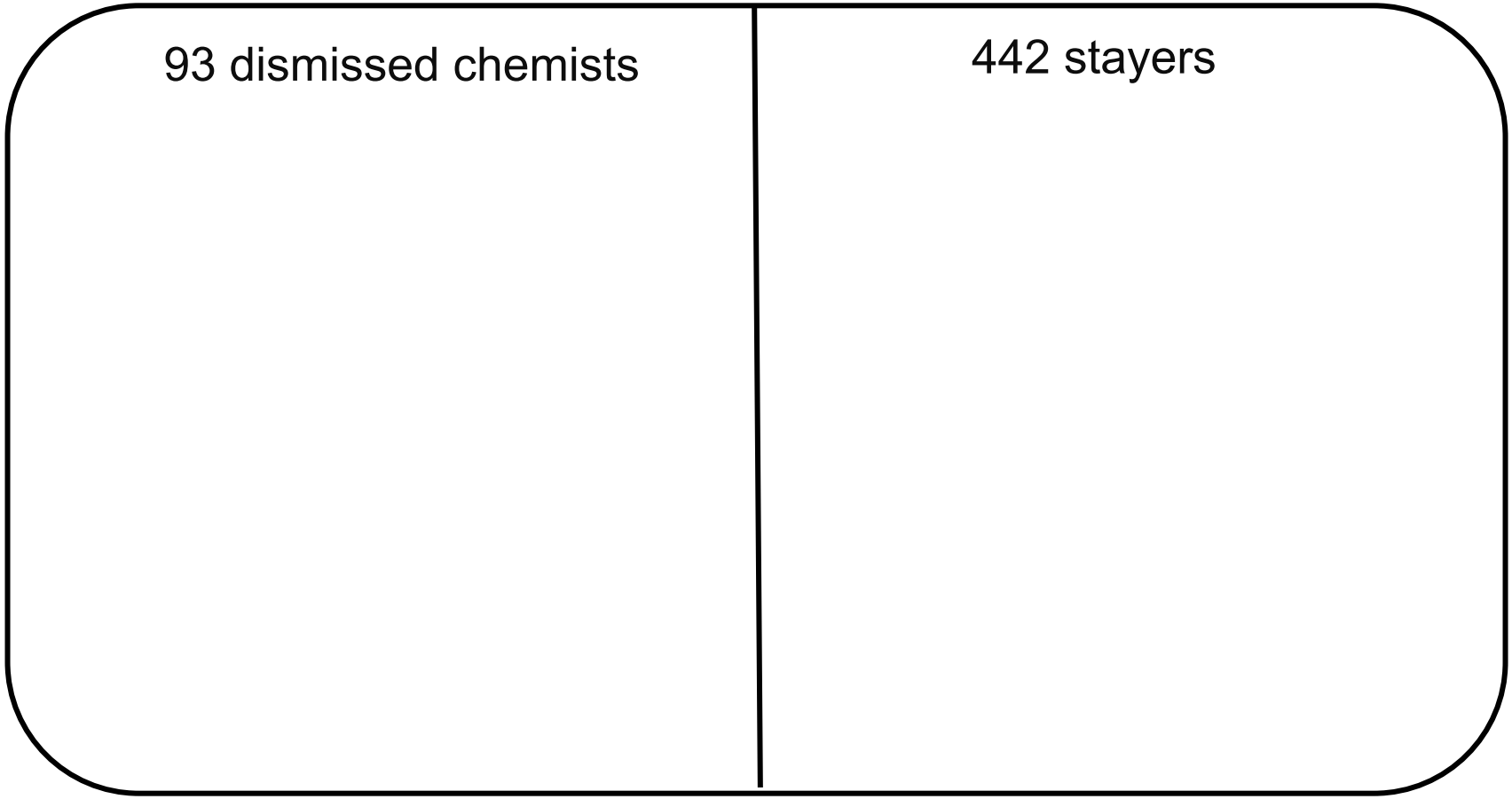
    (Sachar, 1992, also Dinnerstein, 1994)

- Cultural Differences:
  - *"In the Germanic tradition, they often appeared aloof and condescending, a style unfamiliar to the more democratic atmosphere of American campus life "* (Sachar, 1992, p. 499).

# Data 1: Roster of German university chemists

535 chemists

1920-1970



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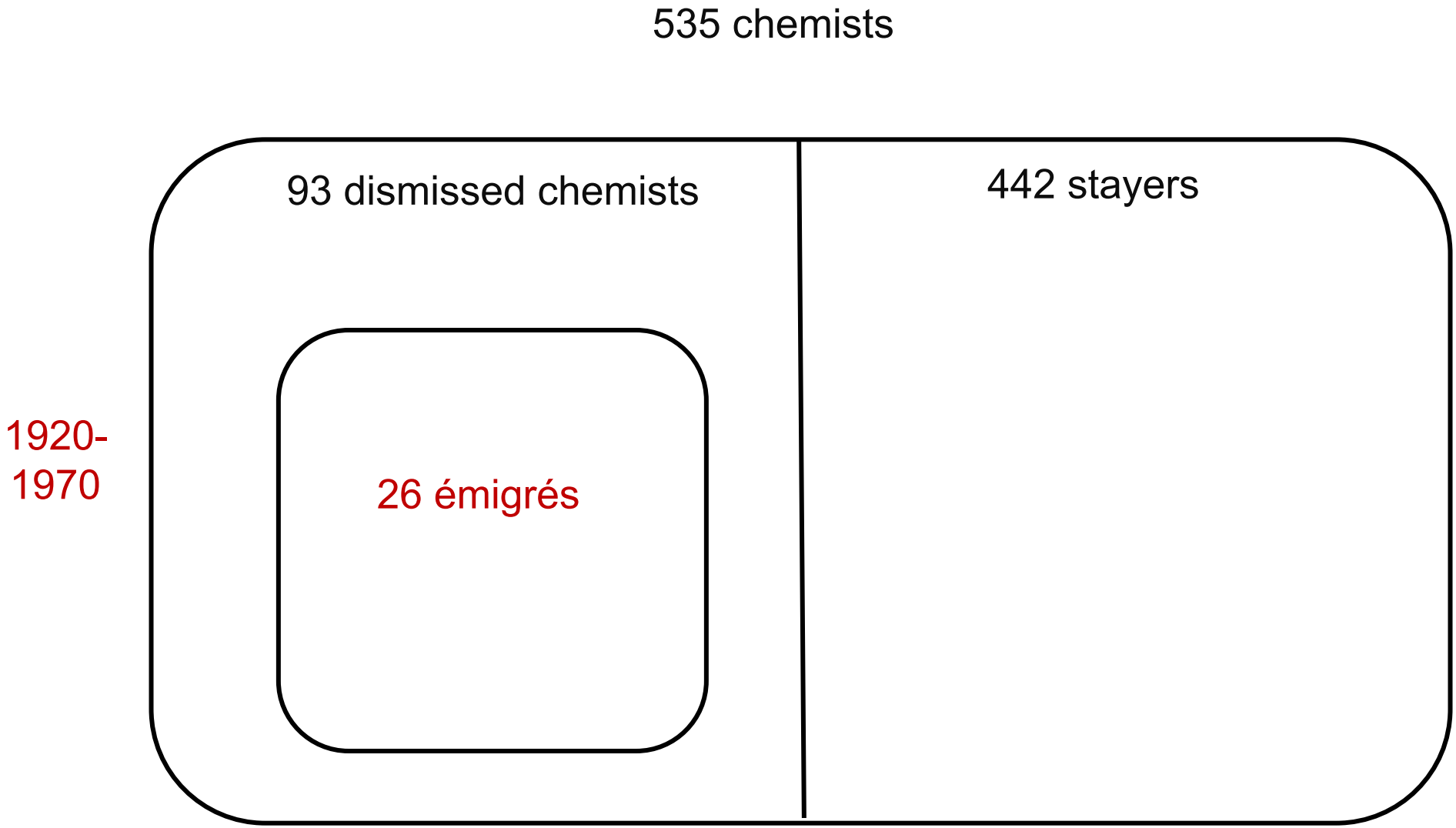


# Data 1: Roster of German university chemists

- Data source German university chemists:
  - Deutscher Universitäts Kalender (1932/33)
    (includes all researchers who were at least Privatdozenten)
- Data source Austrian university chemists:
  - Kürschners Deutscher Gelehrtenkalender (1931)
- Data sources dismissed chemists:
  - List of Displaced German Scholars (1937)
  - Two additional secondary sources:
    - Deichmann (2001)
    - International Biographical Dictionary of Central European Émigrés (1987)

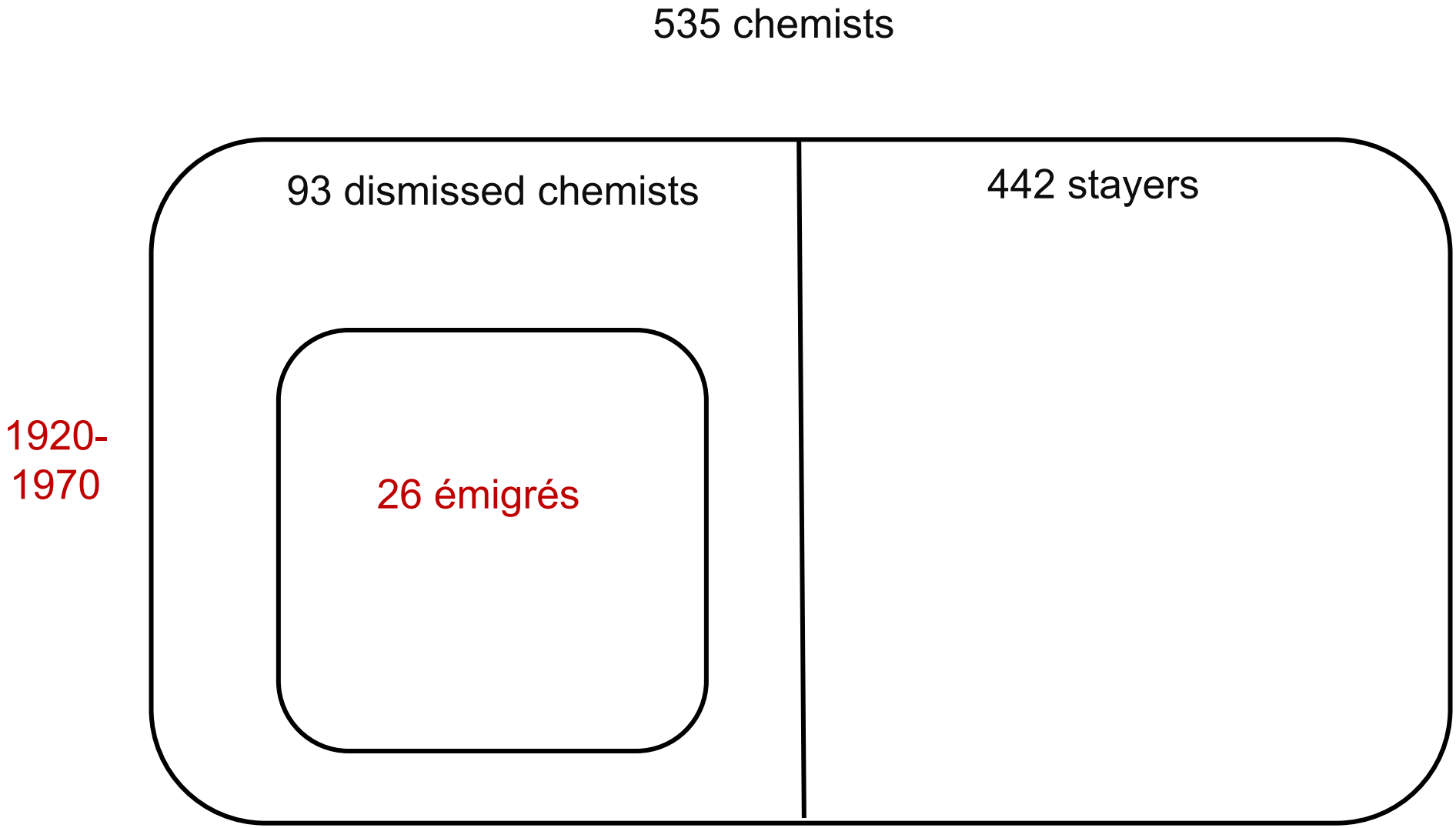
# Arnold Weissberger (1898 – 1984)

