Immigration and Invention:

Evidence from the Quota Acts

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Abstract

Inventions often economize on labor, so economists have long posited that scarce labor should encourage invention (Hicks, 1932). But the production of new inventions often requires a division of labor and economies of scale which are difficult to achieve without plentiful labor, meaning scarce labor could discourage invention. We provide the first causal evidence of the effect of mass immigration on invention, using variation induced by 1920s quotas, which ended history's largest international migration. Inventors working in cities and industries exposed to fewer low-skilled immigrants applied for fewer patents. Industries with small establishment sizes, which attracted few patents when labor was plentiful, attracted an ever-increasing share of invention once labor was scarce. It appears both the rate and direction of inventive activity are crucially tied to available labor. In particular, the inventions characteristic of America's second industrial revolution relied on scale made possible by mass immigration of low-skilled immigrants.

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I Introduction

Mass immigration can affect the potential scale of production. In a world of continuous mass immigration, it is possible to build a large factory in an empty and unattractive area and still attract a sufficient number of workers willing to do repetitive and low-skilled tasks for low pay. This opportunity can affect what and how much inventors choose to invent.

In this paper, we share evidence that the existence of such continuous mass migration from 1880 through 1920 in America affected the rate and direction of inventive activity in the U.S., incentivizing the inventions behind the "American System of Manufacturing", "Fordism", and mass production. We find that strict 1920s immigration quotas largely ended such mass migration to the U.S., bringing about a change in American invention towards inventions whose usefulness was less directly reliant on large scale in production. It is likely that these forces are still at work, affecting the rate and direction of inventive activity around the world today.

Intuitively, it would seem that mass immigration should discourage inventions which economize on labor. Indeed, since Hicks (1932), economists have posited that scarce factors of production will encourage inventions that economize on the scarce factor. The famous Habakkuk hypothesis (Habakkuk, 1962) applied this argument to the first Industrial Revolution, positing that relatively scarce labor in early nineteenth century America incentivized invention. But these classic and intuitive arguments are incomplete. For example, the theoretical results in Acemoglu (2010) show that in general equilibrium, contrary to Hicks and Habakkuk, plentiful labor supply will encourage invention whenever new technology increases the marginal product of labor, and that indeed this is how technology is conceptualized in all canonical macroeconomic models. 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? The intuitive argument of Hicks and Habakkuk suggests that inventions, often labor-saving in a casual sense, will be disincentivized by mass migration; canonical macroeconomic models suggest the opposite. 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.[1] It has been difficult to find a natural experiment that could reveal the effects of truly mass immigration on invention. In this paper, we introduce the first causal evidence to this debate.

In order to fill in this gap in the literature, one needs a shock to mass immigration that is large enough to affect overall labor supply and extends over time for long enough to affect a long-term process such as invention. Furthermore, the shock must vary across a sufficient Number of cities and industries to allow sufficient statistical power to detect changes in rare events such as patenting. Finally, the shock to immigration must be unrelated to changes in the domestic demand for labor across cities and industries over time. We propose the closing of America's borders to Southern and Eastern Europe brought about by the Quotas of 1921 and 1924 as a shock that can satisfy all of these conditions. Abramitzky and Boustan (2017) suggest making use of these quotas, the largest policy reductions of the largest international migration in human history, to estimate the effect of mass immigration on economic outcomes. In the last two years, numerous studies have applied versions of the identification strategy of Ager and Hansen (2018) and Xie (2017) in order to estimate various geographically localized economic effects of mass immigration through the policy shock of the quotas.[2] The Ager and

[1]Previous empirical studies have focused on the effect of small numbers of highly skilled immigrants on innovation, in part because of data availability, and in part because innovation is an inherently social and reciprocal phenomenon among highly skilled peers (Lucas, 2009). See Kerr and Lincoln (2010), Borjas and Doran (2012), Moser, Voena, and Waldinger (2014), Borjas and Doran (2015), and Borjas, Doran, and Shen (2018).

[2]None of the seven papers in this burgeoning literature address the question of how mass migration affects innovation. Rather, they explore the effects of the quotas on: migration (Greenwood and Ward, 2015; Massey, 2016; Ward, 2017); population size, fertility, occupational sorting, and manufacturing productivity (Ager and Hansen, 2018); native migration and investment in human capital (Abramitzky and Boustan, 2017); government spending and politics (Tabellini, 2019); and manufacturing wages and migration (Xie, 2017). In 2017 and early 2018, we presented similar preliminary results to those reported in this paper, using a similar strategy, before we became aware of the existence of papers using the quotas to estimate the effect of mass immigration on other, complementary outcomes. Here, for comparability with the prior literature, we use the "missing immigrant" calculations in Ager and Hansen (2018) and Xie (2017), although our results

Hansen (2018) and Xie (2017) identification strategy is based on variation over time in the enactment of the quotas coupled with variation across locations in the quotas' impact. The quotas targeted immigration from Southern and Eastern Europe, while seeking continued immigration from Northern and Western Europe. America went from nearly open borders with Europe to a reduction in Italian Immigration of over 90%; at the same time, immigration from Scandinavia decreased by only 18%.

Because there is history dependence in which specific cities immigrants from specific source countries tend to choose (Card, 2001), the quotas disproportionately decreased immigration inflows to cities that had tended to receive immigrants from Southern and Eastern Europe before the quotas. As a result, we can learn the impacts of a reduction of immigrant inflows to a city by comparing cities with high Southern and Eastern European immigrant inflows before the quotas with otherwise similar cities with high Northern and Western European immigrant inflows before the quotas.

We apply a version of this identification strategy across both locations and industries in order to address our question of interest through a novel merge of newly released data. We measure outcomes for treated and comparison cities through complete count U.S. Census data with names from the 1920 U.S. Census, merged at the individual person level to all U.S. Patents from 1899 to the present from the PATSTAT database. We supplement this matched data with Census data from the 1910 and 1930 Censuses as well. Using this data, we identify both cities and industries that were highly exposed to the Quotas, and apply difference-in-differences methods to compare the exposed cities and industries with otherwise similar comparison cities and industries.

In cities where the quotas reduced the inflow of immigrants, incumbent inventors reduced their number of patent applications per year compared to what they would have produced based on their previous patenting profiles or based

are robust to any of the small variations in strategy in the existing literature, in particular the alternative instruments and state-year-level dummies used in (Tabellini, 2019).

on the patenting profiles of otherwise similar inventors in otherwise similar but less affected cities. For every ten percent reduction in new immigrants arriving in a city per year, inventors in that city reduced their patent applications by 0.5 percent per year. We also find similar reductions in citation-weighted patents, as well as overall patent applications among the whole population, both incumbent and non-incumbent inventors combined.

Each patent application in our database is relevant to some industries but not others. It turns out that much of the reduction in invention in quota-exposed cities arises because inventors living in these quota-exposed cities had been disproportionately applying for patents that were designed to be relevant for local, quota-exposed industries. In particular, we find that nearly all of the decline in patent applications by inventors living in quota-exposed cities can be explained by a decline in their inventions specifically relevant for local industries above the 75th percentile in their exposure to the quota; inventions relevant for non-quota-exposed industries do not significantly change. This suggests that the mechanism in Acemoglu (2010) is at work: industries experienced reduced inflows of new immigrants as employees, causing local inventors who had specialized in providing the "strongly labor-complementary" inventions relevant for these industries to produce fewer such inventions, and hence fewer inventions overall.

Because the inventions characteristic of the era were all designed to provide more value for less labor, it can be difficult to imagine how the intuitive argument of Hicks/Habakkuk could be overturned here. A specific example can help shed light. Consider the dual clusters of inventions of the automated assembly line and the mass-producible automobile. These inventions were characteristic of the second industrial revolution, in that they used electric-powered machinery and interchangeable parts (the so-called "American system of manufacturing") to provide a new product through very low hours of labor per unit of output. In a casual sense, therefore, these were labor saving inventions, as were most of the famous inventions of the second industrial revolution in America. But the usefulness of these inventions was not unrelated to scale. The new product and method of production made Henry Ford's automobile factory by necessity the largest production facility in the world, in which 3,000 parts needed to be combined through a total of 7,882 tasks. Given so many unique tasks, in order to take full advantage of the division of labor, the new assembly line required 14,000 local employees.[3] Thus, it is possible that the inventions characteristic of America's second industrial revolution were only worthwhile to be produced in the context of plentiful local labor supply. The era of mass migration may have provided necessary fuel for the era of great American invention.[4]

Our results are also consistent with history-dependence in the type of inventions that inventors specialize in. If experienced incumbent inventors spent years specializing in providing the type of inventions that the era of mass migration made worthwhile (i.e., strongly labor-complementary ones), then they may have faced "cognitive mobility costs" that would make them slower to adapt to the new environment when mass migration ended (Borjas and Doran, 2015). In contrast, new inventors and young inventors had no ties to an existing research program, and could have more easily choose to focus on providing strongly labor-saving innovations designed for a labor-scarce society. Indeed, we find that, before the shock, when labor was plentiful, pre-existing inventors assigned an ever-increasing share of their patent applications to industries full of large establishments with many workers each. After the shock, when labor was more scarce, pre-existing inventors assigned an ever-increasing share of their patent applications to industries full of small establishments with few workers each. Likewise, new inventors and young inventors, for whom cognitive mobility costs would plausibly be lower, actually increased their rate of patent applications after the shock.[5]

[3]Furthermore, the work was so repetitive (and thus turnover so rampant), that the actual number of employees required in a year was considerably higher than 14,000. See: (Beniger, 1997); Meyer (1981); and http://corporate.ford.com/innovation/100-years-moving-assembly-line.html (http://www.autolife.umd.umich.edu/Labor/L_Overview/L_Overview3.htm).

[4]Indeed, this conclusion would be consistent with the literature relating the era of mass migration to changes in manufacturing and productivity during the second industrial revolution. Immigrants during this era may have encouraged mass production (Hirschman and Mogford, 2009), been complementary with assembly-line machinery (Lafortune, Tessada, and Lewis, 2018), and allowed for larger, more productive firms (Kim, 2007).

[5]This furthermore confirms that changes in migration policy often produce both winners and losers.

We also empirically consider an alternative mechanism for our patenting results: that the constraints on invention in quota-affected cities increased, because low-skilled immigrants had been substituting for native time on non-innovative tasks, freeing up natives to spend time on innovation instead. Perhaps when the immigrant flows ceased, the cost of such substitution increased. Using our individual Census data on occupations, we do not find much support for this hypothesis.

Our results suggest that the literature's narrow focus on the effects of highly-skilled immigrants on domestic innovation may be misguided, at least from a historical perspective: low-skilled immigration can be a primary driver of both the rate and direction of economic activity. Furthermore, inventions that are labor-saving in a casual sense are not necessarily complementary with scarce labor: the famous hypotheses of Hicks and Habbakuk do not find empirical support from the results of closing America's borders to mass inflows of the low skilled.

