Immigration and Invention: Evidence from the Quota Acts

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Scarce Factors of Production and Technological Change

- Sir John Hicks, *The Theory of Wages*, 1932: "a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind – directed to economizing the use of a factor which has become relatively expensive."

Scarce Factors of Production and Technological Change

- In 1962, Sir John Habakkuk's famous hypothesis applied Hicks' argument to the first Industrial Revolution:
  - Labor scarcity in the United States during the first half of the nineteenth century lead to the development of better labor-saving devices in the United States than in England, where labor was plentiful (Habakkuk, 1962).

Scarce Factors of Production and Technological Change

- Because inventions are often designed to economize on labor, it is intuitive that making labor less plentiful should increase the incentive to invent.
- Consider, for example, the famous inventions of America's Second Industrial Revolution in the late nineteenth and early twentieth centuries:
  - automated assembly lines
  - new consumer goods designed to be mass produced cheaply, such as Ford's automobile, or cheap and long-lasting electric light bulbs.
- Since these inventions allowed the same quality good to be produced for much less labor, the incentive to invent these inventions should have increased when labor was scarce.
  - person hours to produce a usable automobile declined by 80 percent

Scarce Factors of Production and Technological Change

- But, in fact, the usefulness of these inventions was not unrelated to scale.
- Consider the cluster of inventions around the automobile, for example:
  - Henry Ford's new automobile factory was the largest production facility in the world.
  - 3,000 parts needed to be combined through 7,882 tasks.
  - Given so many unique tasks, in order to take advantage of the full benefits of the division of labor, the new assembly line required 14,000 employees.
  - The output totaled 300,000 automobiles a year, requiring a large consumer base to recoup costs.
- Thus, it is possible that, in general equilibrium, it wouldn't have been worthwhile to invent the inventions characteristic of America's second industrial revolution without both plentiful labor supply and consumers.

Scarce Factors of Production and Technological Change

- Indeed, (Acemoglu, 2010) shows that in general equilibrium, contrary to Hicks and Habakkuk, plentiful labor supply will encourage invention in the context of any of the canonical macroeconomic models:
  - "In most models used in the macroeconomics and growth literatures, . . . labor scarcity will discourage rather than induce technological change."
- Outside the context of canonical macroeconomic models, there exist other models in which labor scarcity does encourage technological change in general equilibrium:
  - Chambernowne (1963), Zeira (1998, 2006), and Hellwig and Irmen (2001).

Scarce Factors of Production and Technological Change

- This long-running debate is not only theoretical; it intersects with a policy question of perennial concern: how will mass migration affect the innovativeness of a society, and thus long-term economic growth?
- On the one hand, under the Hicks/Habakkuk hypothesis mass migration will reduce labor scarcity and thereby reduce the incentive to invent.
- On the other hand, under the Acemoglu general equilibrium results, mass migration will reduce labor scarcity and thereby increase the incentive to invent.
- In spite of the importance of this question to both economic theory and policy, the causal empirical literature relating immigration to innovation has not addressed it.

Scarce Factors of Production and Technological Change

- How can we use empirical evidence to address this debate?

How to test whether the relationship is positive or negative

- We need an event which changed immigration rates
- We need the change in immigration to last an extended time
- We need the change in immigration to vary across locations
- We need many such locations, for sufficient statistical power
- We need there to be innovators or potential innovators in each of these locations
- We need to be able to measure innovation outcomes of individuals living in these locations over an extended period of time

How to test whether the relationship is positive or negative

- (Abramitzky and Bouston, 2017) write: "We believe that there is a large scope for future work on the historical effects of immigrant arrivals on the US economy and society. Recent work on contemporary immigration flows has introduced improved identification strategies to study the effect of immigrants on native workers; these empirical innovations have yet to be fully incorporated into work on the Age of Mass Migration. The dramatic shift in immigration regime in the 1920s presents a potentially useful opportunity to design well-identified studies of the effect of immigration on the economy in this era."

How we test this relationship

- In this paper, we consider the closing of the United States' borders in the early 1920s.
- Before 1921, the United States had nearly open borders with Europe.
- By 1921, many people of Western European background became worried about the increasing portion of new immigrants from Southern and Eastern Europe.
- In 1921, and again in 1924, the United States enacted country-specific immigration quotas that targeted immigration from countries such as Italy and Russia, but not Great Britain or Norway.

Potential Strategy

- Some U.S. cities typically received immigrants from Southern and Eastern Europe.
- Other U.S. cities typically received immigrants from Western and Northern Europe.
- By comparing inventors in both groups of U.S. cities with each other over time, we can see how inventors who experienced a large decrease in overall immigration to their city compared to otherwise similar inventors living in otherwise similar cities that did not experience a large decrease in overall immigration.

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- In the last two years, seven papers have used the quotas to estimate the effects of mass migration on economic outcomes, but none of them have estimated its effects on innovation.
- We calculate exposure to the quota using the same quota-exposure formula as Ager and Hanson (April, 2018), also based on (Xie, 2017).