- Age in 1933: 35
- Religion: Jewish
- Emigration record: 1933 UK, 1936 US
- Last position in Germany: University of Leipzig Privatdozent 1933
- Fields: Stereochemistry, reaction mechanisms, synthetic organic chemistry
- Position in the U.S.:
  - 1936-75, Research Labs Eastman Kodak Co. Rochester.
  - Specialized in chemistry of color photography
  - Formulated and developed many of the organic compounds used in the color process, ca. 100 US and foreign patents

# Carl Neuberg (1877 – 1984)

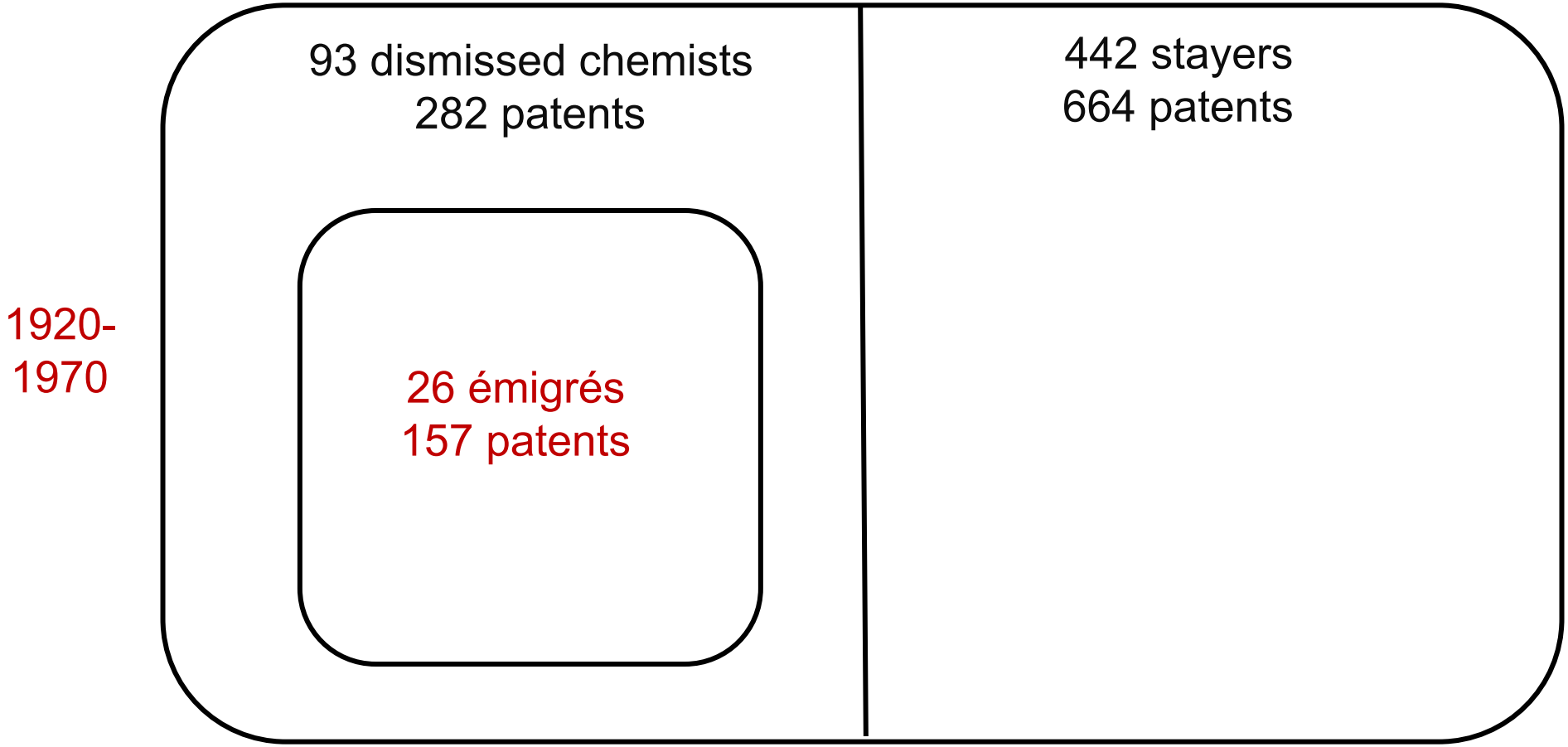
- "Father" of biochemistry
  - Chemotherapy of cancer in mice
  - Discovered Neuberg-ester (fructose-6-phosphate) in 1913
  - Discovered and prepared a total of seven enzymes
- WWI expert on artillery problems
- Founded KWI for biochemistry in Berlin in 1925
- Emigrated to Palestine via Amsterdam in 1938
- Professor at Hebrew U until 1940
- Research professor at NYU since 1940
- 4 total U.S. patents, 1 before 1933

# Data 1: Roster of German university chemists



# Data 2: Identify U.S. patents by chemists

535 chemists
946 U.S. patents



# Matching chemists with U.S. patents

- Hand match U.S. patents to German chemists using *Google Patents.*

- Example:

## UNITED STATES PATENT OFFICE.

ERNST BERL, OF DARMSTADT, GERMANY.

PROCESS FOR THE PRODUCTION OF PRODUCTS CONTAINING CELLULOSE AND ALKYLCELLULOSE.

No Drawing. Application filed October 6, 1922. Serial No. 592,841.

*To all whom it may concern:*

Be it known that I, Ernst Berl, a citizen of Czechoslovakia, residing at Darmstadt, Germany, have invented certain new and useful Improvements in a Process for the Production of Products Containing Cellulose and Alkylcellulose, for which I filed an application for patent in Germany, Sept. 23, 1921, and of which the following is a specification.

Products, such as threads or films from

also favorably influenced by the process. Amongst other advantages with regard to ductility and to the specific weight are obtained, it being possible to make the latter almost like that of natural silk.

*Examples.*

1. A quantity of ethylcellulose dissolved in alcohol, which is equal to 25–75% of the weight of the dry nitro-cellulose is added to a colloidal solution of nitro-cellulose in

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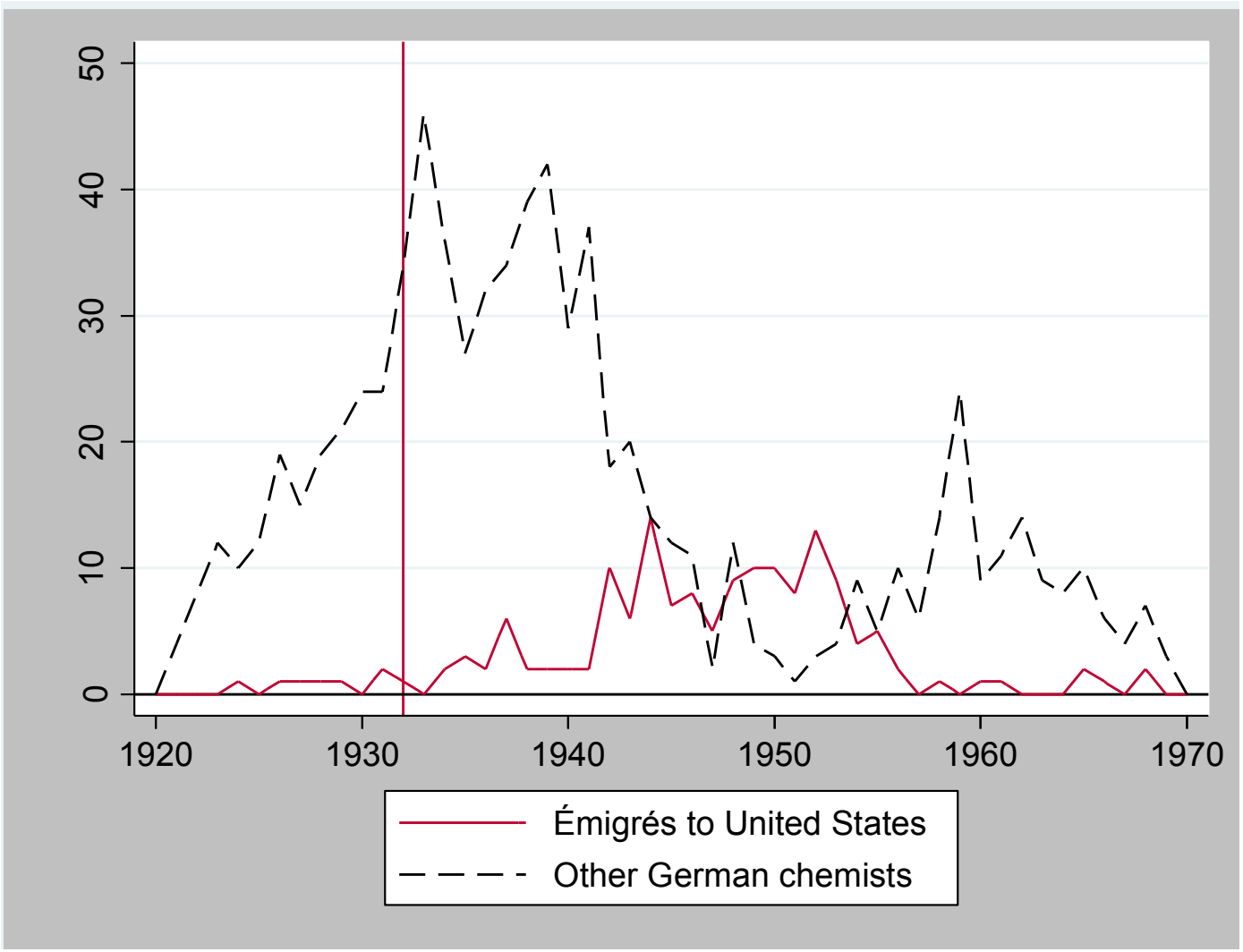
# Émigrés patent more in the U.S. between 1942 and late 1950s