II Historical Context and Empirical Strategy

Between 1850 and 1920, over 30 million Europeans migrated to the United States (Abramitzky, Boustan, and Eriksson, 2014). As Figure 1a shows, at its peak, the annual inflow was over one and one half percent of the pre-existing U.S. population. Such a migration was unprecedented in size, and numerous economists and historians have analyzed its correlates and circumstances. As Figure 1b shows, Southern and Eastern Europeans comprised an increasing portion of the immigrants as the century progressed. Furthermore, the immigrants from Southern and Eastern Europe tended to be negatively selected by skill level (Abramitzky and Boustan, 2017; Spitzer and Zimran, 2018).

American concerns about the effects of immigration grew in proportion to the increased prevalence of Southern and Eastern European immigrants shown in Figure 1b. Figure 1a demonstrates that World War I temporarily reduced immigration rates, but it took federal government policy to nearly end it. A literacy requirement established in 1917 over President Woodrow Wilson's veto was ineffective, but it was the 1921 Emergency Quota Act and the 1924 Immigration Act that effectively reduced immigration to considerably lower rates for the next four decades.

Remarkably, these quotas were precisely calibrated to leave immigration from Northern and Western European countries nearly constant, while nearly ending immigration from much of Southern and Eastern Europe. The precise calibration of the 1921 and 1924 Quotas is apparent through comparing pre-quota immigration from Scandinavia and Italy with the quotas for Scandinavia and Italy. The 1921 law set an annual quota of new immigrants from each nationality at two percent of the number of foreign-born persons of such nationality resident in the US in 1910. The 1924 law set an annual quota of each nationality at three percent of the number of foreign-born persons of such nationality resident in the US in 1890. The results of these calculations were startling. The 1921 Scandinavian immigration flow was 22,854. The post-1921 Scandinavian quota was 41,412. The 1921 Italian immigration flow was 222,260. The post-1921 Italian quota was 40,294. Thus, at the 1921 quota levels, immigration from Italy would still be twice the immigration from all of Scandinavia combined, because the Scandinavian quota was underutilized. It is not surprising, therefore, that the 1924 Quota used new calculations, to arrive at a Scandinavian quota of 18,665, and an Italian quota of only 3,845. The final 1924 quotas appear to have been carefully calibrated to keep immigration from some nations roughly constant, while nearly eliminating immigration from other nations. Table 1 reports the average quotas throughout the period, comparing them with actual immigration numbers from Willcox et al. (1929) and U.S. Department of Commerce (1924, 1929, 1931).

In Figures 2a, 2b, and 3, we present a slightly modified replication of the results in Ager and Hansen (2018) which starkly demonstrates the effects of the quotas' careful calibration. We follow them in regressing actual immigration inflows from 1900 through 1913 on a simple quadratic in time and projecting forward; in our case performing the analysis twice, once for Southern and Eastern

Europe and once for Northern and Western Europe. It is apparent that the actual quotas were strictly binding for Southern and Eastern Europe as a whole, and barely binding for Northern and Western Europe. Figure 3 shows clearly that the quotas resulted in a massive number of "missing" immigrants, nearly all of them from Southern and Eastern Europe.[6]

All of the papers in the recent literature on the quotas use identification strategies that take advantage of the fact that this variation in quotas across source countries induced variation across US locations. Following Abramitzky and Boustan (2017), we map in Figure 4a the share of population in each U.S. county in 1920 from Northern and Western Europe; in Figure 4c from Southern and Eastern Europe. Clearly, there is variation between and within regions of the United States in where immigrants from these different sources tended to settle. Due to history dependence in where immigrants tend to settle (Card, 2001; Moretti, 1999), these pre-quota patterns in immigrant source countries across U.S. locations induced variation in post-quota impacts across U.S. cities, providing the first source of identifying variation we use in this paper. We also expand on the existing literature by demonstrating similar history dependence in which industries immigrants tended to work in before the quotas, thus providing a second source of identifying variation. The identification strategy thus consists in comparing cities and industries that had experienced substantial inflows from Southern and Eastern Europe with otherwise similar locations and industries that had experienced substantial inflows from Northern and Western Europe, before and after the quotas.

One concern with this identification strategy would be if the laws were passed with precisely these induced effects across American cities and industries in mind. A problem for the exclusion restriction implicit in the identification strategy would be a scenario in which senators and representatives from some U.S. locations and industries sought to decrease the economic potential of competing

[6] See Figures 1 and 2 of Ager and Hansen (2018), page 31 for the original Figures that we replicate in Figures 2a, 2b, and 3 of this paper.

U.S. locations and industries by cutting off their supply of low skilled labor while preserving their own. Under this scenario, the identification strategy would confuse the effects of the quotas with the effects of a host of correlated political acts designed by powerful Senators and Representatives to help some U.S. locations and industries and harm others during the early 1920s.

Indeed, Goldin (1994) runs regressions on vote counts to argue that early and unsuccessful attempts in 1915 and 1917 to limit immigration were based in part on economic concerns about immigration in general. But the argument of Goldin (1994) is that the economic concerns were national, and that so many voters supported an immigration restriction precisely because native rural voters (who did not live near immigrants) were concerned about the perceived plight of native workers in the cities. Furthermore, her work does not address the successful attempts to curtail immigration in the 1921 and 1924 Quotas, in which the votes were nearly unanimous (89% of votes cast in the House were in favor of the 1921 restriction; 99% of votes cast in the Senate were). Thus, the 1921 and 1924 Quotas represented national concerns that affected natives everywhere, and were not part of an organized campaign to promote the economic well-being of one location over another.

Finally, we can learn what these national concerns were by examining the historical record of the debate leading up to the passage of these laws. During the discussions on the 1924 restriction, senators and representatives from around the country repeatedly expressed concerns about the ethnic heritage of people from Southern and Eastern Europe, as well as their religious affiliation (i.e., Catholic or Jewish). At the same time, they extolled the ethnic heritage of people from "Nordic" countries as well as people of Protestant background. For example, Representative Ira Hersey of Maine complained: "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 explained: "The Nordic People laid the foundations of society in America. They have built 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 stated his goal to "maintain the racial preponderance of the basic strain on our people and thereby to stabilize the ethnic composition of the population." Representative William Vaile of Colorado stated: "What we do claim is that the Northern Europeans, and particularly Anglo-Saxons, made this country."[7]

Thus, far from local efforts to reduce all immigration to some locations but not others, these laws were national efforts to reduce all immigration from some sources but not others. As historian Robert Fleegler recounts, "during the 1924 congressional debate over immigration restriction ... the supporters of restriction espoused a conception of American identity that excluded eastern and southern European migrants. Only a small minority disagreed" (Fleegler, 2013).

In the next section, we describe the data that we use to analyze the impacts of these quota-related declines in mass immigration on American innovation.

III Data and Matching

Administrative data from Willcox et al. (1929) and U.S. Department of Commerce (1924, 1929, 1931) gives us exact immigration counts by source country and year. IPUMS full count Census data tell us characteristics by locations, industry and year of arrival in the United States in 1900, 1910, 1920, and 1930: total population, foreign-born population, southern and eastern European foreign-born population, and northern and western European foreign-born population. Complete count Census data with names from 1920 tell us: full names, genders, birth years, birthplaces, arrival years, locations, and occupations of everyone living in the United States in 1919 (the year the 1920 Census took place). The European Patent Office's PATSTAT database tell us characteristics of each patent appli-

[7] Quotes are from "Ellis Island Nation: Immigration Policy and American Identity in the 20th Century" by Fleegler (2013).

cation granted by the United States Patent Office from 1899 to the present: inventor's full name, year of application, International Patent Classification (IPC), and number of citations.

The identification strategy depends on variation across locations, industries, and years. Thus, it is helpful to observe immigration inflows into locations and industries on a yearly basis if possible. The 1910, 1920, and 1930 United States Censuses report the nativity status, birth country, and year of arrival for every person living in the United States in 1909, 1919, and 1929, respectively. We can therefore use these three censuses to determine the exact initial location choice and industry choice of immigrants who arrived in 1909, 1919, and 1929.

This would provide us with two pre-quota years for immigration inflows across locations and industries, and one post-quota year for immigration inflows across locations and industries. A difference-in-differences strategy relies on the assumption that treated and comparison groups have similar levels and trends of relevant variables before the treatment begins. While two pre-quota years (1909 and 1919) are useful for establishing pre-quota trends, it would be helpful to have richer data to establish the pre-quota trends, as well as to establish the exact year when the trends diverge post-quota. To do so, we develop a proxy for the initial locations and industries of immigrants who arrived in the years between censuses. Our proxy uses information from the 1910, 1920, and 1930 censuses, assigning immigrants who arrived in year t to the city and industry they report living and working in in the census closest to year t. Thus, for immigrants who arrived in 1919, the proxy corresponds with the true (contemporaneously observed) observations of initial locations and industries of new 1919 arrivals gleaned from the 1920 census. For immigrants who arrived in 1925, the proxy corresponds with the circa-1929 locations and industries reported in the 1930 Census for immigrants who report first arriving in 1925.

While the proxy corresponds with the truth during Census years themselves, the proxy will diverge from the truth in the years between censuses in two ways: through movement within the United States between year t and the next Census year, and through return migration. Fortunately, we can test the accuracy of the proxy by comparing the proxy vectors of the number of 1919-arrival immigrants across locations and industries reported in the 1930 Census with the true (contemporaneously observed) vectors of the number of 1919-arrival immigrants across locations and industries reported in the 1920 Census. We find that the location proxy and the industry proxy have correlations of approximately 0.9 with their respective true vectors. We can also perform all of the analysis below ignoring the proxy and relying only on three observations of newly arrived immigrants in 1909, 1919, and 1929, as in the existing literature on the effects of the quotas.

To determine the effect of the quotas on inventors who lose geographically close immigrants, we need to know where inventors were living just before the quotas occurred. An inventor i is treated by the 1921 and 1924 quotas if he or she is living in a city with a large fraction of southern and eastern European immigrants in 1919, just before the quotas. Patent applications report locations of their inventors that are valid at the moment the patent application was filed. But the median number of patent applications conditional on ever patenting is one (Bell et al., 2018), so the vast majority of incumbent inventors living in any given city in 1919 would be unlikely to happen to apply for a patent (and thereby reveal their current location) in 1919. This means that using the location data embedded in 1919 patent applications would cause us to substantially underestimate the number of inventors living in each location.