Total immigration inflows per fiscal year from administrative data

Immigration from Southern and Eastern Europe as a fraction of total immigration

History of Quotas

- 1921: annual quota of each nationality at 3% of the number of foreign-born persons of such nationality resident in the US in 1910
- 1924: annual quota of each nationality at 2% of the number of foreign-born persons of such nationality resident in the US in 1890

Annual Size of the 1924 Quota, by country

Northwest Europe and Scandinavia		Eastern and Southern Europe		Other Countries	
Germany	51,227	Poland	5,982	Africa	1,100
UK	34,007	Italy	3,845	Armenia	124
Ireland	28,567	Czechoslovakia	3,073	Australia	121
Sweden	9,561	Russia	2,248	Palestine	100
Norway	6,453	Yugoslavia	671	Syria	100
France	3,954	Romania	603	Turkey	100
Denmark	2,789	Portugal	503	Egypt	100
Total (Number)	142,483	Total (Number)	18,439	Total (Number)	3,745
Total (%)	86.50%	Total (%)	11.20%	Total (%)	2.30%

New Immigration from Italy in 1921 = 222,260
Quota for Italy after 1921 = 40,294
Quota for Italy after 1924 = 3,845

New Immigration from Scandanavia in 1921 = 22,854
Quota for Scandanavia after 1921 = 41,412
Quota for Scandanavia after 1924 = 18,665

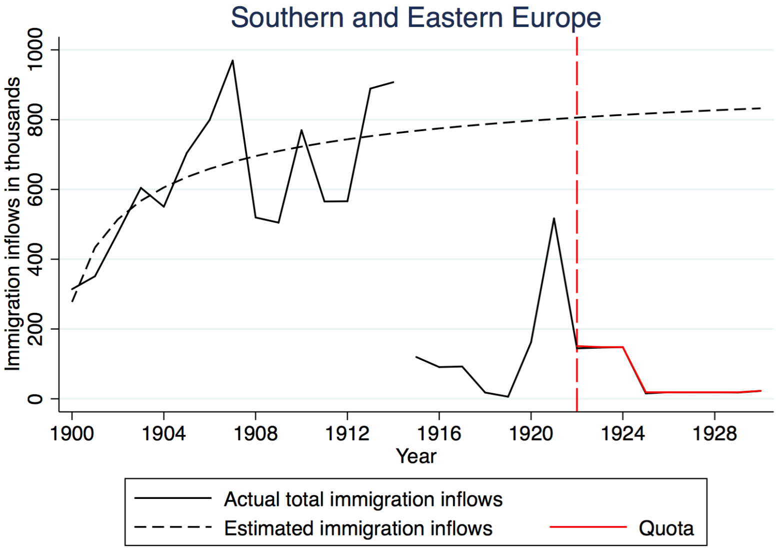
History of Quotas

- Representative Ira Hersey of Maine: "We have thrown open wide our gates and through them have come other alien races, of alien blood, from Asia and southern Europe . . . with their strange and pagan rites, their babble of tongues."
- Senator Earl Michener of Michigan: "The Nordic People laid the foundations of society in America. They have builded this Republic, and nothing would be more unfair to them and their descendants than to turn over this Government and this land to those who had so little part in making us what we are"
- Senator Reed of Pennsylvania: "maintain the racial preponderance of the basic strain on our people and thereby to stabilize the ethnic composition of the population."
- Opposed to ethnic organizations such as the Sons of Italy

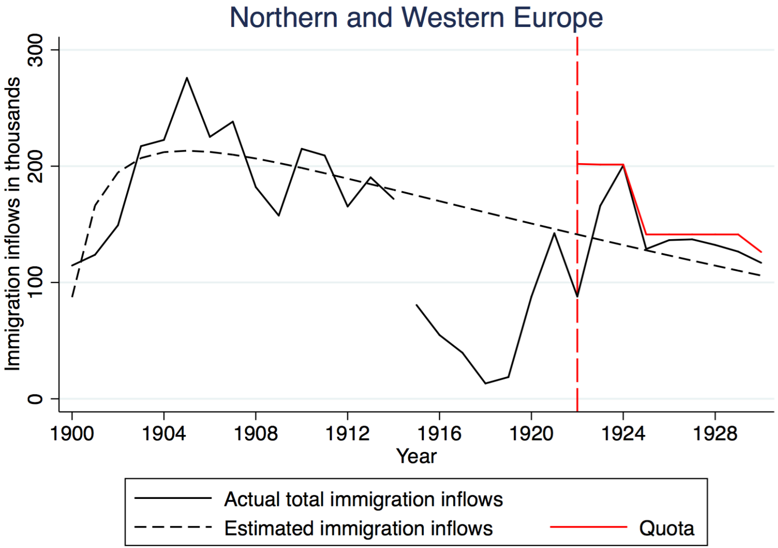
How many immigrants were "missing" due to the Quotas?