U.S. PATENTS BY GERMAN CHEMISTS



# Data 3: Treatment and control classes

535 chemists
946 U.S. patents
166 USPTO classes

93 dismissed chemists
282 patents

442 stayers
664 patents

**106 USPTO classes**

1920-
1970

26 émigrés
157 patents
**60 USPTO classes**

# USPTO classes

- 475 narrowly-defined technology fields across USPTO

- Examples:
  - Class 423: Chemistry of inorganic compounds
  - Class 430: Radiation imagery chemistry: process, composition, or product thereof
  - Class 435: Class Chemistry: molecular biology and microbiology

# Data 4: All patents by U.S. inventors

- Patents by U.S. inventors between 1920-1970 from www.*uspto.gov.*
  - Émigré classes: 771,377 patents in 60 classes
  - Non émigré classes: 1,302,394 patents in 106 classes

- Identify U.S. inventors:
  - search for inventors from other countries (Google Patents)
  - exclude patents by foreign inventors

    (see Moser and Voena 2011 for reliability of this method)

# Summary statistics at the class level

SUMMARY STATISTICS: U.S. PATENTS BY DOMESTIC INVENTORS ACROSS USPTO CLASSES

| | (1) All Classes | (2) Classes with 1920-70 patents by U.S. émigrés | (3) Classes without 1920-70 patents by U.S. émigrés | (4) Classes with pre-1933 patents by dismissed | (5) Classes without pre-1933 patents by dismissed |
|---|---|---|---|---|---|
| Patents by U.S. inventors 1920-70 | 2,073,771 | 771,377 | 1,302,394 | 619,308 | 1,454,463 |
| Number of classes | 166 | 60 | 106 | 48 | 118 |
| Mean class age in 1932 | 87.23 | 84.6 | 88.7 | 87.4 | 87.3 |
| P-value of equality of means test | | 0.085 | | 0.929 | |
| Mean # of foreign patents in 1932 | 0.93 | 0.92 | 0.93 | 0.70 | 1.01 |
| P-value of equality of means test | | 0.942 | | 0.216 | |
| Mean patents per class and year 1920-70 | 244.95 | 252.08 | 240.92 | 252.99 | 241.69 |
| Mean patents per class and year 1920-32 | 193.39 | 149.25 | 218.38 | 157.50 | 207.99 |
| Mean patents per class and year 1933-70 | 262.59 | 287.26 | 248.63 | 285.65 | 253.21 |

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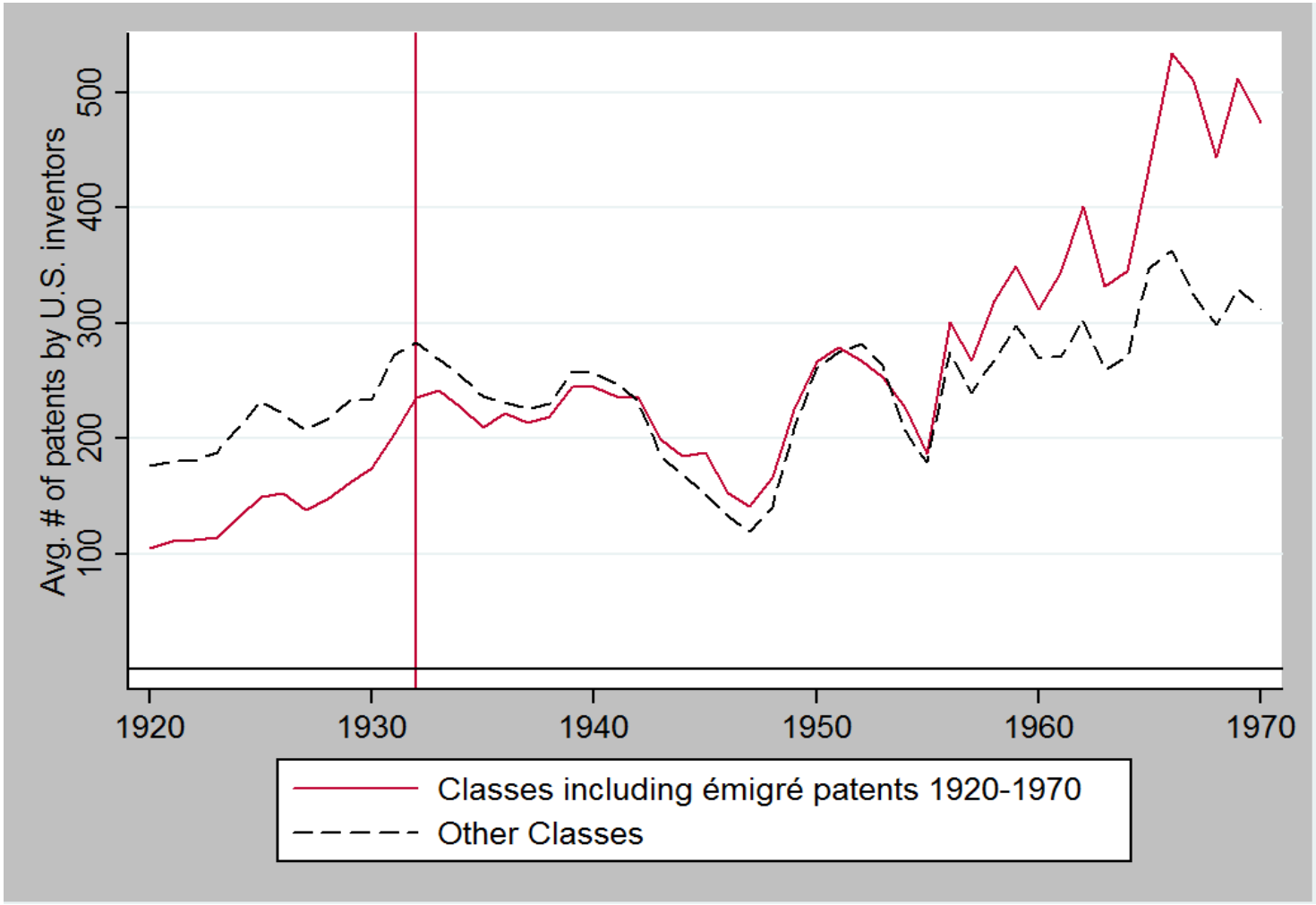
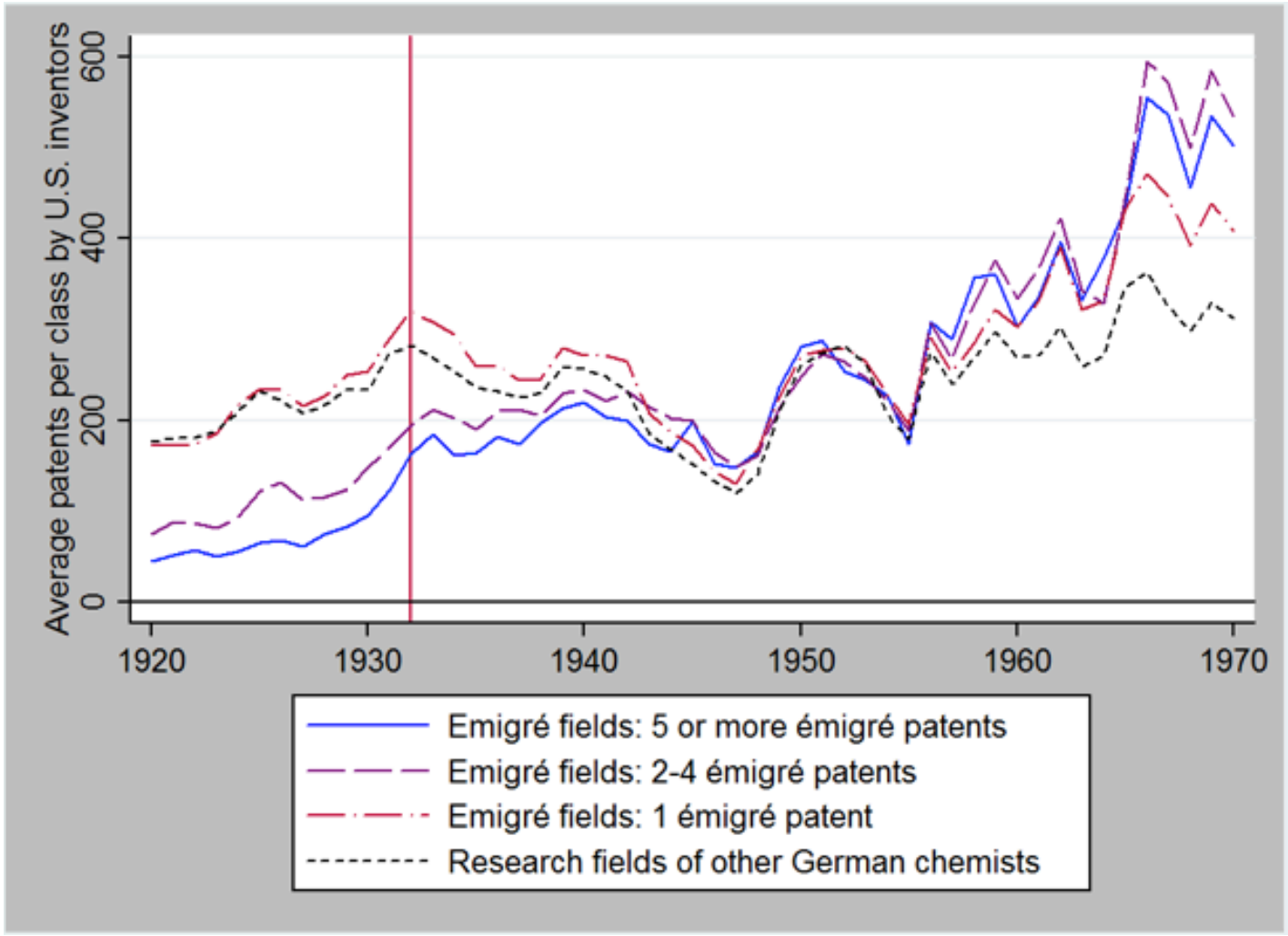
# Data 5: Panel data on productivity of U.S. inventors

- Extract inventors' names from the data on the universe of U.S. patents
  - Data source: USPTO Patent Grant OCR text (1920-1970)
  - Use regular expressions to identify the inventors' names
  - Assign inventor to 85% of the patents in our sample
- Assign unique identifiers to inventors over time
  - Levenshtein distance matches inventors' names across patents
  - 680,453 unique inventors for 1,167,679 patents
  - 215,439 inventors active before 1933
- Follow inventors over time
  - Inventor productivity: number of patents in each year
  - Entry in a field: number of new inventors in each class and in each year