Therefore, we merge patent data into census data at the individual person level. We can then know where all inventors subject to the matching criteria were living in 1919, regardless of whether they applied for a patent that year. Furthermore, we can also control for demographic characteristics which are proven determinants of the probability of invention (Bell et al., 2018), thus improving the precision of our estimates.

We use a match between the EPO's PATSTAT patent database and the complete count 1920 U.S. Census with names. A fuzzy matching procedure merges patents and publications at the individual-name level into the 1900, 1910, 1920, 1930, and 1940 complete-count U.S. Censuses with names. Each such Census can tell us how many people living in the US at the time of that Census had any given first name, middle name, and last name combination. In any given Census, 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. In particular, in the 1920 US Census, 43% of the US population is made up of people with unique names. The fuzzy matching procedure accounts for common misspellings and assigns each patent to the person or persons with a matching name in the Census. We impose three restrictions to increase the probability of matches being correct. First, and most importantly, we only consider the 43% of the population with a unique name. Second, we only consider matching patent applications with an implied age at application between the ages of 18 and 80. Finally, in most regressions we restrict attention to patents matched between the years 1919 and 1929.

Given these restrictions, it is very likely that the resulting matched patents are correct. Given a person with a unique name in the 1920 Census (observed in 1919), we know that any patents applied for in the years 1919 through 1929 with that unique name must be either from that person, or from someone who immigrated to the United States with that person's unique name during those years. They could not be from someone born after 1919 with the same unique name, because any such person would be younger than 10 years old. They could not be from someone with the same name born before 1919 who died by 1919, because such a person would be dead. Thus, for the 43% of people in our sample restriction, and for the eleven years in our primary regressions, the matched patents should only be incorrect if there are transcription errors in the names recorded in the raw data or if a new immigrant arrived with the same full name and patented shortly after arrival.[8]

[8] It is also be possible to use raw patent data from the PATSTAT database to construct city-year level patents to be used in regressions without the benefit of individual demographic characteristics to control for. We are pursuing this alternative technique which does not require matching in our current extensions to this

We will also make use of the full PATSTAT database, with no matching restrictions, below, in order to determine the effect of the quotas on inventions relevant to specific industries. To determine the effect of the quotas on inventions relevant for the NAICS industry classifications in the 1920 U.S. Census, we use an IPC to NACE concordance and a NACE to NAICS concordance. The IPC to NACE (the industry standard classification system used in the EU) concordance is available in the PATSTAT data. The U.S. Census Bureau provides the NAICS to NACE concordance. Using these two concordances, we assign each of the USPTO patent applications in each year to a weighted set of NAICS industry classifications. The IPC information becomes less prevalent in the PATSTAT data before 1919, thus our assignment of patents to industries begins for 1919 patent applications.

Given the data described above, we construct a treatment group of locations likely to be exposed to the effects of the quotas, a treatment group of incumbent inventors already living in such cities before the quotas, and a treatment group of industries whose workforces were likely to be exposed to the effects of the quotas.

In the 1920 U.S. Census, there are a total of 3030 locations that are either cities or non-city regions of a county. We follow the "missing immigrants" method in Ager and Hansen (2018) to assign the missing immigrants in Figure 3 to different locations over time. For each location, we calculate the quota exposure through the following equation:

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

where $\widehat{Immig}_{j,22-30}$ 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 estimates are predicted from the pre-WWI annual immigration flows 1900-1914 based on the following regression model: $Immig_{jt} = \beta_1 lnt + \beta_2 (lnt)^2 + \epsilon_{jt}$. The variable $QuotaExposure_c$ represents the average annual

work.

number of "missing" immigrants per-100-inhabitants in city c due to quotas (Ager and Hansen, 2018). In most specifications, we use a continuous version of this variable, but in those in which we use a discontinuous version we choose as our treated locations the 313 locations with the highest quota exposure (these represent the top ninety percent of locations ranked by quota exposure). A total of 145,842 incumbent inventors were living in these treated cities as of 1919.

In the 1920 U.S. Census, there are a total of 146 industries; seventy of these industries report more patents in the industry-patent match described above. For each such industry, we calculate a measure of quota exposure analogous to that for locations above.

We report simple statistics based on these data in Table 2. In the next section, we determine the effects of the quotas on immigration rates, labor force, and population size in quota-exposed locations and industries.

IV The Effects of the Quotas on Immigration Rates, Labor Force, and Population Size

We begin our analysis by verifying that the Quotas decreased immigration rates in quota-exposed locations and industries, decreased the labor force in quota-exposed locations and industries, and decreased the population size in quota-exposed locations.

We estimate difference-in-differences specifications of the following form:

$$Y_{ct} = \alpha + \beta(QuotaExposure_c \times PostTreatment_t) + \tau_t + \gamma_c + \epsilon_{ct} \qquad (2)$$

In Table 3, we report the results when the outcome variable is newly arrived immigrant inflows (rescaled by the 1910 population) in a given location in a given year, proxied for the years between censuses by the technique described in the Data section above. It is apparent that regardless of the years included in the sample, the cutoff year chosen for the beginning of the quotas, or the base year to rescale the immigration rates, the quotas resulted in substantial reductions of immigration inflows relative to pre-quota means.

In Figure 5, we report the proxied inflows of southern and Eastern European immigrants by year into highly treated locations (those with quota-exposures above the 90th percentile) versus comparison locations. It is apparent that a relative decline in immigration inflows occurred immediately after the 1921 and 1924 quotas. It is also clear that this relative decline was not the result of differential pre-quota trends.

In Table 4, we report the results using the characteristics of the locations during the 1910, 1920, and 1930 Censuses. We modify equation (2) above slightly by taking first differences within locations before the quotas and first differences within locations after the quotas, and reporting the results separately. It is apparent that there were substantial declines in southern and eastern European populations, foreign-born populations, and total populations after the quotas. These declines are clearly not the result of pre-quota trends. The same holds true when we restrict attention to southern and eastern European workers, foreign-born workers, and total workers. In Figures 6, 7, and 8, we display graphically the results reported in Panel A of Table 4. Greater quota exposure is only associated with declines after the quotas, not before it.

In the next section, we determine how the quotas, which reduced populations and labor forces in affected cities, affected innovation as measured by patents and patent citations.

V The Effect of Immigration on Geographically Close Inventors

We estimate difference-in-differences specifications on incumbent native-born inventors of the following form:

$$Y_{ict} = \alpha + \beta(QuotaExposure_c \times PostTreatment_t) + \theta X_{it} + \tau_t + \gamma_i + \epsilon_{ict} \quad (3)$$

where Y_{ict} is the number of patents or citations of incumbent inventor i in city c and year t. We includes the quartic of age of person i in year t, the individual fixed effect, and the year fixed effect. We report the results from this estimation in Table 5. Clearly, regardless of the sample restrictions, years covered, or cutoff year for the post-quota period, we find large declines in the number of patents applied for per year by incumbent inventors living in quota-exposed locations. The magnitudes are large, but not implausible: an increase in quota exposure from 0 to 1 decreases patent applications per year by 5%. According to the results in Table 3, the equivalent increase in quota exposure decreases immigration inflows by 100%, while the results in Table 4 show that the equivalent increase in quota exposure decreases the overall number of employed individuals by as much as 3%. Thus, we find that for every 10% decrease in immigration, patent applications by incumbent native-born inventors decrease by 0.5%.

We compare the patent applications of inventors living in locations whose quota-exposure was greater than the 90th percentile compared with inventors living in other locations in Figure 9a and Figure 9b. It is clear from the timing of the trend break that the results are not an artifact of pre-quota differential trends. Note that because the analysis restricts itself to incumbent native-born inventors, the results are also not an artifact of differing probabilities of invention across native-born and immigrants, nor are they a direct artifact of differing selection of immigrant inventors on ability after the quotas.

It is possible that the marginal inventions were not useful ones; perhaps the inventors would have invented the most useful inventions anyway, regardless of the shock of the quotas. To examine this possibility, we reestimate the results in Table 7 with citation-weighted patents as the outcome variable. It is evident that the results are very similar in sign, significance, and magnitude. Thus, incumbent inventors did not merely neglect their least successful patent applications; weighted by its later influence, native invention substantially declined. The graphical results reported in Figure 10a and Figure 10b demonstrate that these results are also not an artifact of differential pre-quota trends.

In the next section, we explore two possible mechanisms for this decline.

VI The Effect of Industry Labor Supply on Relevant Inventions

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.

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:

$$Y_{jt} = \alpha + \beta(QuotaExposure_j \times PostTreatment_t) + \tau_t + \gamma_j + \epsilon_{jt} \tag{4}$$

where Y_{jt} is the number of newly arrived immigrants per year into industry j rescaled by 1920 total workers in that industry j. We report the results of this estimation in Table 8. While the sample size is limited, it appears that there was a decline in the inflows of immigrant workers into industries that were more exposed to the quota after the quotas.

Thus, if the hypothesis above was at work, these quota-exposed industries should have demanded fewer inventions after the quota than they had before. Using the assignment of patents to relevant industries described in the Data section, we reestimate equation (3) and report the results in Table 9. 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".

An alternative hypothesis is that before the quotas immigrants may have disproportionately taken occupations that freed up native time for invention instead. After the quotas, natives would have to spend time that otherwise would have been spent inventing doing tasks immigrants had formerly done. Indeed, there is evidence that low skilled immigrants free high skilled women's time in general, although the evidence does not address invention in particular (Cortes and Tessada, 2011; Cortes and Pan, 2013). To consider this hypothesis, we examine the fraction of each occupation in the 1920 Census held by the foreign-born, as well as the specifically southern and eastern European foreign-born. We do not find that occupations related to household-help were especially filled by either group.

VII Cognitive Mobility in the Space of Possible Inventions

Implicitly, throughout the work above, we have referred to a space of ideas (Azoulay et al., 2010), in which some possible inventions are complementary to labor and others are strong labor substitutes. While our work above analyzes the effect of the extant labor market on the *rate* of inventive activity, a fuller analysis must address possible effects of the labor market on the *direction* of inventive activity within this space of ideas (Lerner and Stern, 2012). The fact that the rate of patent applications decreased among incumbent inventors suggests the possibility of history-dependence in the type of inventions that inventors specialize in. If experienced incumbent inventors spent years specializing in providing the type of inventions that the era of mass migration made worthwhile (i.e., strongly labor-complementary ones), then they may have faced "cognitive mobility costs" that would make them slower to adapt to the new environment when mass migration ended (Borjas and Doran, 2015). In contrast, new inventors and young inventors had no ties to an existing research program, and could have more easily chosen to focus on providing strongly labor-saving innovations designed for a labor-scarce society.