- Following (Ager and Hanson, 2018) and (Xie, 2017), we can project earlier immigration flows by source country forward in time, and calculate the difference between what immigration we would have expected based on previous flows and what we got under the quotas.
- We do this twice, once for Southern and Eastern Europe source countries, and once for Northern and Western Europe source countries.

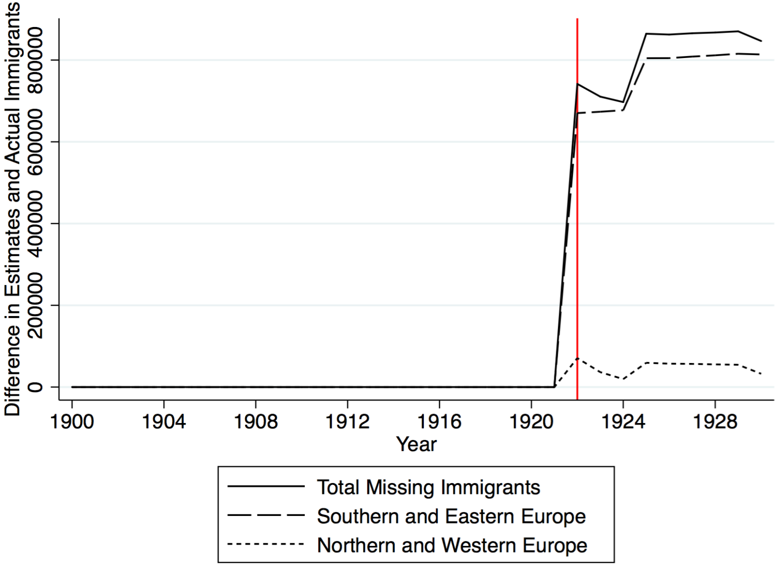
Immigration inflows versus quota



Immigration inflows versus quota



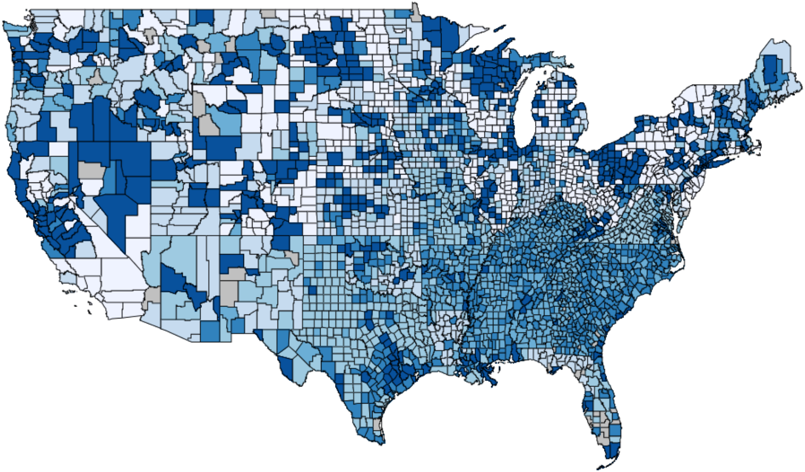
Missing immigration inflows under quota



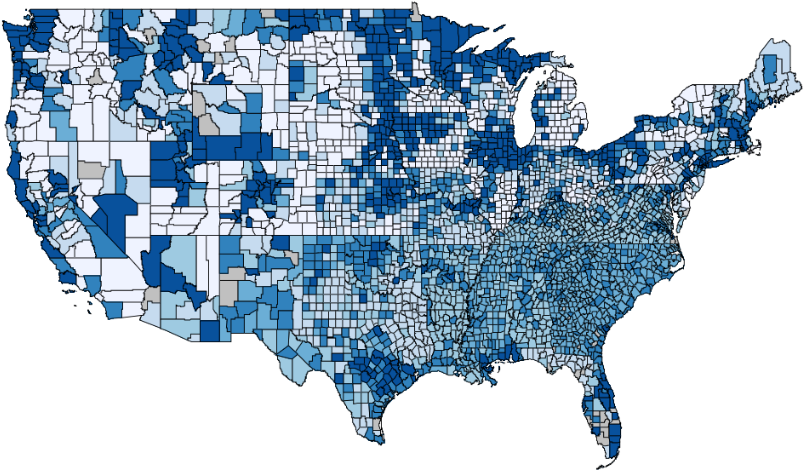
Different cities attracted different immigrants

- Some cities should be missing more immigrants than others, because some cities had a history of receiving immigrants from some sources but not others.
- Boston, MA had a total population in 1920 of about 650,000 people, of which about 35% were foreign born.
- Cleveland, OH had a total population in 1920 of about 560,000 people, of which about 35% were foreign born.
- But Cleveland was about twice as likely as Boston to have immigrants who were from countries targeted in the quota.