# U.S. patents by U.S. inventors in classes with and without émigrés (Fig 2A)



# U.S. patents by U.S. inventors in classes with 1, 2-4, >5 émigré patents (Fig 2B)



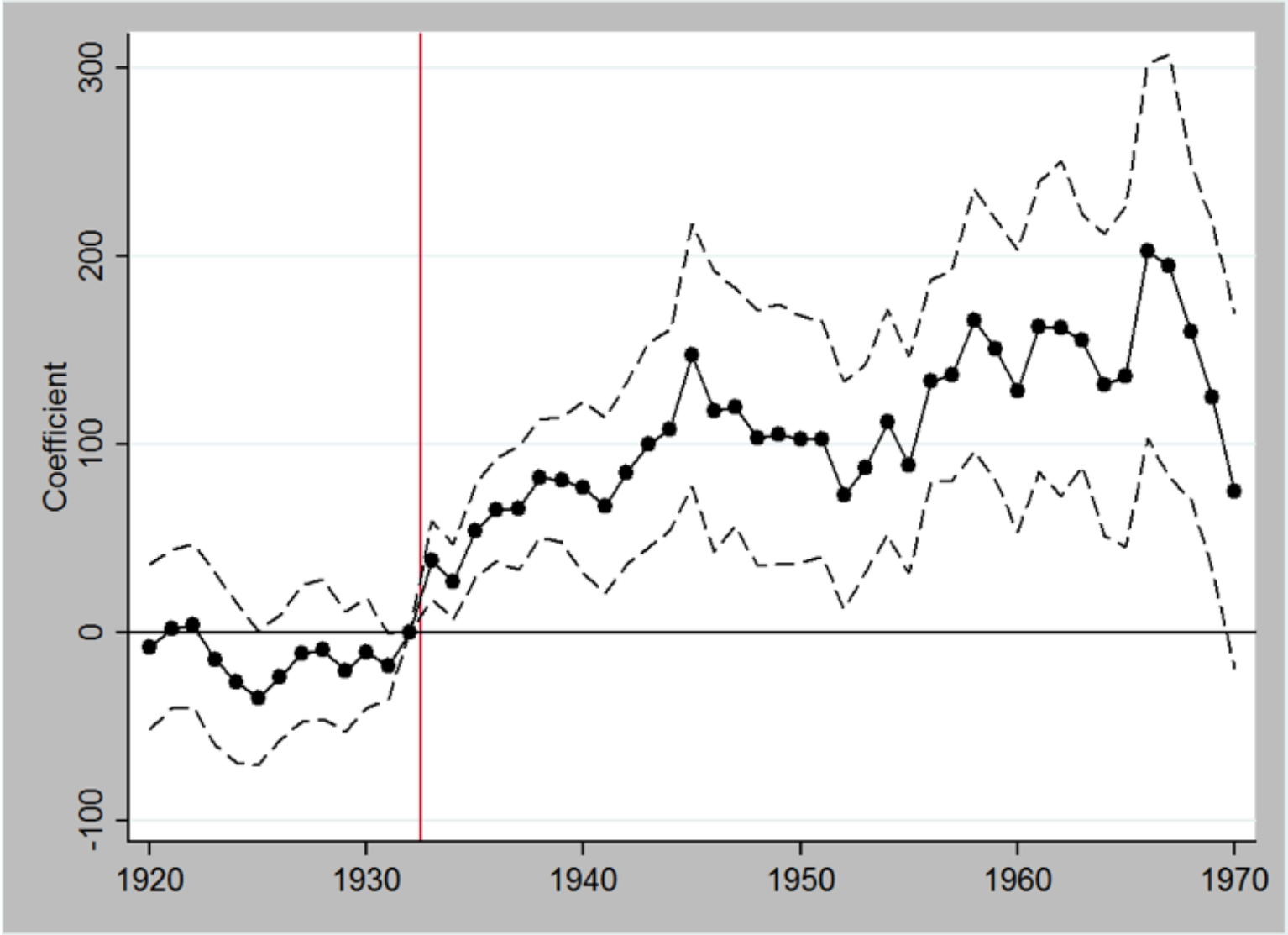
# Classes with émigré patents produce 31% more patents after 1933 (Tab 2, compared with mean of 240.9 patents per class and year in classes with patents by other German chemists)

ORDINARY LEAST SQUARES REGRESSIONS
DEPENDENT VARIABLE IS PATENTS PER CLASS AND YEAR BY U.S. INVENTORS

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Émigré class * Post | 105.222*** | 91.712*** | 84.803*** | 75.439*** | | | | |
| | (22.203) | (19.212) | (18.950) | (19.326) | | | | |
| # émigré patents * Post | | | | | 5.848* | 4.992* | 4.527** | 3.991** |
| | | | | | (3.058) | (2.561) | (2.182) | (1.956) |
| # foreign patents | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Quadratic class age | No | No | Yes | Yes | No | No | Yes | Yes |
| Patent pools | No | No | No | Yes | No | No | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 |
| R-squared | 0.783 | 0.845 | 0.849 | 0.851 | 0.779 | 0.842 | 0.846 | 0.848 |

Standard errors clustered at the class level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Annual coefficients: OLS (Fig 3)
# US patents per year in fields of émigrés

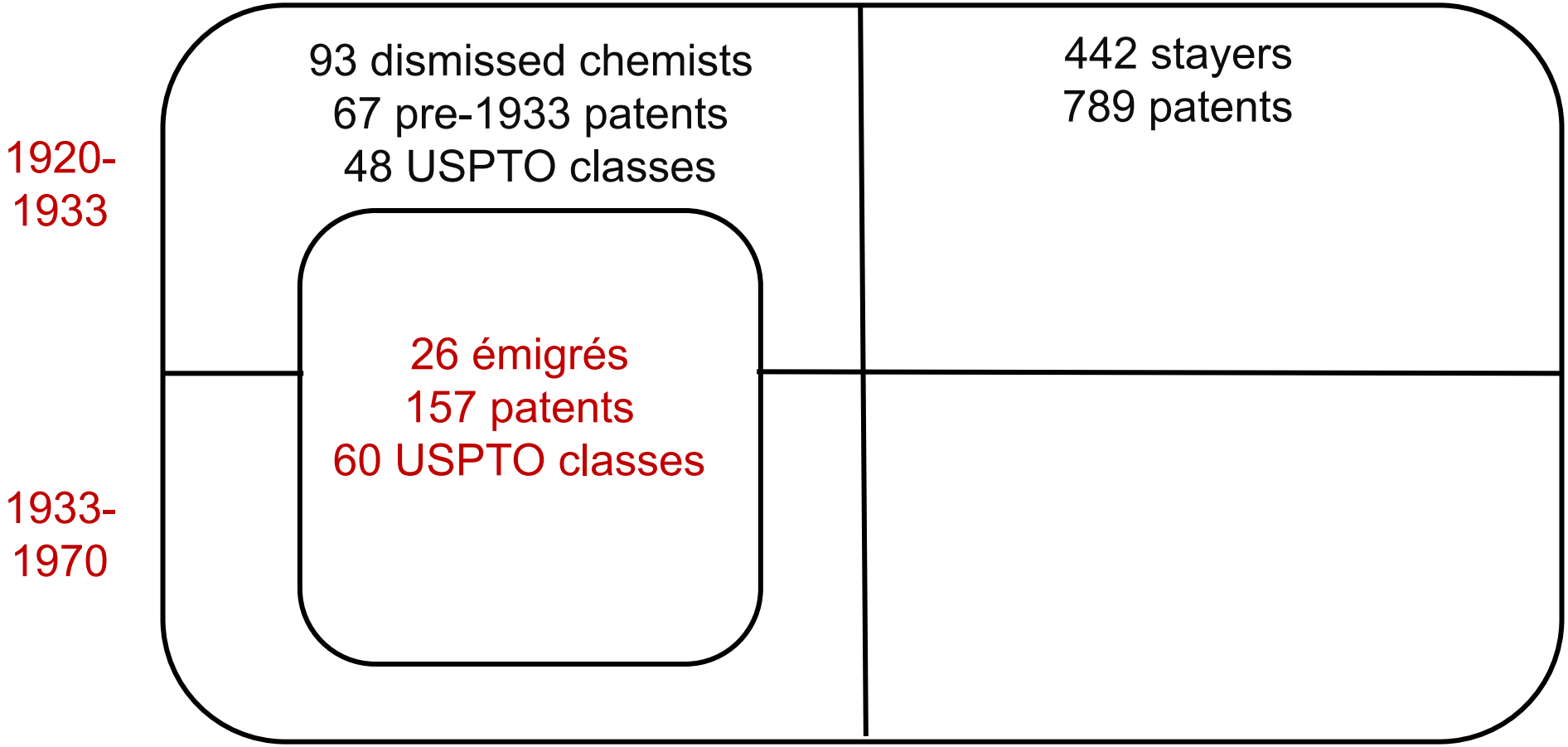


# Selection into research fields?

- Multiple sources of bias in *Émigré class*$_c$ and in # *Émigré patents*$_c$
  - More productive scientists may migrate to U.S.
    - High-skilled migrants are more likely to move to countries with higher returns to skills (Borjas, 1987, Borjas, 2008, Ramos, 1992)
    - Migration costs may be higher for low skilled individuals (Chiquiar and Hanson, 2005)
  - Chemists whose fields are complementary to U.S. research may be more likely to emigrate
  - After arrival in United Stats, émigrés may switch to "hot" fields
- Anecdotal evidence suggests negative selection
  - Migration selection: prominent scientists stayed in the U.K.
  - Hiring selection: find job in areas with less domestic capacity
  - For example, Arnold Weissberger and Gertrud Kornfeld
- Empirical strategy: instrument for *Émigré class*$_c$ and # *Émigré patents*$_c$
  - Use patents by *dismissed* chemists
  - Only consider *pre-1933* U.S. patents