To analyze this possibility, we once again make use of the assignment of patent IPC codes to relevant industries, this time dividing these industries into two groups: one, those in which the typical establishment had few workers, and two, those in which the typical establishment had many workers. The latter group of industries may have been a particularly attractive place in the space of ideas for inventors to specialize in when labor was plentiful before the quotas. The former group of industries may have attracted more invention after labor became scarce.

In Figure 11, we consider the effect of the quotas on the share of incumbent inventors' patents relevant for small-establishment industries over time. In particular, in each year, we plot the difference in this share between inventors in highly-quota-exposed cities and those in comparison cities. We find that this relative share was decreasing until the time of the quotas, at which point the relative share of patents by incumbent inventors in small-establishment industries in quota-exposed cities suddenly begins to rise. Of course, this rise could be caused by changes in *who* is inventing in each city in each year, or relative differences in age-productivity profiles across groups. Therefore, in Table 10 we report the results of estimating a version of equation (3) in which the unit of observation is a patent applied for by a given inventor in a given year, and in which the outcome variable takes the value 1 if the patent is in a small-establishment industry and 0 if the patent is in a large-establishment industry. The results demonstrate that individual quota-exposed inventors assigned an ever-increasing share of their patents to small-establishment industries after the quota.

If inventors, like mathematicians, face "Cognitive Mobility Costs" for changing their position in the space of ideas in response to a new set of opportunities and incentives, then this movement in the space of ideas may explain much of the decline in the rate of patent applications among incumbent inventors we report above (Borjas and Doran, 2015). In contrast, since new inventors and young inventors would have invested little or nothing in an existing invention program at the time of the quotas, they should have had lower or non-existent cognitive mobility costs. And if it was these cognitive mobility costs which lead to the decline in invention among pre-existing inventors, then therefore the new and young inventors may have faced no decline in the rate of patent applications at all.

We test this possibility by estimating equation (3) on a sample of all individuals aged 18 to 18 at the time of the quotas, including those who had never submitted a patent application before the quotas were enacted. We report the results in Table 11. In Panel A, we show that across all seventy million adults in the United States at the time, the total patents per year declined among quota-exposed people after the quotas. The magnitude of the effect relative to the pre-quota dependent variable mean is a two percent decline, about half the size of that reported in the main results for incumbent inventors in Table 5. In Panel B, we show similar results when the dependent variable is a 1-0 indicator for any patent applications at all in a given year. In Panels C and D, we consider the 99.8% subset of the seventy million adult Americans who had never had a patent before the quotas were enacted. We find that the quota-exposed subset of these individuals were more likely to begin patenting for the first time, and completed more patents, then otherwise similar non-quota-exposed individuals after the quotas began. Thus, all of the negative effect reported in Panels A and B is the result of the 0.2% subset of the American population who were incumbent inventors at the time of the quotas. New inventors increased their likelihood and rate of patenting when they were exposed to the quotas.

Likewise, in Table 12, we estimate the same specifications above separated by age groups. Once again, we see that all of the decline in the rate of patent applications reported in Panel A of Table 11 is due to a decline by individuals aged 31-80 at the time of the shock. Younger individuals aged 18-30 at the time actually increased their rate of patenting.

Taken together, this evidence is consistent with: (a) the incentives and opportunities for different types of inventions depended on extant labor market conditions; (b) inventors chose where in the space of ideas to specialize in in response to these extant labor market conditions; (c) inventors who had already specialized at the time of a change in labor market conditions incurred substantial cognitive mobility costs for changing their location in idea space; and (d) new and young inventors who had been on the margins of invention during previous labor market conditions took advantage of the change to increase their inventive output.

VIII Conclusion

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. 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 for local industries (Acemoglu, 2010). 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.

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. 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.

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

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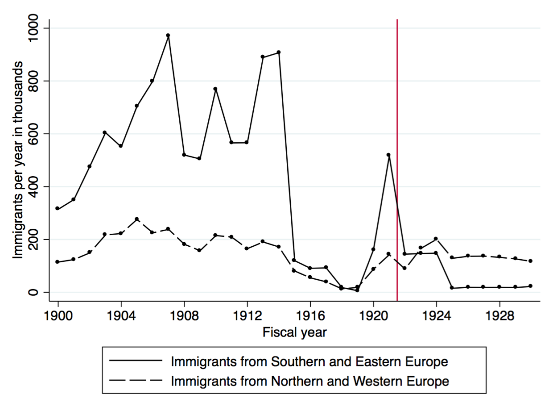
Figure 1: IMMIGRATION INFLOWS FROM ADMINISTRATIVE DATA

(a) Total immigration inflows per year

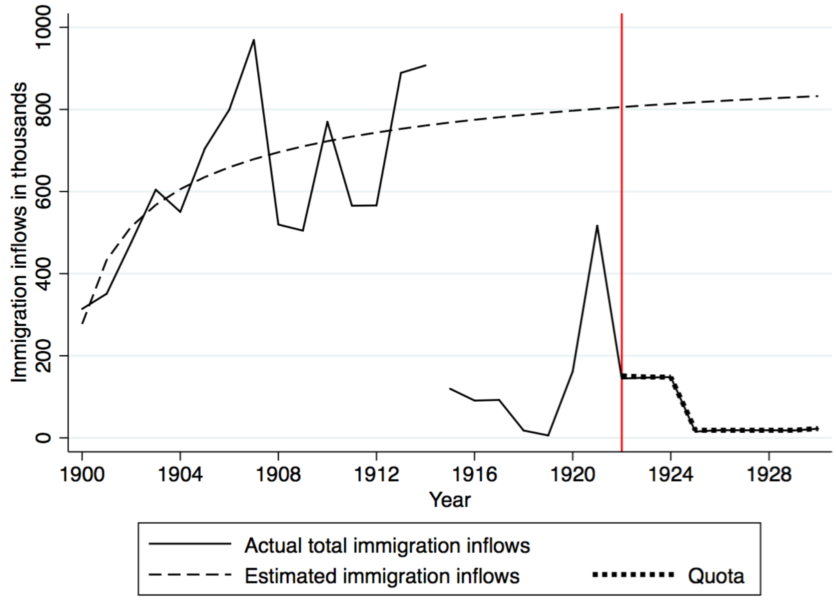
(b) Fraction of immigration from Southern and Eastern Europe



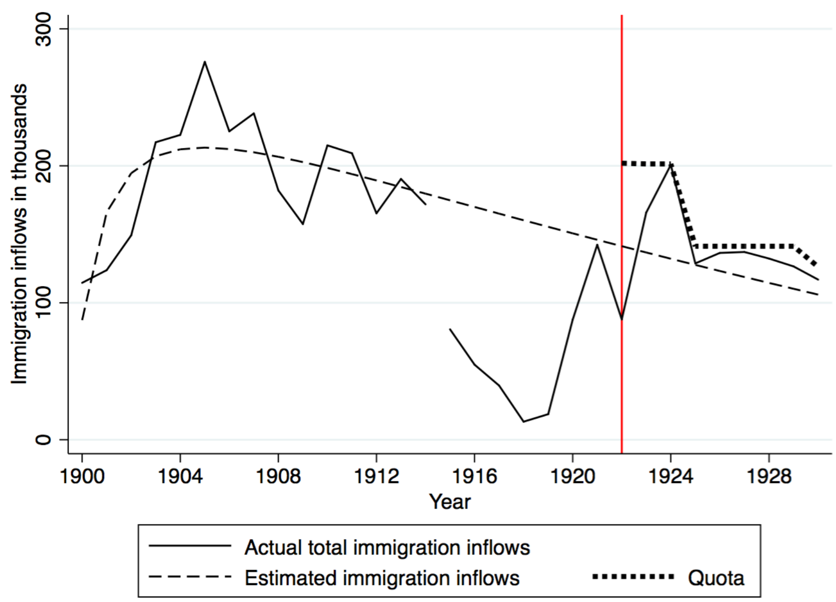
(c) Immigration inflows by region

Notes: The administrative data come from Willcox et al.(1929) and U.S. Department of Commerce (1924, 1929, 1931). Figure 1a shows the annual inflows and Figure 1b shows Southern and Eastern Europeans as a fraction of total immigrants. Figure 1c shows immigration inflows from Southern and Eastern Europe and Northern and Western Europe respectively.