Geographic distribution of foreign born from Southern and Eastern Europe as a fraction of 1920 total population conditional on state fixed effects



Geographic distribution of foreign born from Northern and Western Europe as a fraction of 1920 total population conditional on state fixed effects



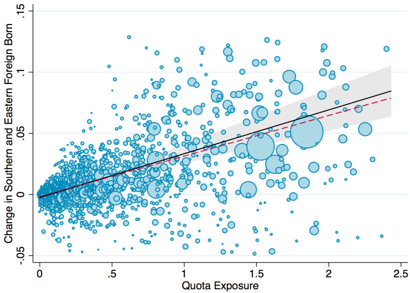
Treated cities

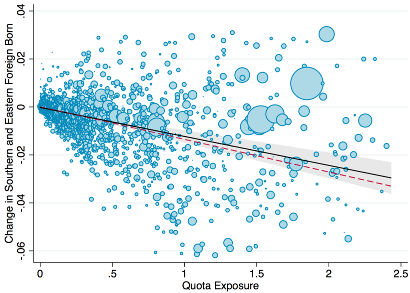
- There are 3,339 cities in our data. each city, we calculate its quota exposure:

$$QuotaExposure_c = \frac{100}{P_{c,1920}} \sum_{j=1}^{J} \left(\widehat{I}_{j,22-30} - Quota_{j,22-30} \right) \frac{FB_{jc,1920}}{FB_{j,1920}} \tag{1}$$

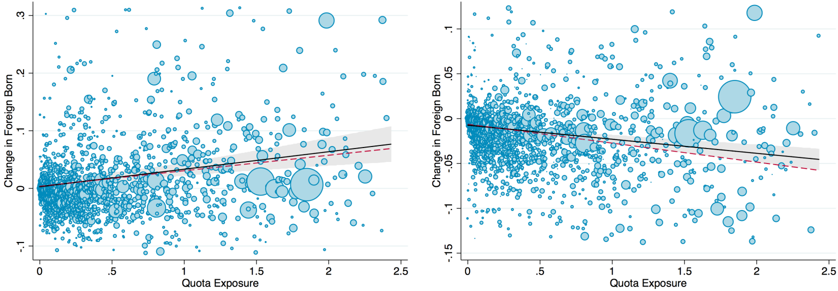
  where $\widehat{I}_{j,22-30}$ is the estimated average immigration inflows per year from country j during the post-quota years from 1922 and 1930 if the quota acts had not been enacted.
- The variable $QuotaExposure_c$ represents the average annual number of "missing" immigrants per-100-inhabitants in city c due to quotas.
- We usually use a continuous measure of treatment, but when we use a discontinuous measure, we choose as our treated cities the 273 cities with the highest quota exposure.

Change in foreign born population from Southern and Eastern Europe, 1910-1920, 1920-1930

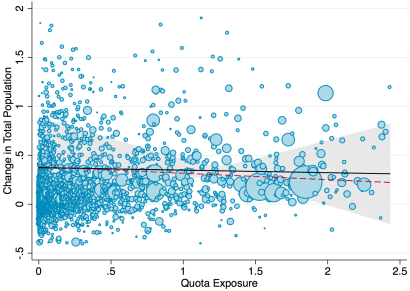


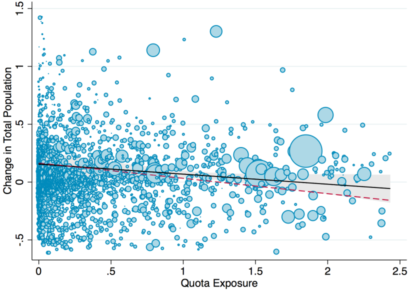


Change in foreign born population, 1910-1920, 1920-1930



Change in total population, 1910-1920, 1920-1930





Effect of Quota on Population and Workforce

	Southern/Eastern FB		Foreign Born		Total	
	1910-1920	1920-1930	1910-1920	1920-1930	1910-1920	1920-1930
Dependent Variable: Change in Population as a Fraction of Total City Population						
Quota	0.0358***	-0.0121***	0.0304***	-0.0157***	-0.0257	-0.0870*
	(0.0047)	(0.0014)	(0.0081)	(0.0027)	(0.2141)	(0.0450)
Mean	0.0082	-0.0038	0.0119	-0.0117	0.3660	0.1301
Cities	3208	3327	3208	3327	3208	3327
R-squared	0.1691	0.1230	0.0028	0.0173	0.0000	0.0004
Dependent Variable: Change in Workers as a Fraction of Total City Population						
Quota	0.0092***	-0.0062***	-0.0013	-0.0074***	-0.0188	-0.0292**
	(0.0029)	(0.0008)	(0.0046)	(0.0014)	(0.0551)	(0.0145)
Mean	0.0010	-0.0018	-0.0030	-0.0043	0.0481	0.0520
Cities	3206	3323	3206	3323	3206	3323
R-squared	0.0561	0.0996	0.0000	0.0151	0.0000	0.0004

Effect of Quota on Immigrant Inflows

Dependent Variable: New Immigrants as a Fraction of 1910 Population

	1900-1929		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota $\times$ Post	-0.0036***	-0.0037***	-0.0010***	-0.0015***
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Dep.Var.Mean	0.0029	0.0028	0.0022	0.0022
N	92190	92190	33803	33803
Cities	3073	3073	3073	3073
R-squared	0.5708	0.5691	0.6495	0.6534