# Empirical Strategy: IV

535 chemists
946 U.S. patents
166 USPTO classes



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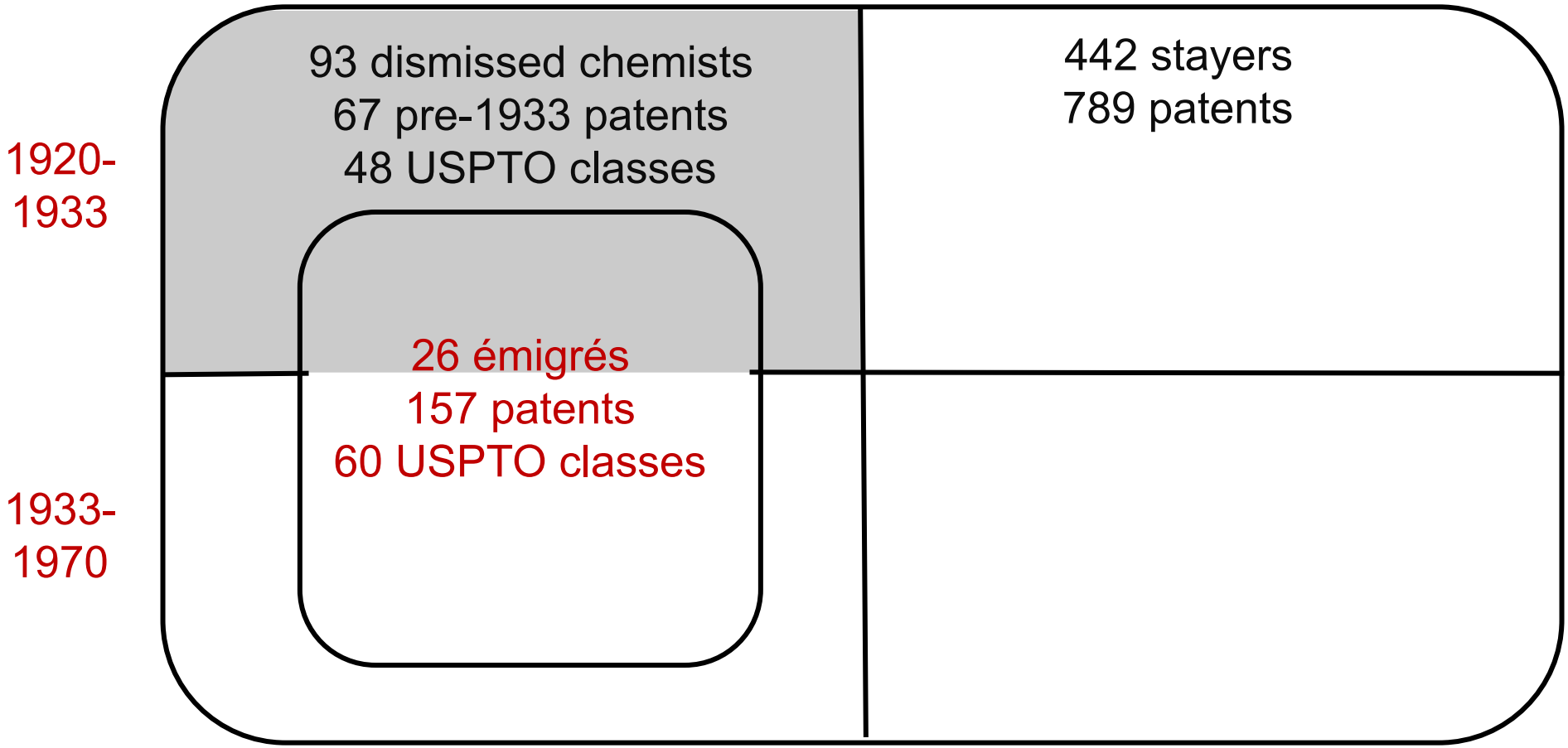

# IV first stage (Tab 3)

First Stage and Reduced Form
Dependent Variables are Émigré Class*Post (Cols 1-2), # of Émigré Patents * Post (Cols 3-4), and Patents Per Class and Year by U.S. Inventors (Cols 5-8)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | First Stage | | | | Reduced Form | | | |
| | Émigré class * Post | | # Émigré patents * Post | | | | | |
| Dismissed class * Post | 0.370*** | 0.339*** | | | 80.821*** | 57.752*** | | |
| | (0.081) | (0.079) | | | (23.155) | (19.436) | | |
| # dismissed patents * Post | | | 1.384*** | 1.303*** | | | 35.595*** | 22.330*** |
| | | | (0.442) | (0.435) | | | (6.547) | (6.339) |
| # foreign patents | No | Yes | No | Yes | No | Yes | No | Yes |
| Quadratic class age | No | Yes | No | Yes | No | Yes | No | Yes |
| Patent pools | No | Yes | No | Yes | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 |
| R-squared | 0.801 | 0.809 | 0.770 | 0.773 | 0.779 | 0.849 | 0.782 | 0.849 |
| F-statistic | 20.80 | 18.25 | 9.79 | 8.99 | | | | |

Standard errors clustered at the class level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Reduced form: 24% increase in domestic patenting
## (Tab 3, compared with mean of 240.9 patents per class and year)

FIRST STAGE AND REDUCED FORM
DEPENDENT VARIABLES ARE ÉMIGRÉ CLASS*POST (COLS 1-2), # OF ÉMIGRÉ PATENTS * POST (COLS 3-4), AND PATENTS PER CLASS AND YEAR BY U.S. INVENTORS (COLS 5-8)

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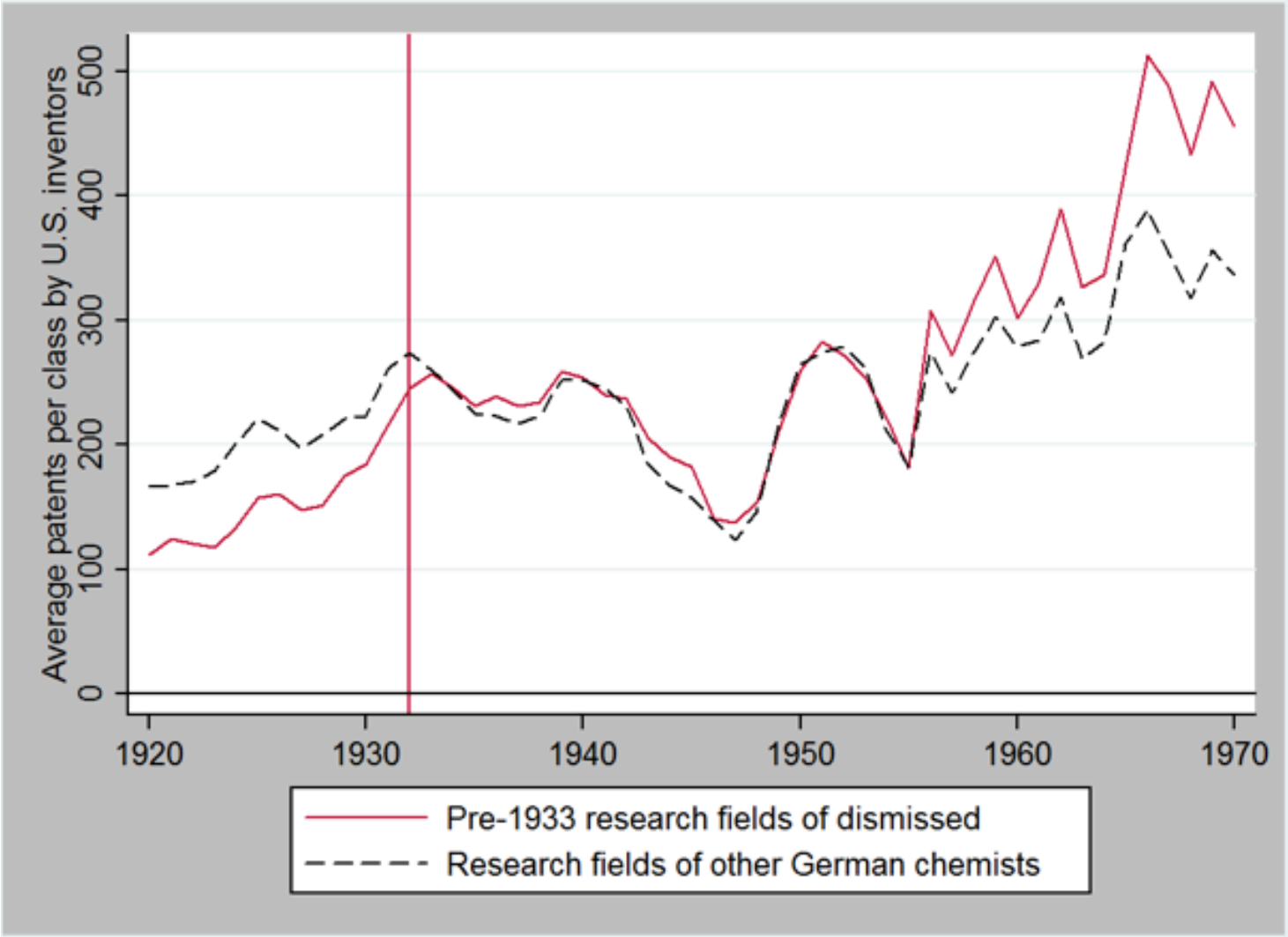
# By mid 1950s, U.S. inventors produced more patents in pre-1933 fields of dismissed German-Jewish scientists (Fig 4)



# Instrumental variables (Table 4)
# 71% increase in domestic patenting

INSTRUMENTAL VARIABLE REGRESSIONS
DEPENDENT VARIABLE IS PATENTS PER CLASS AND YEAR BY U.S. INVENTORS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Émigré class * Post | 218.707*** | 170.136*** | | |
| | (60.614) | (57.992) | | |
| # émigré patents * Post | | | 25.717*** | 17.137** |
| | | | (8.750) | (6.909) |
| # foreign patents | No | Yes | No | Yes |
| Quadratic class age | No | Yes | No | Yes |
| Patent pools | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes |
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# Investigate two competing mechanisms

- U.S. scientists became more productive in émigré fields
- More scientists started working on émigré fields after 1933

- Examine newly-collected data on U.S. inventors
  - Productivity of U.S. scientists who worked on same fields as dismissed scientists before 1933
  - Entry of scientists in technological fields over time

# No significant difference for incumbents who were more or less exposed to émigrés (Tab 5)

SUMMARY STATISTICS: U.S. PATENTS BY DOMESTIC INVENTORS WHO WERE ACTIVE PRIOR TO 1933

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | | Fraction of patents in research fields of émigrés | | | Fraction of pre-1933 patents in research fields of dismissed chemists | | |
| | All Inventors | <50% | 50% | >50% | <50% | 50% | >50% |
| Total inventors active before 1933 | 210,410 | 144,647 | 7,842 | 57,921 | 155,261 | 4,719 | 50,430 |
| Annual probability of patenting 1920-70 | 0.035 | 0.034 | 0.050 | 0.036 | 0.035 | 0.067 | 0.034 |
| Annual probability of patenting 1920-32 | 0.098 | 0.098 | 0.120 | 0.097 | 0.098 | 0.161 | 0.094 |
| Annual probability of patenting 1933-70 | 0.014 | 0.013 | 0.026 | 0.015 | 0.013 | 0.036 | 0.013 |
| Patents per inventor and year 1920-70 | 0.043 | 0.042 | 0.055 | 0.045 | 0.043 | 0.084 | 0.042 |
| Patents per inventor and year 1920-32 | 0.112 | 0.111 | 0.132 | 0.111 | 0.111 | 0.184 | 0.107 |
| Patents per inventor and year 1933-70 | 0.020 | 0.018 | 0.029 | 0.023 | 0.019 | 0.050 | 0.019 |