Figure 2: IMMIGRATION INFLOWS UNDER QUOTAS BY REGION



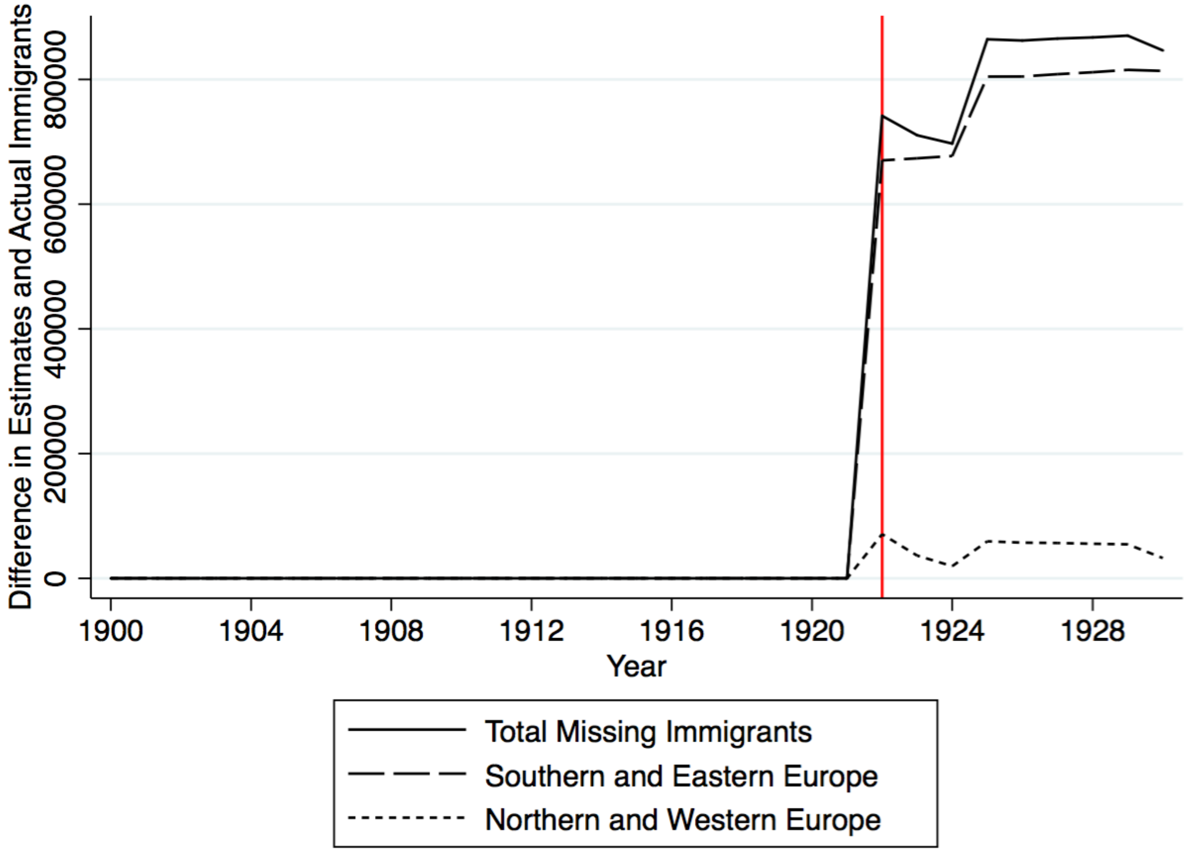
(a) Southern and Eastern Europe



(b) Northern and Western Europe

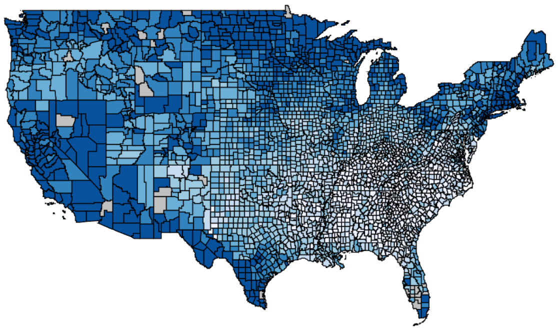
Notes: This figure is a replication of Figure 1 of Ager and Hanson (2018), pg. 31, modified through aggregating immigration into two groups: Southern and Eastern Europe, and Northern and Western Europe. The data from this replication come from Willcox et al.(1929) and U.S. Department of Commerce (1924, 1929, 1931).

Figure 3: MISSING IMMIGRATION INFLOWS UNDER QUOTAS

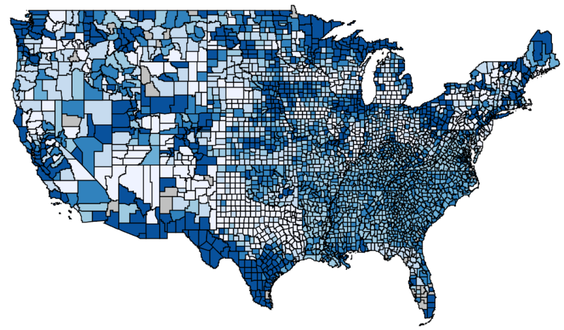


Notes: This Figure is a replication of Figure 2 of Ager and Hanson (2018), pg. 31, modified through aggregating immigration into two groups: Southern and Eastern Europe, and Northern and Western Europe. The data from this replication come from Willcox et al.(1929) and U.S. Department of Commerce (1924, 1929, 1931).

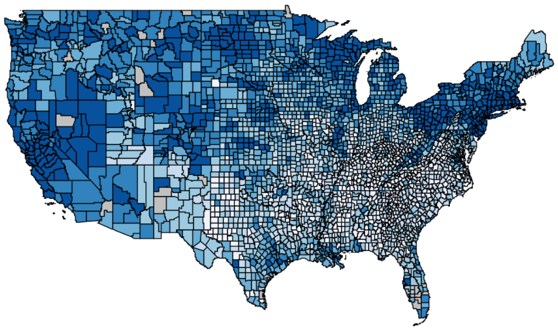
Figure 4: GEOGRAPHIC DISTRIBUTION OF FOREIGN BORN



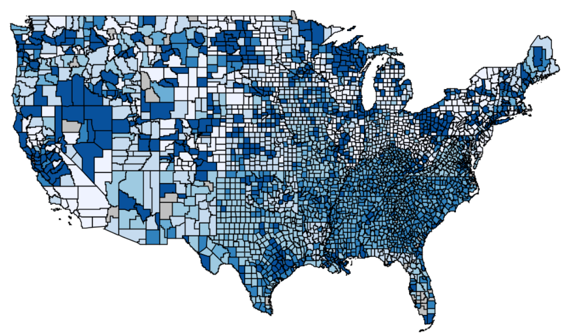
(a) Total foreign born as a fraction of 1920 total population



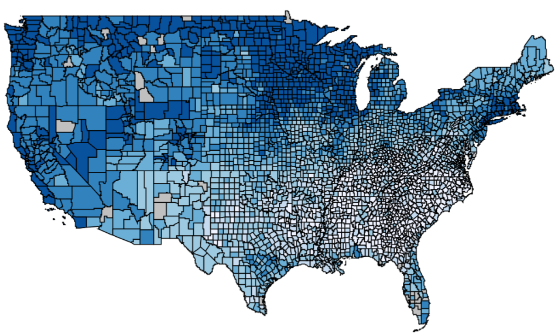
(b) State fixed effects



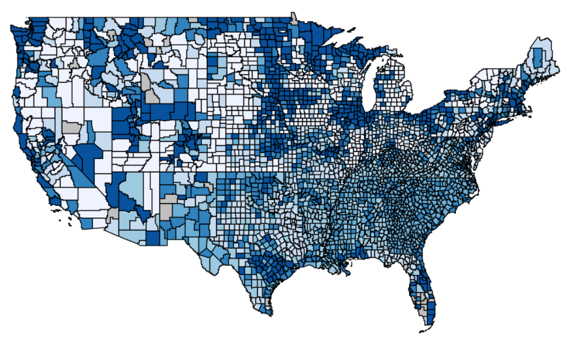
(c) Fraction of foreign born from Southern and Eastern Europe



(d) State fixed effects



(e) Fraction of foreign born from Northern and Western Europe



(f) State fixed effects

Notes: The figures show the share of foreign born population in each U.S. county in 1920; in Figure 4a total foreign born; in Figure 4c from Southern and Eastern Europe; in Figure 4e from Northern and Western Europe. Figure 4b, 4d, and 4f are the share of population with state fixed effects, respectively.

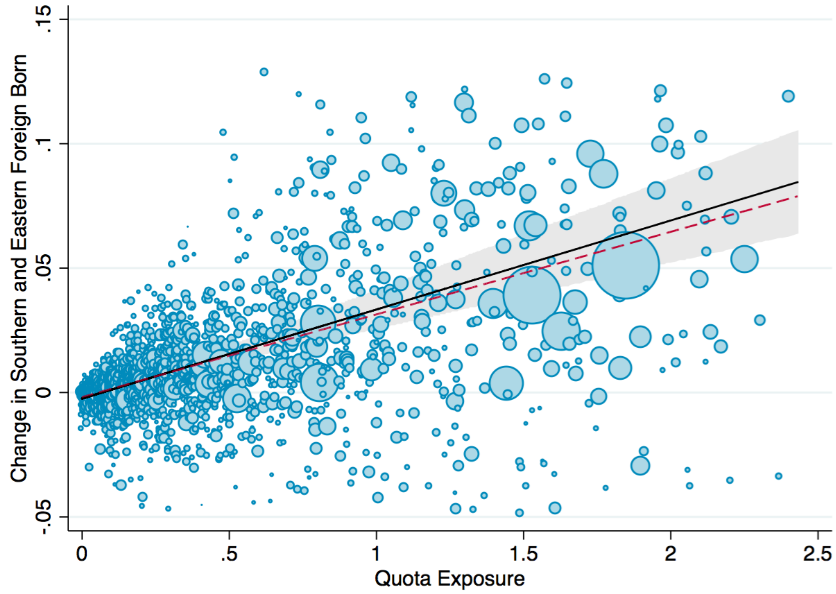
Figure 5: THE EFFECT OF THE QUOTAS ON IMMIGRATION INFLOWS

(a) New immigrants as a fraction of 1920 population

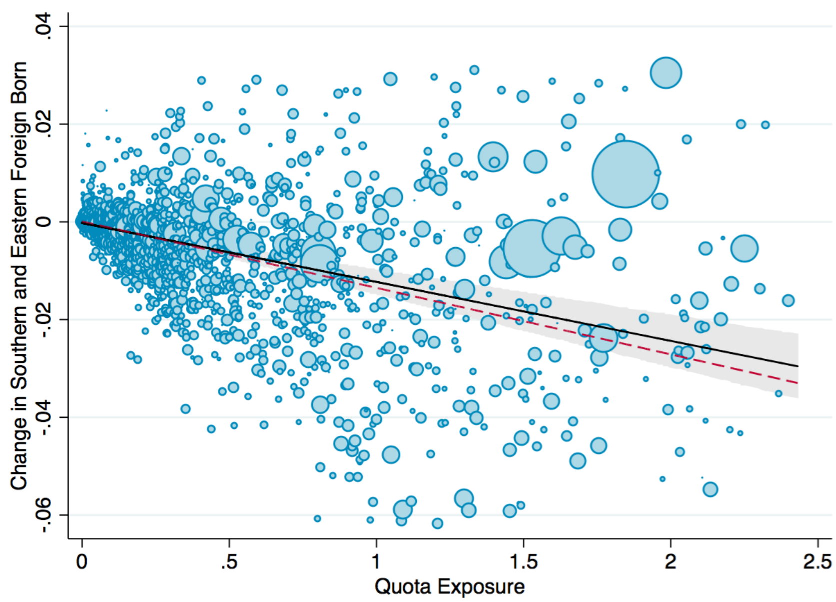
(b) New immigrants as a fraction of 1910 population

Notes: The figure shows immigration inflows as a fraction of 1910 population by year into highly quota exposed cities (those with the Quota exposure variable above the 90th percentile) versus comparison cities.