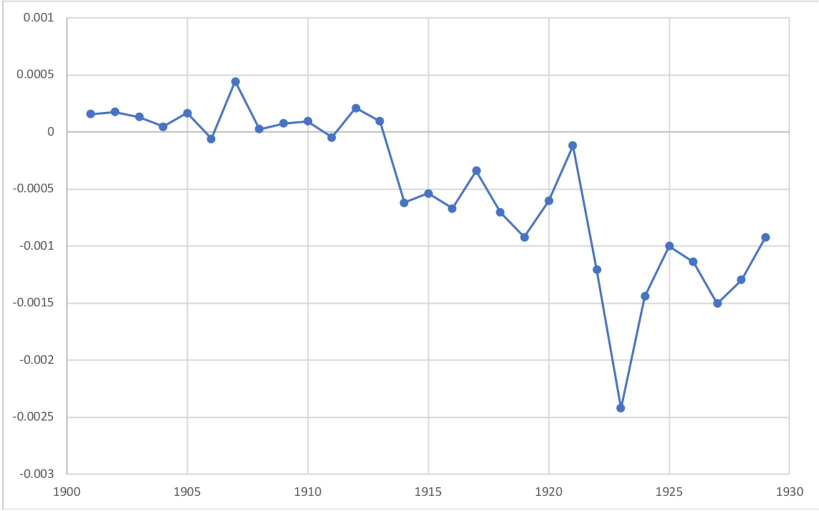
Can we make even better comparison groups?

- The treated cities had higher levels of immigration overall than the comparison cities before the quotas.
- It would be useful to compare cities that had similar levels of immigration before the quotas, but were differentially affected.
- We create synthetic controls for each of the 273 cities with high exposure to the quotas, choosing cities with similar pre-quota immigration levels, total populations, and patents per person. The synthetic controls are intentionally dissimilar in one important way: they have immigrants from non-quota-affected source countries.
- We then compare people living in highly exposed cities to those in the synthetic controls before and after the shock. We consider outcomes such as patents per year, citations per year, as well as lifetime patents for those who experienced the shock as children.

Synthetic Control Method

- We use the synthetic control method of Abadie, Diamond, and Hainmueller (2011).
- It provides a data-driven procedure to construct synthetic control units based on a convex combination of comparison units that approximates the characteristics of the unit that is exposed to the intervention.
- Donor pool of potential synthetic control cities: 2,932
- We match cities on: (1) total population in 1910; (2) foreign born population 1910; (3) average patents per year between 1915 and 1921; and (4) the number of immigrants with arrival years 1905, 1910, 1913, 1917, and 1921 as a fraction of the city's 1910 total population.

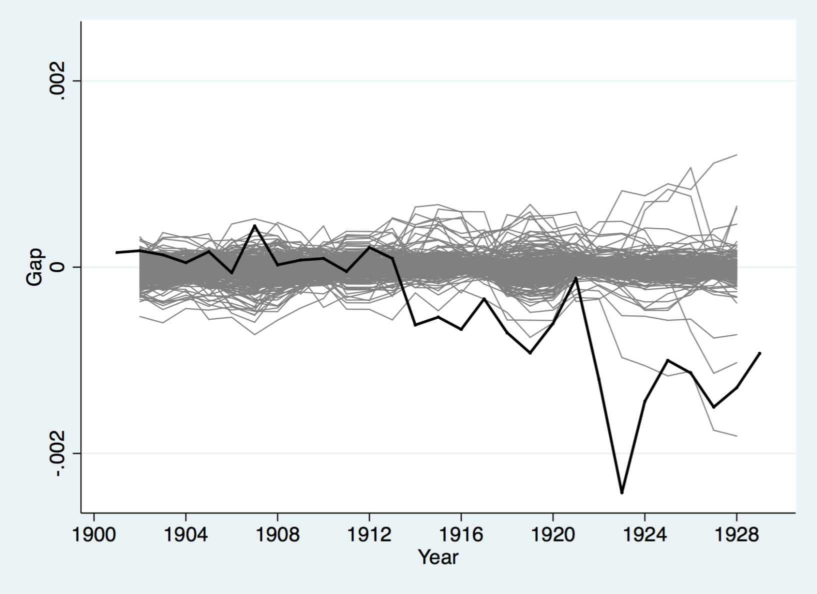
New Immigrants to the U.S. per year as a fraction of 1910 U.S. population
The average of GAPS between highly exposed cities and synthetic cities.