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| Patents per inventor and year 1933-70 | 0.020 | 0.018 | 0.029 | 0.023 | 0.019 | 0.050 | 0.019 |

# IV first stage coefficient of 0.402, F-statistic on excluded instrument of 21.65 (Tab 7)

Dependent variable equals 1 if inventor *i* patented at least 1 invention in year t

FIRST STAGE AND REDUCED FORM

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | First Stage | | Reduced Form | |
| Share of pre-1933 patents in dismissed classes * Post | 0.403*** | 0.402*** | -0.0003 | -0.009*** |
| | (0.086) | (0.086) | (0.001) | (0.002) |
| Quadratic time to first patent | No | Yes | No | Yes |
| Quadratic time since first patent | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes |
| Inventor fixed effects | Yes | Yes | Yes | Yes |
| Observations | 10,730,910 | 10,730,910 | 10,730,910 | 10,730,910 |
| F-statistic | 21.83 | 21.65 | | |
| R-squared | 0.434 | 0.434 | 0.045 | 0.147 |

Standard errors in parentheses clustered at the level of an inventor's main class of patenting

*** p<0.01, ** p<0.05, * p<0.1

# Researchers with 10% more pre-1933 patents in fields of dismissed became 0.09% less likely to patent (Tab 7)

Dependent variable equals 1 if inventor *i* patented at least 1 invention in year t

FIRST STAGE AND REDUCED FORM

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | First Stage | | Reduced Form | |
| Share of pre-1933 patents in dismissed classes * Post | 0.403*** | 0.402*** | -0.0003 | -0.009*** |
| | (0.086) | (0.086) | (0.001) | (0.002) |
| Quadratic time to first patent | No | Yes | No | Yes |
| Quadratic time since first patent | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes |
| Inventor fixed effects | Yes | Yes | Yes | Yes |
| Observations | 10,730,910 | 10,730,910 | 10,730,910 | 10,730,910 |
| F-statistic | 21.83 | 21.65 | | |
| R-squared | 0.434 | 0.434 | 0.045 | 0.147 |

Standard errors in parentheses clustered at the level of an inventor's main class of patenting

*** p<0.01, ** p<0.05, * p<0.1

# U.S. inventors with 10% larger share of patents in émigré classes become 0.22% less likely to patent (Tab 6)

Dependent variable equals 1 if inventor *i* patented at least 1 invention in year t

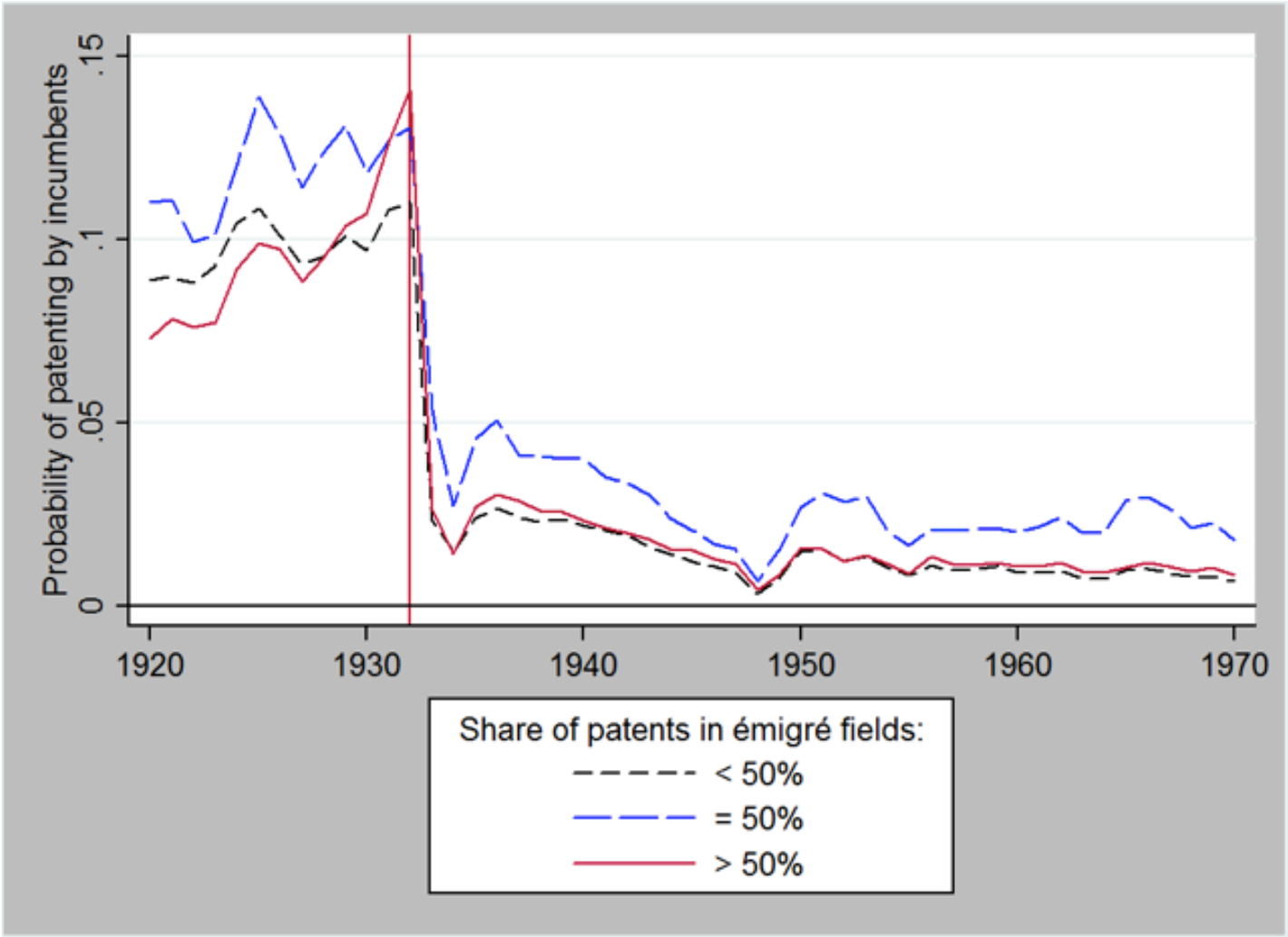
ORDINARY LEAST SQUARES AND INSTRUMENTAL VARIABLES, DEPENDENT VARIABLE IS PATENTING BY U.S. INVENTORS THAT WERE ACTIVE BEFORE 1933

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | OLS (Linear Probability) | | IV | |
| Share of patents in émigré classes * Post | 0.002** | -0.007*** | -0.001 | -0.022*** |
| | (0.001) | (0.002) | (0.002) | (0.006) |
| Quadratic time to first patent | No | Yes | No | Yes |
| Quadratic time since first patent | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes |
| Inventor fixed effects | Yes | Yes | Yes | Yes |
| Observations | 10,730,910 | 10,730,910 | 10,730,910 | 10,730,910 |
| R-squared | 0.045 | 0.147 | - | - |

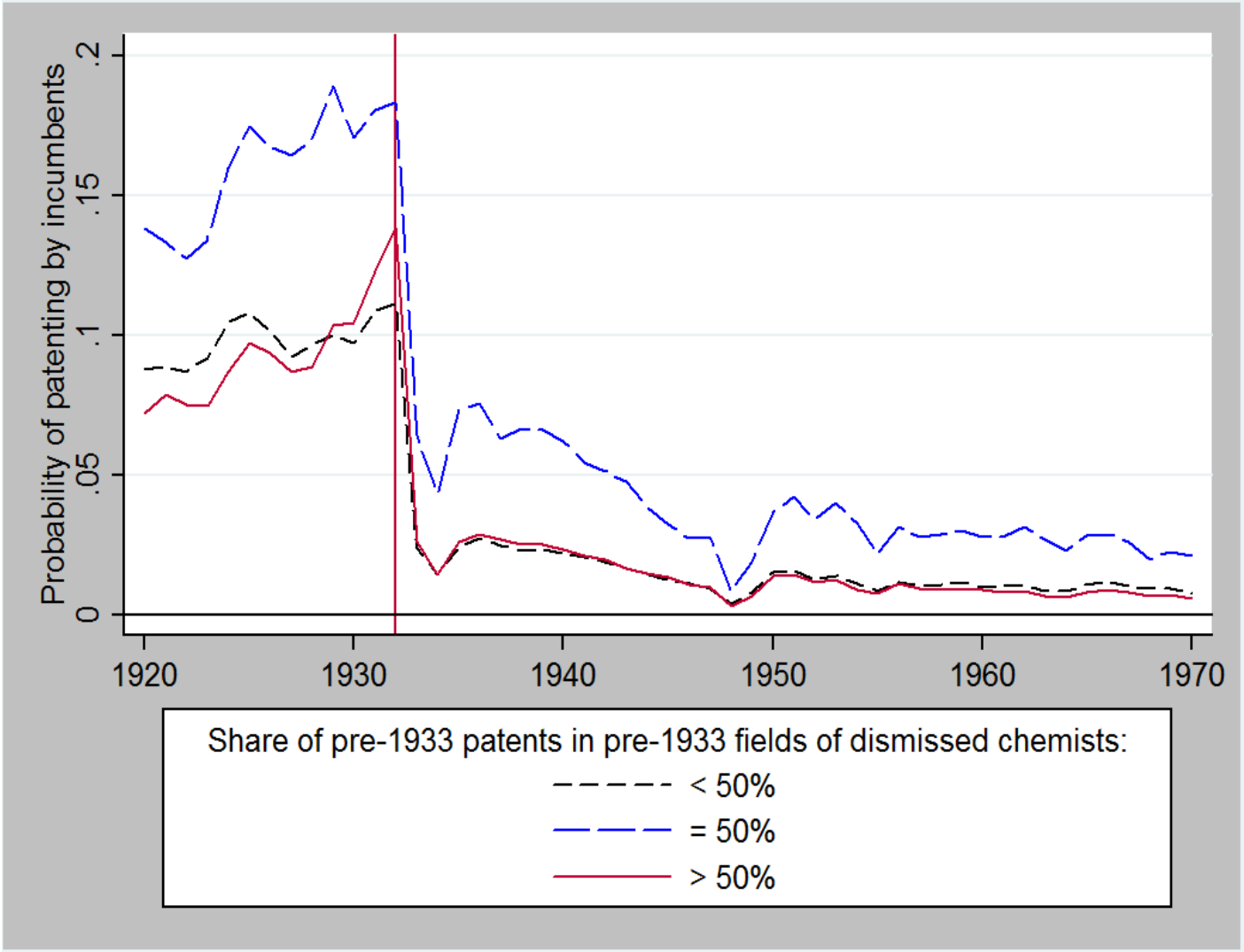
Standard errors clustered at the level of an inventor's main class