Figure 6: CHANGE IN FOREIGN BORN POPULATION FROM SOUTHERN AND EASTERN EUROPE



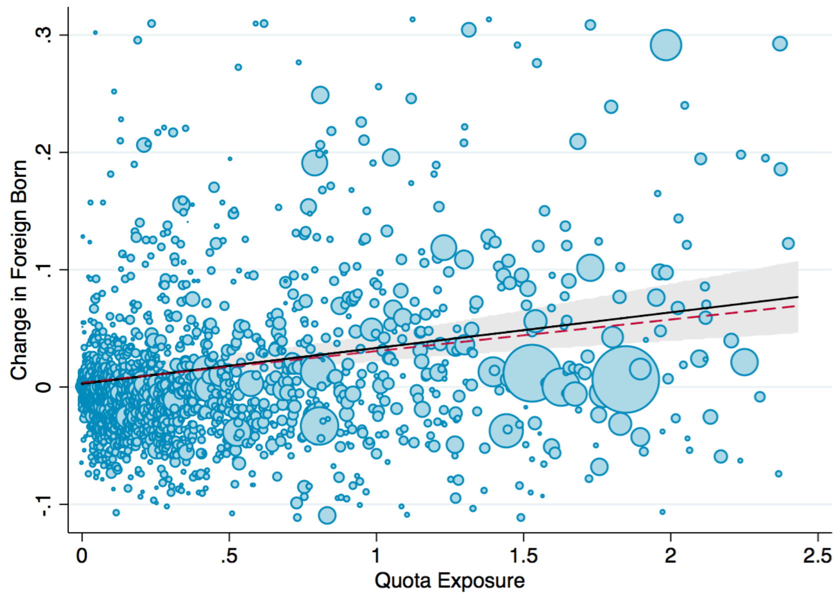
(a) Change between 1910 and 1920 as a fraction of 1910 population



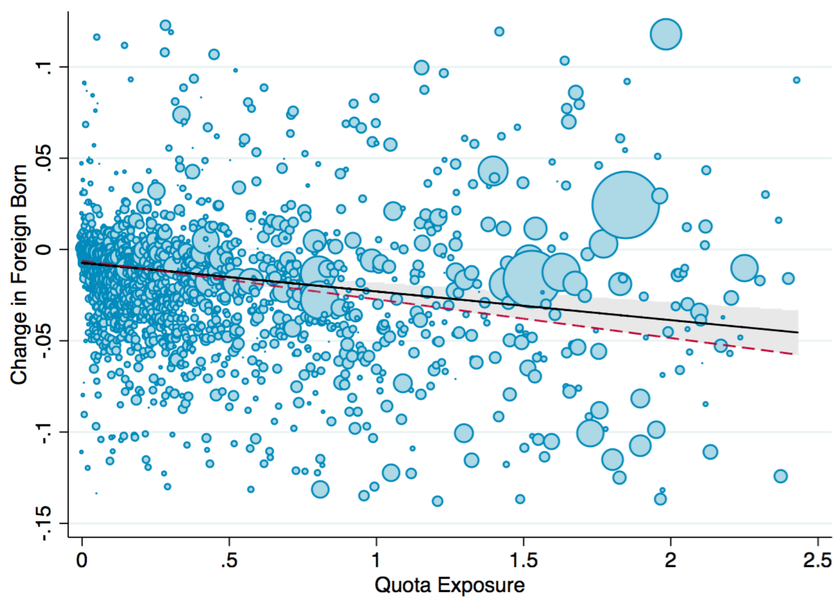
(b) Change between 1920 and 1930 as a fraction of 1920 population

Notes: The figure shows the change in foreign born population from Southern and Eastern Europe (change between 1910 and 1920 in Panel (a); change between 1920 and 1930 in Panel (b)) against the Quota exposure. The solid line shows the coefficient from the regression of change on Quota exposure and the red dot line shows the regression coefficient after the top 1% of highly quota exposed cities is excluded. Marker size represents the city population.

Figure 7: CHANGE IN FOREIGN BORN POPULATION



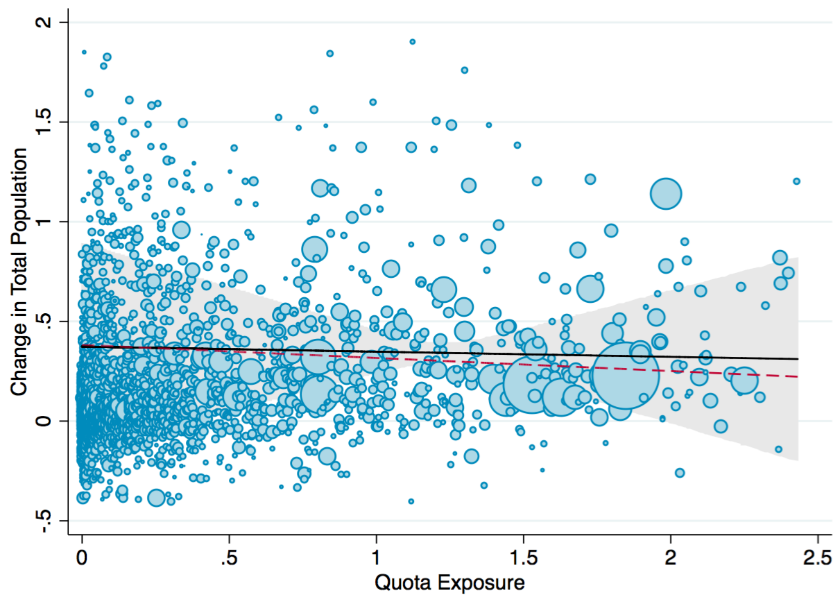
(a) Change between 1910 and 1920 as a fraction of 1910 population



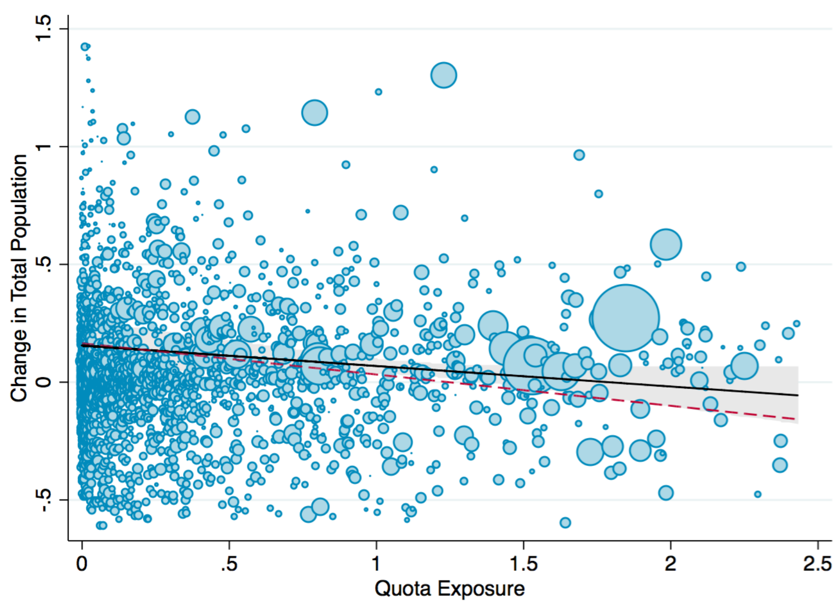
(b) Change between 1920 and 1930 as a fraction of 1920 population

Notes: The figure shows the change in foreign born population (change between 1910 and 1920 in Panel (a); change between 1920 and 1930 in Panel (b)) against the Quota exposure. The solid line shows the coefficient from the regression of change on Quota exposure and the red dot line shows the regression coefficient after the top 1% of highly quota exposed cities is excluded. Marker size represents the city population.

Figure 8: CHANGE IN TOTAL POPULATION



(a) Change between 1910 and 1920 as a fraction of 1910 population



(b) Change between 1920 and 1930 as a fraction of 1920 population

Notes: The figure shows the change in total population (change between 1910 and 1920 in Panel (a); change between 1920 and 1930 in Panel (b)) against the Quota exposure. The solid line shows the coefficient from the regression of change on Quota exposure and the red dot line shows the regression coefficient after the top 1% of highly quota exposed cities is excluded. Marker size represents the city population.

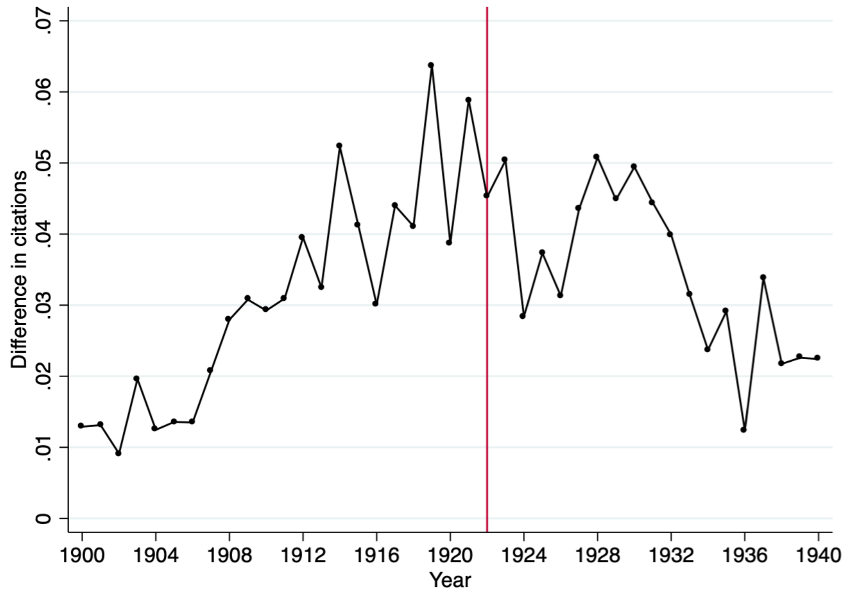
Figure 9: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR

(a) Difference in patent applications by incumbent inventors in 1919

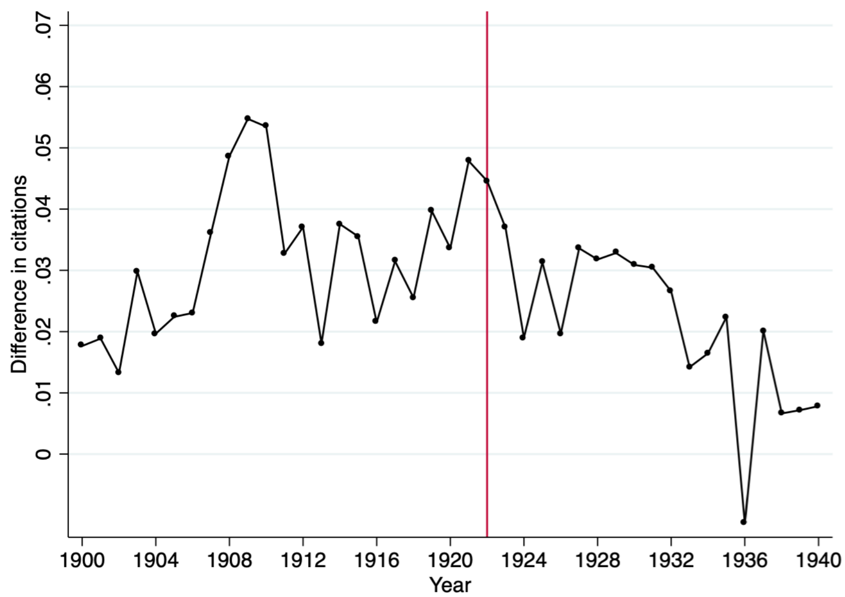
(b) Difference in patent applications by incumbent inventors in 1910

Notes: The figures show the difference in patent applications per year by incumbent inventors between quota exposed cities (those where the Quota exposure variable above 90th percentile) and other cities. Panels (a) and (b) use the number of patent applications per year by native-born incumbent inventors who already had at least one patent in 1919 and 1910, respectively.