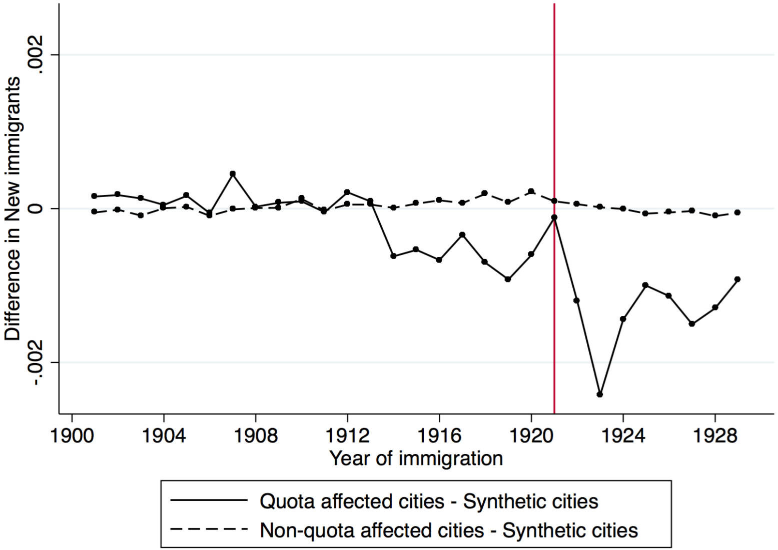
How unusual is it for otherwise similar cities to diverge after 1921?

- Do otherwise similar cities with immigrants from the same source countries also have diverging immigration rates after 1921?
- We consider 524 placebo treatment cities between the 10 and 25 percentiles of quota-exposure.
- We use the same synthetic control method to pick synthetic control cities for these placebo treatment cities.
- Placebo treatment cities do not vary from their control cities much compared to the actually treated cities from their control cities.

New Immigrants to the U.S. per year as a fraction of 1910 U.S. population



New Immigrants to the U.S. per year as a fraction of 1910 U.S. population



How did innovators living in these cities respond?

- We consider people living in treated and control cities in 1919 (observed in 1920 US Census).
- First sample of interest: people who have already completed at least one patent by the year 1919 (pre-existing inventors).
- We need the data to accomplish this.

Data

- We identify who is living where in 1919 through the complete count 1920 US Census with names.
- We identify inventors of all US patents from 1899 to the present through the EPO's PATSTAT database.
- We make use of a merge between the 1920 US census and the PATSTAT database at the individual name level from Doran (2018).

Merging Patents into the Census

- In Doran (2018), I use a fuzzy matching procedure to merge patents and publications at the individual-name level into the 1900, 1910, 1920, 1930, and 1940 US Censuses.
- Idea: each US Census tells us how many people living in the US at that time had your unique first name, middle name, and last name combination.
- Almost half of the population is made up of people who are the only person in the country with their first name, middle name, and last name combination.

Merging Patents into the Census

- Names restriction: 43% of US population made up of people with unique names in 1920 Census
- Years restriction: patents by these people btwn ages of 18 and 80
- How plausible is the merge?
  - If you have a unique name in the 1920 Census (observed in 1919), then any patents applied in the years 1919 through 1929 with your unique name must either be from you, or from someone who immigrated to the United States with your unique name during those years. They could not be from someone born after 1919 with your unique name, because any such person would be younger than 10 years old. They could not be from someone born before 1919 who died by 1919, because such a person would be dead.

Difference-in-Differences Specifications

- We estimate regressions of the following form:

$$Y_{ict} = \alpha + \beta(Quota_c \times Post_t) + X_{it} + \tau_t + \gamma_i + \epsilon_{ict}$$

- Y_{ict}: The number of patents or citations of person i in year t
- $Quota_c$: Quota exposure of city c
- $Post_t$: 1 if year $\geq$ 1924, 0 otherwise
- X_{it}: Quartic of age of person i in year t
- Standard errors are clustered at the city level.

Difference-in-Differences Results

Dependent Variable: Patents by Incumbent Inventors in 1919

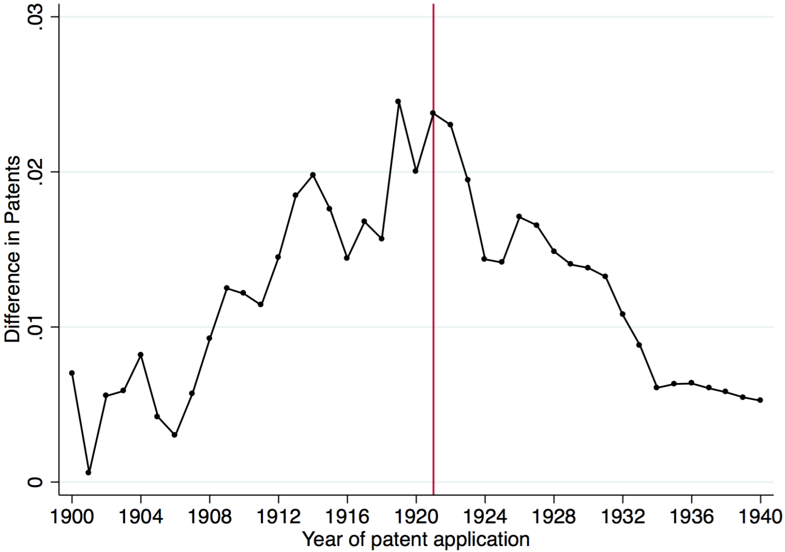
	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota $\times$ Post	-0.0018**	-0.0031***	-0.0037***	-0.0046***
	(0.0009)	(0.0009)	(0.0012)	(0.0011)
Dep.Var.Mean	0.1252	0.1206	0.1060	0.0936
N	6577575	6577575	1573627	1573627
Inventors	145842	145842	145842	145842
Cities	3311	3311	3311	3311
R-squared	0.2327	0.2327	0.4003	0.4003