*** p<0.01, ** p<0.05, * p<0.1

# No noticeable difference in probability of patenting for incumbents U.S. inventors with more or fewer than half of their patents in fields of émigrés (Fig 5)



# No noticeable difference in probability of patenting for incumbents U.S. inventors with more or fewer than half of their patents in fields of dismissed (Fig 6)



# New patentees over time and across fields (Tab 8)

SUMMARY STATISTICS ON ENTRY OF NEW PATENTEES ACROSS RESEARCH FIELDS

| | (1) All Classes | (2) Classes with 1920-70 patents by U.S. émigrés | (3) Classes w/o 1920-70 patents by U.S. émigrés | (4) Classes with pre-33 patents by dismissed | (5) Classes w/o pre-33 patents by Dismissed |
|---|---|---|---|---|---|
| Number of classes | 166 | 60 | 106 | 48 | 118 |
| *Panel A: Entrants into research fields:* | | | | | |
| Total entrants into classes 1920-1970 | 1,396,318 | 499,417 | 896,901 | 404,927 | 991,391 |
| Mean entrants per class and year 1920-70 | 164.9 | 163.2 | 165.9 | 165.4 | 164.7 |
| Mean entrants per class and year 1920-32 | 153.8 | 116.1 | 175.1 | 121.6 | 166.8 |
| Mean entrants per class and year 1933-70 | 168.8 | 179.3 | 162.8 | 180.4 | 164.0 |
| *Panel B: Entrants into patenting:* | | | | | |
| Total entrants (no prior patents) 1920-1970 | 964,526 | 327,224 | 637,302 | 268,084 | 696,442 |
| Mean entrants (no prior patents) per class and year 1920-70 | 113.9 | 106.9 | 117.9 | 109.5 | 115.7 |
| Mean entrants (no prior patents) per class and year 1920-32 | 125.0 | 92.0 | 143.8 | 97.2 | 136.3 |
| Mean entrants (no prior patents) per class and year 1933-70 | 110.1 | 112.1 | 109.0 | 113.7 | 108.7 |

# New patentees over time and across fields (Tab 8)

SUMMARY STATISTICS ON ENTRY OF NEW PATENTEES ACROSS RESEARCH FIELDS

| | (1) All Classes | (2) Classes with 1920-70 patents by U.S. émigrés | (3) Classes w/o 1920-70 patents by U.S. émigrés | (4) Classes with pre-33 patents by dismissed | (5) Classes w/o pre-33 patents by Dismissed |
|---|---|---|---|---|---|
| Number of classes | 166 | 60 | 106 | 48 | 118 |
| *Panel A: Entrants into research fields:* | | | | | |
| Total entrants into classes 1920-1970 | 1,396,318 | 499,417 | 896,901 | 404,927 | 991,391 |
| Mean entrants per class and year 1920-70 | 164.9 | 163.2 | 165.9 | 165.4 | 164.7 |
| Mean entrants per class and year 1920-32 | 153.8 | 116.1 | 175.1 | 121.6 | 166.8 |
| Mean entrants per class and year 1933-70 | 168.8 | 179.3 | 162.8 | 180.4 | 164.0 |
| *Panel B: Entrants into patenting:* | | | | | |
| Total entrants (no prior patents) 1920-1970 | 964,526 | 327,224 | 637,302 | 268,084 | 696,442 |
| Mean entrants (no prior patents) per class and year 1920-70 | 113.9 | 106.9 | 117.9 | 109.5 | 115.7 |
| Mean entrants (no prior patents) per class and year 1920-32 | 125.0 | 92.0 | 143.8 | 97.2 | 136.3 |
| Mean entrants (no prior patents) per class and year 1933-70 | 110.1 | 112.1 | 109.0 | 113.7 | 108.7 |

# An additional 58.2 scientists entered class of émigré scientists per year after 1932 (Tab 9, 35% compared with mean of 165.9 entrants for fields of other German chemists)

ORDINARY LEAST SQUARES AND INSTRUMENTAL VARIABLES REGRESSIONS
DEPENDENT VARIABLE IS NUMBER OF ENTRANTS PER YEAR

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | OLS | | | | Instrumental Variables | | | |
| | Entrants into field | | Entrants into patenting | | Entrants into field | | Entrants into patenting | |
| Émigré class * Post | 73.799*** | 58.181*** | 53.434*** | 43.967*** | 162.287*** | 142.119*** | 116.707*** | 109.466*** |
| | (15.674) | (14.715) | (12.522) | (12.261) | (44.195) | (45.982) | (34.565) | (37.863) |
| # foreign patents | No | Yes | No | Yes | No | Yes | No | Yes |
| Quadratic class age | No | Yes | No | Yes | No | Yes | No | Yes |
| Patent pools | No | Yes | No | Yes | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 |
| R-squared | 0.781 | 0.835 | 0.763 | 0.805 | 0.767 | 0.824 | 0.750 | 0.792 |

Standard errors clustered at the class level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# New inventors account for about half of entry (Tab 9)

ORDINARY LEAST SQUARES AND INSTRUMENTAL VARIABLES REGRESSIONS
DEPENDENT VARIABLE IS NUMBER OF ENTRANTS PER YEAR

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | OLS | | | | Instrumental Variables | | | |
| | Entrants into field | | Entrants into patenting | | Entrants into field | | Entrants into patenting | |
| Émigré class * Post | 73.799*** | 58.181*** | 53.434*** | 43.967*** | 162.287*** | 142.119*** | 116.707*** | 109.466*** |
| | (15.674) | (14.715) | (12.522) | (12.261) | (44.195) | (45.982) | (34.565) | (37.863) |
| # foreign patents | No | Yes | No | Yes | No | Yes | No | Yes |
| Quadratic class age | No | Yes | No | Yes | No | Yes | No | Yes |
| Patent pools | No | Yes | No | Yes | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 |
| R-squared | 0.781 | 0.835 | 0.763 | 0.805 | 0.767 | 0.824 | 0.750 | 0.792 |

Standard errors clustered at the class level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

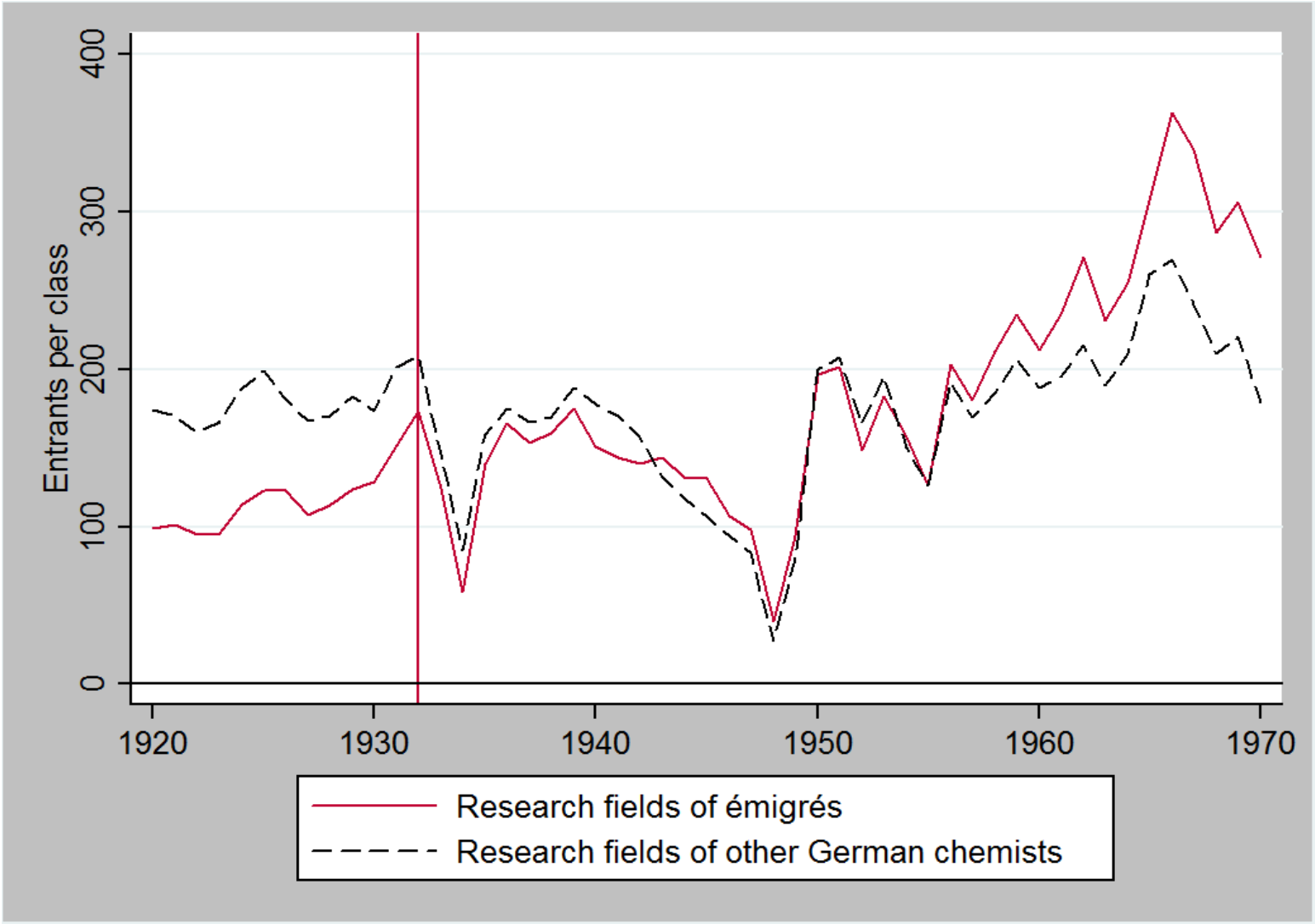
# IV regressions indicate that 142 additional researchers entered fields of émigrés after 1932, about three quarters were new inventors