Figure 10: THE EFFECT OF THE QUOTAS ON PATENT CITATIONS PER YEAR



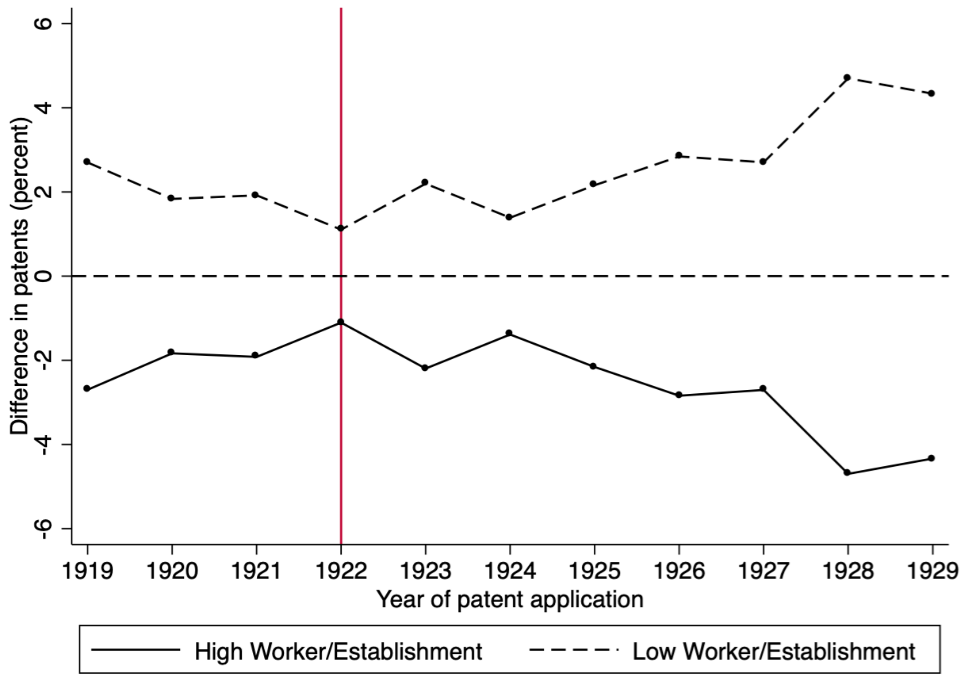
(a) Difference in patent citations by incumbent inventors in 1919



(b) Difference in patent citations by incumbent inventors in 1910

Notes: The figures show the difference in patent citations per year by native-born incumbent inventors who already had at least one patent in 1910 between quota exposed cities (those where the Quota exposure variable above 90th percentile) and other cities. Panels (a) and (b) use the number of patent citations per year by native-born incumbent inventors who already had at least one patent in 1919 and 1910, respectively.

Figure 11: THE EFFECT OF THE QUOTAS ON THE SHARE OF PATENT APPLICATIONS RELEVANT FOR INDUSTRIES WITH SMALL ESTABLISHMENTS VS. INDUSTRIES WITH LARGE ESTABLISHMENTS



Notes: In this figure, we consider the effect of the quotas on the share of incumbent inventors' patents relevant for small-establishment industries vs. large-establishment industries over time. The solid line represents the share of incumbent inventors' patents in any given year that were relevant for industries with high workers per establishment. The dotted line represents the share of incumbent inventors' patents in any given year that were relevant for industries with low workers per establishment. The lines are smoothed with a three-year moving average.

Table 1: QUOTAS BY COUNTRY

Country	Quota	Actual immigrants	Missing immigrants	1920 Population in thousands	Fraction of missing immigrants
	(1)	(2)	(3)	(4)	(5)
A. Southern and Eastern Europe					
Austria	3,065	2,756	66,145	689	0.096
Bulgaria	167	160	7,600	10	0.781
Czechoslovakia	6,804	6,742	3,112	319	0.010
Greece	1,162	1,177	37,909	160	0.237
Hungary	2,251	2,279	67,420	407	0.166
Italy	16,800	16,655	187,287	1,609	0.116
Poland	13,820	13,594	129,258	1,135	0.114
Portugal	1,156	1,143	12,627	113	0.112
Romania	2,841	2,839	0	92	0.000
Russia	10,791	10,127	163,786	1,424	0.115
Spain	405	400	8,948	50	0.179
Turkey	714	760	47,282	27	1.767
Yugoslavia	2,609	2,598	31,160	128	0.244
Total	62,584	61,231	762,535	6,163	0.303
B. Northern and Western Europe					
Belgium	950	931	5,918	65	0.091
Denmark	3,562	3,155	433	186	0.002
Finland	1,632	1,532	3,067	151	0.020
France	4,449	4,084	4,502	155	0.029
Germany	53,929	45,165	0	1,633	0.000
Ireland	27,377	21,584	0	1,051	0.000
Netherlands	2,468	2,258	6,740	133	0.051
Norway	7,916	7,048	0	367	0.000
Sweden	12,361	10,758	0	631	0.000
Switzerland	2,596	2,500	255	121	0.002
UK	42,453	37,920	20,446	1,159	0.018
Total	159,695	136,934	41,361	5,651	0.019

Notes: This table shows information on quotas for countries restricted by quota limits. In columns (1), (2), and (3), the variable is calculated as the average number per year during the quotas, 1922-1930. Missing immigrants are estimated by the difference between average estimated immigrants per year without quotas based on immigration flows from 1900 and 1914 before the WWI and average actual quota limits per year. Column (5) reports the average missing immigrants as a fraction of 1920 population in that country.

Table 2: SUMMARY STATISTICS

	Means (Standard deviation)			
	All cities	Cities less exposed to quotas		Cities more exposed to quotas
		Cities with low FB	Cities with high FB	
	(1)	(2)	(3)	(4)
A: New immigrants, patents and citations				
New immigrants per year and city as a fraction of 1920 population, 1900-1923	0.0022 (0.0043)	0.0012 (0.0030)	0.0045 (0.0053)	0.0077 (0.0064)
New immigrants per year and city as a fraction of 1920 population, 1924-1929	0.0009 (0.0023)	0.0005 (0.0019)	0.0022 (0.0031)	0.0029 (0.0032)
Patents per year and inventor, 1900-1923	0.1413 (0.2326)	0.1422 (0.2498)	0.1334 (0.1238)	0.1414 (0.1462)
Patents per year and inventor, 1924-1950	0.0440 (0.1648)	0.0457 (0.1787)	0.0337 (0.0629)	0.0395 (0.0964)
Citations per year and inventor, 1900-1923	0.2343 (0.5620)	0.2357 (0.6069)	0.2212 (0.2690)	0.2345 (0.3303)
Citations per year and inventor, 1924-1950	0.1681 (0.6667)	0.1750 (0.7235)	0.1288 (0.2599)	0.1477 (0.3741)
Number of incumbent inventors	80,206	35,066	20,939	24,201
B: Demographic characteristics				
1910 Population	27,698 (83,059)	18,059 (10,953)	54,189 (71,892)	82,289 (243,837)
1920 Population	32,889 (93,705)	19,770 (13,149)	71,467 (90,871)	104,888 (267,598)
1930 Population	34,217 (109,914)	19,595 (14,423)	79,087 (121,991)	112,873 (311,300)
1910 Foreign born	4,069 (31,153)	885 (1,156)	9,101 (12,508)	25,488 (95,194)
1920 Foreign born	4,332 (28,983)	780 (993)	10,450 (13,531)	27,773 (87,200)
1930 Foreign born	3,913 (29,845)	581 (809)	9,306 (18,044)	26,255 (89,854)
1910 Southern and Eastern foreign born	1,467 (17,048)	159 (323)	1,986 (4,189)	11,677 (52,855)
1920 Southern and Eastern foreign born	1,931 (17,559)	172 (314)	2,857 (5,250)	15,450 (53,594)
1930 Southern and Eastern foreign born	1,711 (17,198)	128 (262)	2,501 (5,709)	13,941 (52,775)
Number of cities	3,154	2,556	285	313

Notes: This table shows means and standard deviations (in parenthesis) of variables used in our analysis. Columns (2) and (3) report simple statistics for cities with less exposure to quotas (below the 90th percentile of Quota exposure) and column (4) reports simple statistics for cities with high exposure to the quotas. Column (2) reports the subset of low-quota-exposure cities with very low FB population (below the 90th percentile of foreign-born population in 1920 Census), while column (3) reports the subset of low-quota-exposure cities with high FB population (above the 90th percentile of foreign-born population in the 1920 Census). The patents and citations are calculated from incumbent inventors who had patents before the year 1910. The number of patents and citations per inventor per year are winsorized at 10 and 20 respectively.

Table 3: THE EFFECT OF THE QUOTAS ON IMMIGRATION INFLOWS

	Year of immigration			
	1900-1929		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: New immigrants as a fraction of 1920 population				
Quota exposure × Post-treatment	-0.0028***	-0.0029***	-0.0007***	-0.0010***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Dependent variable mean	0.0023	0.0022	0.0016	0.0016
Number of observations	92,190	92,190	33,803	33,803
Number of cities	3,073	3,073	3,073	3,073
R-squared	0.5526	0.5496	0.6740	0.6794
B. Dependent variable: New immigrants as a fraction of 1910 population				
Quota exposure × Post-treatment	-0.0036***	-0.0037***	-0.0010***	-0.0015***
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Dependent variable mean	0.0029	0.0028	0.0022	0.0022
Number of observations	92,190	92,190	33,803	33,803
Number of cities	3,073	3,073	3,073	3,073
R-squared	0.5708	0.5691	0.6495	0.6534

Notes: The outcome variable of new immigrants is constructed by combining information from the 1910, 1920, and 1930 U.S. Census. Specifically, new immigrants per year between the years 1900 and 1909 are obtained from the 1910 Census data, those between 1910 and 1919 from the 1920 U.S. Census, etc. We restrict data to cities that exist in all three censuses to obtain a balanced panel.