Difference-in-Differences Results

Dependent Variable: Patents by Incumbent Inventors in 1910

	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota × Post	-0.0051***	-0.0061***	-0.0039**	-0.0048***
	(0.0017)	(0.0017)	(0.0018)	(0.0015)
Dep.Var.Mean	0.1448	0.1389	0.0808	0.0784
N	3700540	3700540	871536	871536
Inventors	81308	81308	81308	81308
Cities	3275	3275	3274	3274
R-squared	0.2655	0.2655	0.4425	0.4425

Difference in patent applications per year between highly exposed inventors and comparison inventors;



What about the synthetic comparison groups?

- We need to weight each inventor in each treated city and each control city by the right amount using the city-level weights produced by the synthetic control method.
- $weight_j = \sum_q \frac{w_j^q}{p_j} \cdot \frac{p_q}{\sum_q p}$

  where j $\in$ control city, q $\in$ treatment city

  w_j^q: weight, p: the number of individuals given a city

Difference-in-Differences Results using Synthetic Matching

Dependent Variable: Patents by Incumbent Inventors in 1919

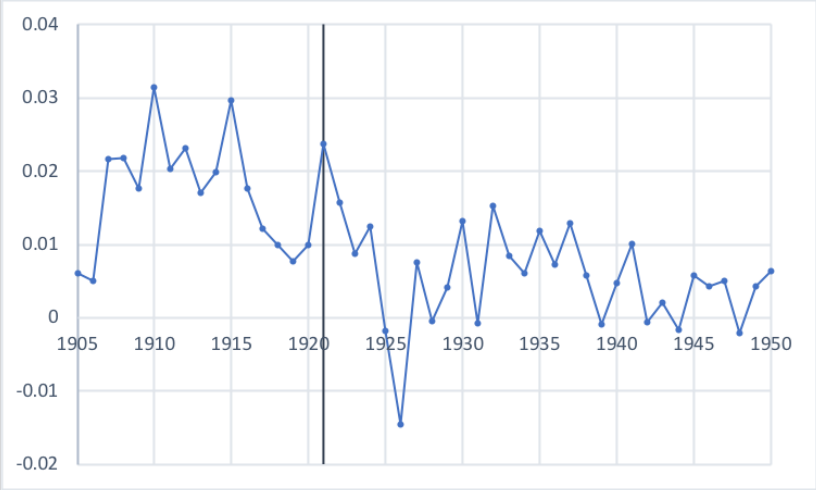
	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota $\times$ Post	-0.0020**	-0.0034***	-0.0033**	-0.0044***
	(0.0009)	(0.0010)	(0.0014)	(0.0013)
Dep.Var.Mean	0.1252	0.1207	0.1070	0.0945
N	5185714	5185714	1237749	1237749
Inventors	114568	114568	114568	114568
Cities	1824	1824	1824	1824
R-squared	0.2243	0.2244	0.3974	0.3974

Difference-in-Differences Results using Synthetic Matching

Dependent Variable: Patents by Incumbent Inventors in 1910

	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota × Post	-0.0058***	-0.0068***	-0.0034*	-0.0046***
	(0.0019)	(0.0020)	(0.0021)	(0.0016)
Dep.Var.Mean	0.1443	0.1384	0.0810	0.0785
N	2906830	2906830	682911	682911
Inventors	63621	63621	63621	63621
Cities	1802	1802	1801	1801
R-squared	0.2584	0.2584	0.4459	0.4460

Gap in the Number of Patents per year between inventors in highly exposed cities and inventors in synthetic cities.



Difference-in-Differences Results

Dependent Variable: Citations by Incumbent Inventors in 1910

	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota $\times$ Post	-0.0109***	-0.0130***	-0.0077	-0.0103**
	(0.0033)	(0.0034)	(0.0069)	(0.0049)
Dep.Var.Mean	0.2402	0.2353	0.1828	0.1825
N	3700540	3700540	871536	871536
Inventors	81308	81308	81308	81308
Cities	3275	3275	3274	3274
R-squared	0.1616	0.1616	0.2536	0.2536

Magnitudes

- Pre-existing inventors completed 0.5% fewer patents per year for every 10% fewer immigrants entering their city that year.