ORDINARY LEAST SQUARES AND INSTRUMENTAL VARIABLES REGRESSIONS
DEPENDENT VARIABLE IS NUMBER OF ENTRANTS PER YEAR

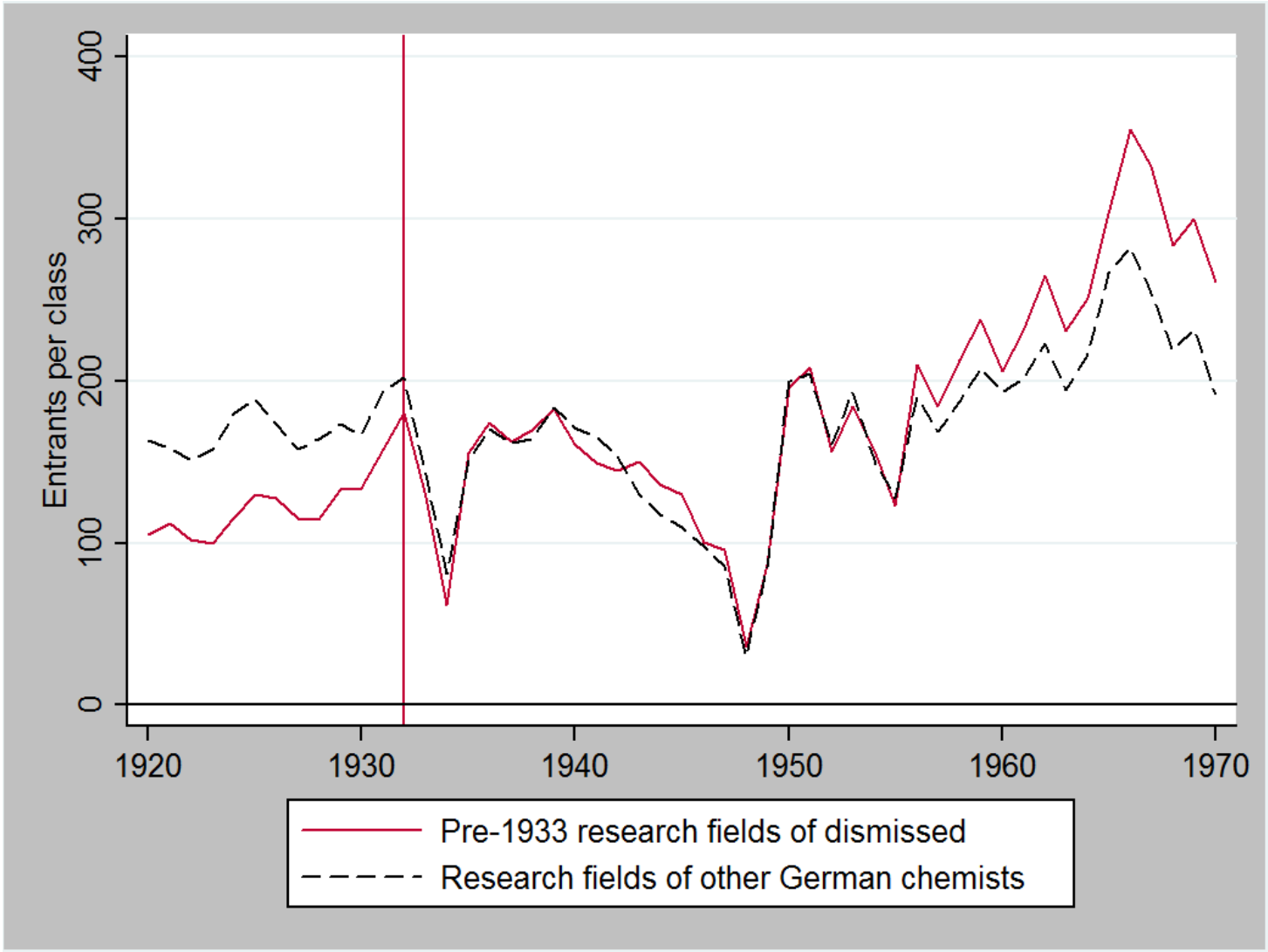
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | OLS | | | | Instrumental Variables | | | |
| | Entrants into field | | Entrants into patenting | | Entrants into field | | Entrants into patenting | |
| Émigré class * Post | 73.799*** | 58.181*** | 53.434*** | 43.967*** | 162.287*** | 142.119*** | 116.707*** | 109.466*** |
| | (15.674) | (14.715) | (12.522) | (12.261) | (44.195) | (45.982) | (34.565) | (37.863) |
| # foreign patents | No | Yes | No | Yes | No | Yes | No | Yes |
| Quadratic class age | No | Yes | No | Yes | No | Yes | No | Yes |
| Patent pools | No | Yes | No | Yes | No | Yes | No | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Class fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 | 8,466 |
| R-squared | 0.781 | 0.835 | 0.763 | 0.805 | 0.767 | 0.824 | 0.750 | 0.792 |

Standard errors clustered at the class level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Entry in émigré classes (Fig 7)



# Entry in pre-1932 fields of dismissed (Fig 8)



# Mechanism: Younger émigrés and co-inventors

- Augment sample to include émigrés below the level of privatdozent
  - Chemists above 17 years in 1933 from *Dictionary of Central European Émigrés* (1987)
  - 139 younger chemists: post-docs, PhD students, RAs
  - 67 migrated to the United States and obtained 175 patents
  - Almost no patents prior to 1933, but active after 1970
- Collect patent records of émigrés' 1st and 2nd order co-inventors
  - 47 co-inventors between 1920 and 1970 who obtained 576 patents
  - 149 2nd order co-inventors who obtained 1,660 patents

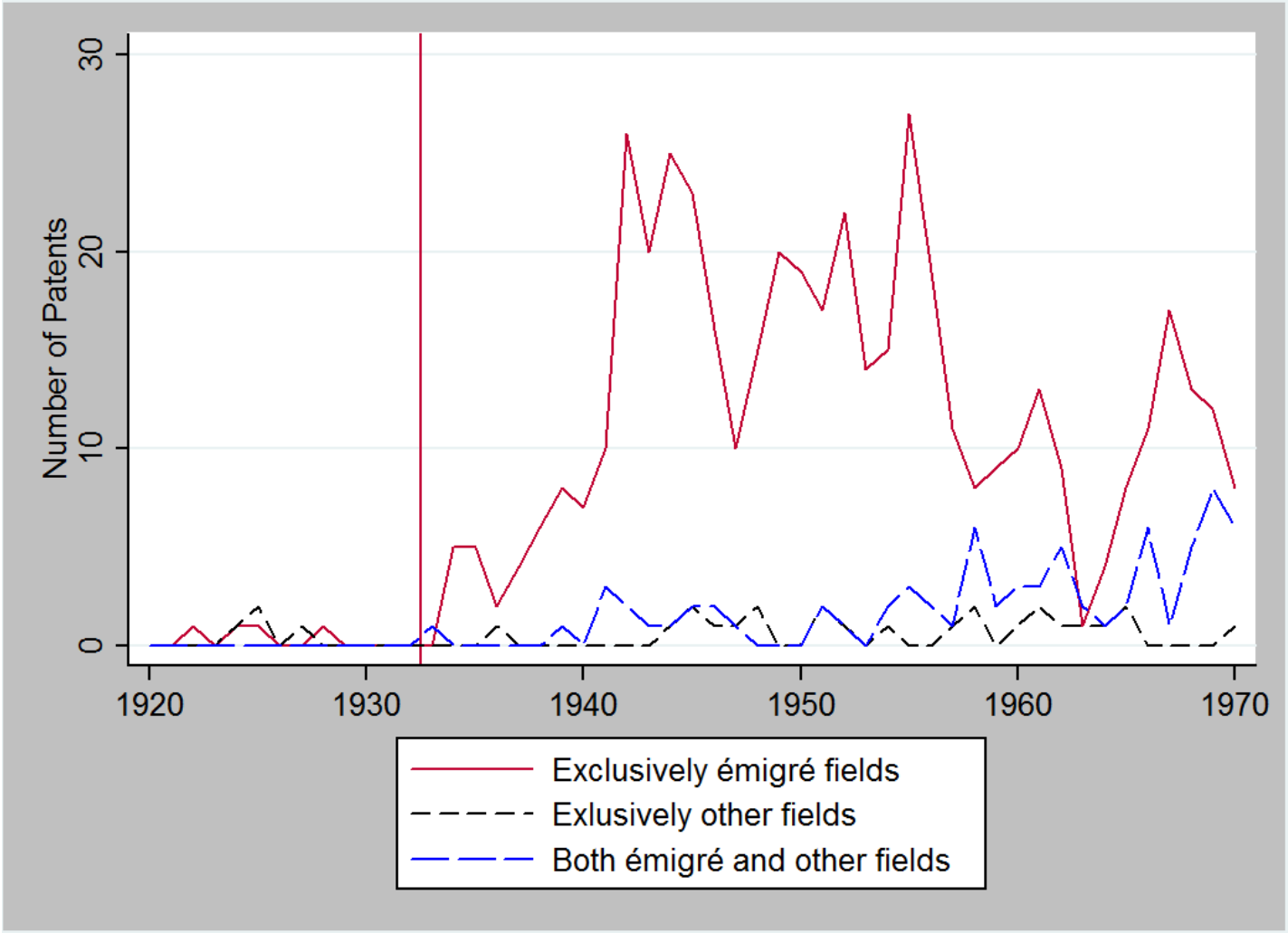
# Co-inventors of émigrés became more likely to patent in émigré fields

| | Patents in 166 technology classes | | |
|---|---|---|---|
| | Patents assigned only to 60 émigré classes | Patents assigned only to 106 non- émigré classes | Patents assigned to both émigré and non- émigré classes |
| *Panel A: Co-inventors of senior émigrés:* | | | |
| 1920-1932 | 4 | 4 | 0 |
| 1933-1970 | 469 | 24 | 75 |
| 1920-1970 | 473 | 28 | 75 |
| *Panel B: Co-inventors of co-inventors of senior émigrés:* | | | |
| 1920-1932 | 48 | 59 | 24 |
| 1933-1970 | 1,103 | 162 | 264 |
| 1920-1970 | 1,151 | 221 | 288 |

# Co-inventors of émigrés became more likely to patent in émigré fields

| | Patents in 166 technology classes | | |
|---|---|---|---|
| | Patents assigned only to 60 émigré classes | Patents assigned only to 106 non- émigré classes | Patents assigned to both émigré and non- émigré classes |
| *Panel A: Co-inventors of senior émigrés:* | | | |
| 1920-1932 | 4 | 4 | 0 |
| 1933-1970 | 469 | 24 | 75 |
| 1920-1970 | 473 | 28 | 75 |
| *Panel B: Co-inventors of co-inventors of senior émigrés:* | | | |
| 1920-1932 | 48 | 59 | 24 |
| 1933-1970 | 1,103 | 162 | 264 |
| 1920-1970 | 1,151 | 221 | 288 |

# Co-inventors patenting activity in émigré fields increased most dramatically after 1940 and remained high through the 1950s



# Younger émigrés move into patenting in émigré fields

| | Patents in 166 technology classes | | |
|---|---|---|---|
| | Patents assigned only to 60 émigré classes | Patents assigned only to 106 non- émigré classes | Patents assigned to both émigré and non- émigré classes |
| 1920-1932 | 6 | 0 | 0 |
| 1933-1970 | 113 | 22 | 34 |
| 1920-1970 | 119 | 22 | 34 |

# Conclusions

- Émigrés had significant positive effect on patents by U.S. inventor
  - OLS estimates imply a 30% increase in U.S. patenting in émigré classes
- Selection into U.S. research fields was negative
  - IV estimates imply a 66% increase in U.S. patenting
  - Pre-1933 knowledge had large impact: reduced form implies a 24% increase
- Mechanisms:
  - No evidence of increased productivity of U.S. inventors
  - Émigrés attracted a new group of scientists to work in their fields
  - Effects prolonged and amplified through émigrés influence on collaborators