Mechanisms

- One possible mechanism for the results above is one inspired by (Acemoglu, 2010).
  - It is possible that the equilibrium quantity of “strongly labor-complementary” inventions is lower in an industry in which labor is scarce compared with an industry in which labor is plentiful.
  - If many incumbent inventors had been used to supplying strongly labor-complementary inventions to quota-exposed local industries before the quotas, then it is possible that decreased incentives to do so after the quotas decreased their overall rates of invention.

Mechanisms

- To test this hypothesis, we first determine whether some industries were more exposed to the quotas than others. We estimate the following equation at the industry-year level:

$$Y_{jt} = \alpha + \beta(QuotaExposure_j \times PostTreatment_t) + \tau_t + \gamma_j + \epsilon_{jt} \quad (2)$$

where Y_{jt} is the number of newly arrived immigrants per year into industry j rescaled by 1920 total workers in that industry j.

Difference-in-Differences Results

Dependent Variable: Industry Immigration Inflows as a Fraction of Total Workers

	1900-1929		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota × Post	-0.0944*	-0.0777**	-0.0593	-0.0307***
	(0.0524)	(0.0378)	(0.0359)	(0.0112)
Dep.Var.Mean	0.0157	0.0190	0.0207	0.0280
N	2920	2920	1606	1606
Industries	146	146	146	146
R-squared	0.4073	0.4056	0.7682	0.7677

Mechanisms

- How much of the decline in patents by incumbent inventors in quota affected locations can be attributed to their decline in patents relevant for local quota-affected industries?
- How much of the decline in patents can be attributed to a decline in patents for non-quota affected industries?

Difference-in-Differences Results

Dependent Variable: Patents Related to Affected Industry

	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota $\times$ Post	-0.0034***	-0.0041***	-0.0045***	-0.0048***
	(0.0012)	(0.0012)	(0.0017)	(0.0015)
Dep.Var.Mean	0.0965	0.0853	0.0748	0.0727
N	1572390	1572390	870996	870996
Inventors	145842	145842	81308	81308
Cities	3311	3311	3274	3274
R-squared	0.4271	0.4271	0.4974	0.4974

Difference-in-Differences Results

Dependent Variable: Patents Unrelated to Affected Industry

	1900-1950		1919-1929	
	Post-Treatment Year			
	1922	1924	1922	1924
Quota × Post	-0.0004	-0.0005	0.0004	0.0001
	(0.0003)	(0.0003)	(0.0004)	(0.0004)
Dep.Var.Mean	0.0078	0.0071	0.0056	0.0054
N	1572390	1572390	870996	870996
Inventors	145842	145842	81308	81308
Cities	3311	3311	3274	3274
R-squared	0.2853	0.2853	0.2750	0.2750

Mechanisms

- It is apparent that nearly all of the reduction in patent applications reported in Table 5 was due to a reduction in applications relevant for highly quota-exposed industries (those with quota-exposure above the 75th percentile). Patent applications relevant for non-highly quota-exposed industries did not significantly change.
- These results suggest that what declined substantially after the quotas was the invention of technology relevant for industries that lost workers due to the quotas.
- In these industries, labor became scarce, and this discouraged particular types of invention.
- In the context of (Acemoglu, 2010), this suggests that much of the invention at the time was "strongly labor-complementary".

Mechanisms

- We are still trying to determine whether occupations that may free inventor's time (such as household help) lost immigrants after the shock.
- This could provide an additional mechanism for the effects (Cortes and Tessada, 2011); (Cortes and Pan, 2013).

Conclusions

- In this paper, we provide the first causal evidence on the effect of mass immigration on U.S. inventors.
- We do so at the end of the largest international migration in history, during the tail end of America's second Industrial Revolution.
- Our results suggest that a ten percent reduction in mostly low-skilled immigration results in a 0.5 percent reduction in the number of patent applications by incumbent U.S. inventors.

Conclusions

- The results are not an artifact of a changing pool of inventors, differential pre-quota trends, or the loss of uncited patent applications.
- The results seem to be driven by inventors who had specialized in providing "strongly labor complementary" inventions (Acemoglu, 2010) for local industries.
- Assigning each patent to its' relevant industries, we find that nearly all of the decline occurred among the subset of patents relevant for the industries whose workforces were most exposed to declining immigrant flows after the quotas.

Conclusions

- Because inventions in general, and the inventions of the second industrial revolution in particular, are often designed to economize on labor, it is intuitive that making labor less plentiful should increase the incentive to invent.
- Since the work of Sir John Hicks (1932) and Sir John Habakkuk (1962), this intuition has suggested that America's early labor scarcity promoted its early technological development.
- But, building off of the general equilibrium results of (Acemoglu, 2010), our paper suggests that at least during the golden age of American invention, it was plentiful labor that made invention worthwhile.

Conclusions

- From a historical perspective, therefore, it appears that it was not necessity that was the mother of invention, but rather opportunity.

Next Steps

- What about the extensive margin? Does more years of exposure to unexpectedly low immigration levels reduce one's probability of *becoming* an inventor?
- What kinds of inventions were not produced? Does immigration impact some areas in the space of ideas more than others?