Table 4: THE EFFECT OF THE QUOTAS ON POPULATION AND WORKERS

	Southern/Eastern FB		Foreign born		Total	
	1910-1920 (1)	1920-1930 (2)	1910-1920 (3)	1920-1930 (4)	1910-1920 (5)	1920-1930 (6)
A. Dependent variable: Change in population as a fraction of total city population						
Quota exposure	0.0358***	-0.0121***	0.0304***	-0.0161***	-0.0257	-0.0878*
	(0.0047)	(0.0014)	(0.0081)	(0.0027)	(0.2141)	(0.0450)
Dependent variable mean	0.0082	-0.0038	0.0119	-0.0117	0.3660	0.1301
Number of cities	3,208	3,329	3,208	3,329	3,208	3,329
R-squared	0.1691	0.1231	0.0028	0.0161	0.0000	0.0004
B. Dependent variable: Change in workers as a fraction of total city population						
Quota exposure	0.0092***	-0.0062***	-0.0013	-0.0075***	-0.0188	-0.0295**
	(0.0029)	(0.0008)	(0.0046)	(0.0014)	(0.0551)	(0.0145)
Dependent variable mean	0.0010	-0.0018	-0.0030	-0.0043	0.0481	0.0520
Number of cities	3,206	3,325	3,206	3,325	3,206	3,325
R-squared	0.0561	0.0996	0.0000	0.0144	0.0000	0.0004

Notes: The dependent variable is the change in the outcome between censuses as a fraction of total population given a city in the previous census. For instance, the change in workers between 1920 and 1930 is the difference in workers between 1920 and 1930 divided by the 1920 population in a city. In Panel B, workers are defined as people aged from 16 to 64 with a specified industry code in the labor force.

Table 5: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: Patent applications by inventors active as of 1919				
Quota exposure × Post-treatment	-0.0018**	-0.0031***	-0.0037***	-0.0046***
	(0.0009)	(0.0009)	(0.0012)	(0.0011)
Dependent variable mean	0.1230	0.1184	0.0996	0.0897
Number of observations	6,577,575	6,577,575	1,573,627	1,573,627
Number of inventors	145,842	145,842	144,994	144,994
Number of cities	3,311	3,311	3,311	3,311
R-squared	0.2327	0.2327	0.4003	0.4003
B. Dependent variable: Patent applications by inventors active as of 1910				
Quota exposure × Post-treatment	-0.0051***	-0.0061***	-0.0039**	-0.0048***
	(0.0017)	(0.0017)	(0.0018)	(0.0015)
Dependent variable mean	0.1419	0.1361	0.0808	0.0772
Number of observations	3,700,540	3,700,540	871,536	871,536
Number of inventors	81,308	81,308	80,632	80,632
Number of cities	3,275	3,275	3,274	3,274
R-squared	0.2655	0.2655	0.4425	0.4425

Notes: The outcome variable is the number of patent applications per year by native-born incumbent inventors who already had at least one patent as of 1919 and 1910 respectively. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals.

Table 6: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR THROUGH REWEIGHTED PATENTS

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: Patent applications by inventors active as of 1919				
Quota exposure × Post-treatment	-0.0018**	-0.0031***	-0.0037***	-0.0046***
	(0.0009)	(0.0009)	(0.0012)	(0.0011)
Dependent variable mean	0.1230	0.1184	0.0996	0.0897
Number of observations	6,577,575	6,577,575	1,573,627	1,573,627
Number of inventors	145,842	145,842	144,994	144,994
Number of cities	3,311	3,311	3,311	3,311
R-squared	0.2327	0.2327	0.4003	0.4003
B. Dependent variable: Patent applications by inventors active as of 1910				
Quota exposure × Post-treatment	-0.0051***	-0.0061***	-0.0039**	-0.0048***
	(0.0017)	(0.0017)	(0.0018)	(0.0015)
Dependent variable mean	0.1419	0.1361	0.0808	0.0772
Number of observations	3,700,540	3,700,540	871,536	871,536
Number of inventors	81,308	81,308	80,632	80,632
Number of cities	3,275	3,275	3,274	3,274
R-squared	0.2655	0.2655	0.4425	0.4425

Notes: The outcome variable is the number of patent applications per year by native-born incumbent inventors who already had at least one patent as of 1919 and 1910 respectively after the number of patent applications are reweighted by the number of co-inventors. Specifically, one patent application is divided by the number of co-inventors. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals.

Table 7: THE EFFECT OF THE QUOTAS ON PATENT CITATIONS PER YEAR

	Year			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: Citations of patent applications by inventors active as of 1919				
Quota exposure × Post-treatment	-0.0036	-0.0060**	-0.0088**	-0.0090**
	(0.0023)	(0.0024)	(0.0041)	(0.0037)
Dependent variable mean	0.2222	0.2186	0.2404	0.2175
Number of observations	6,577,575	6,577,575	1,573,627	1,573,627
Number of inventors	145,842	145,842	144,994	144,994
Number of cities	3,311	3,311	3,311	3,311
R-squared	0.1442	0.1442	0.2264	0.2264
B. Dependent variable: Citations of patent applications by inventors active as of 1910				
Quota exposure × Post-treatment	-0.0109***	-0.0130***	-0.0077	-0.0103**
	(0.0033)	(0.0034)	(0.0069)	(0.0049)
Dependent variable mean	0.2402	0.2353	0.1828	0.1825
Number of observations	3,700,540	3,700,540	871,536	871,536
Number of inventors	81,308	81,308	80,632	80,632
Number of cities	3,275	3,275	3,274	3,274
R-squared	0.1616	0.1616	0.2536	0.2536

Notes: The outcome variable is the number of patent citations per year earned by patent applications made by native-born incumbent inventors who already had at least one patent as of 1919 and 1910 respectively. The number of citations per inventor per year is winsorized at 20. Standard errors are clustered by individuals.

Table 8: THE EFFECT OF THE QUOTAS ON IMMIGRANT INFLOWS INTO INDUSTRIES

	Year of immigration			
	1900-1929		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: Industry immigration inflows as a fraction of total workers				
Quota exposure × Post-treatment	-0.0116*	-0.0097**	-0.0057	-0.0019
	(0.0062)	(0.0048)	(0.0045)	(0.0012)
Dependent variable mean	0.0113	0.0126	0.0127	0.0182
Number of observations	4,380	4,380	1,606	1,606
Number of Industries	146	146	146	146
R-squared	0.2600	0.2563	0.7390	0.7383
B. Dependent variable: Industry immigration inflows as a fraction of total native workers				
Quota exposure × Post-treatment	-0.0175**	-0.0152**	-0.0086	-0.0037**
	(0.0081)	(0.0063)	(0.0060)	(0.0016)
Dependent variable mean	0.0173	0.0187	0.0174	0.0245
Number of observations	4,380	4,380	1,606	1,606
Number of Industries	146	146	146	146
R-squared	0.2651	0.2608	0.7389	0.7380

Notes: The unit of observation is at the industry-year level. The outcome variable is the number of newly arrived immigrants per year into industry j rescaled by the total number of workers in industry j in the year 1920.

Table 9: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR RELEVANT FOR INDUSTRIES AFFECTED BY QUOTA-INDUCED LOSSES IN IMMIGRANT WORKERS

	Incumbent inventors before the year			
	1919		1910	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: Patents related to affected industry				
Quota exposure × Post-treatment	-0.0034***	-0.0041***	-0.0045***	-0.0048***
	(0.0012)	(0.0012)	(0.0017)	(0.0015)
Dependent variable mean	0.0965	0.0853	0.0748	0.0727
Number of observations	1,572,390	1,572,390	870,996	870,996
Number of inventors	145,842	145,842	81,308	81,308
Number of cities	3,311	3,311	3,274	3,274
R-squared	0.4271	0.4271	0.4974	0.4974
B. Dependent variable: Patents unrelated to affected industry				
Quota exposure × Post-treatment	-0.0004	-0.0005	0.0004	0.0001
	(0.0003)	(0.0003)	(0.0004)	(0.0004)
Dependent variable mean	0.0078	0.0071	0.0056	0.0054
Number of observations	1,572,390	1,572,390	870,996	870,996
Number of inventors	145,842	145,842	81,308	81,308
Number of cities	3,311	3,311	3,274	3,274
R-squared	0.2853	0.2853	0.2750	0.2750

Notes: Using the assignment of patents to relevant industries described in the Data section, we reestimate equation (3) and report the results in Table 9. The unit of observation is at the inventor-year level. The outcome variable measures patents in quota-affected industries (those with quota-exposure above the 75th percentile). The sample covers patent applications from 1919 to 1929. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals.

Table 10: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS RELATED TO INDUSTRIES WITH FEWER WORKERS PER ESTABLISHMENT

	Year of patent application 1919-1929	
	Post-treatment year	
	1922	1924
	(1)	(2)
Quota exposure × Post-treatment	0.0097	0.0110**
	(0.0064)	(0.0054)
Number of observations	65,934	65,934
Number of inventors	18,479	18,479
Number of cities	2,727	2,727
R-squared	0.3313	0.3314

Notes: The outcome variables is patent applications by incumbent inventors in 1910 associated with industries with a low worker-to-establishment ratio.

Table 11: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR BY ALL INDIVIDUALS (INCLUDING THOSE WHO HAD NEVER PATENTED BEFORE THE SHOCK)

	Year of patent application 1919-1929	
	Post-treatment year	
	1922	1924
	(1)	(2)
A. Dependent variable: Patents by all individuals		
Quota exposure × Post-treatment	-0.00001***	-0.00001***
	(0.00000)	(0.00000)
Dependent variable mean	0.00043	0.00042
Number of observations	660,677,674	660,677,674
Number of individuals	70,745,716	70,745,716
Number of cities	3,337	3,337
R-squared	0.3004	0.3004
B. Dependent variable: Any patent by all individuals		
Quota exposure × Post-treatment	-0.00001***	-0.00000**
	(0.00000)	(0.00000)
Dependent variable mean	0.00027	0.00026
Number of observations	660,677,674	660,677,674
Number of individuals	70,745,716	70,745,716
Number of cities	3,337	3,337
R-squared	0.1558	0.1558
C. Dependent variable: Patents by all individuals who had no patent before the quota		
Quota exposure × Post-treatment	0.00004***	0.00003***
	(0.00001)	(0.00001)
Dependent variable mean	0.00000	0.00000
Number of observations	658,934,727	658,785,434
Number of individuals	70,585,147	70,571,188
Number of cities	3,337	3,337
R-squared	0.1262	0.1074
D. Dependent variable: Any Patent by all individuals who had no patent before the quota		
Quota exposure × Post-treatment	0.00003***	0.00002***
	(0.00001)	(0.00000)
Dependent variable mean	0.00000	0.00000
Number of observations	658,934,727	658,785,434
Number of individuals	70,585,147	70,571,188
Number of cities	3,337	3,337
R-squared	0.0749	0.0658

Notes: The outcome variable is the number of patent applications per year by all individuals aged 18-80 in Panels (a) and (b). The outcome variable of patents in Panels (c) and (d) is the number of patent applications per year by all individuals who had no patent before the quota was enacted. Panels (b) and (d) use an indicator whether a person has a patent or not. The number of patent applications per inventor per year in Panels (a) and (c) is winsorized at 10. Standard errors are clustered by individuals.

Table 12: HOW THE EFFECT OF THE QUOTAS ON PATENTS VARIES WITH AGE

	Year of patent application 1919-1929	
	Post-treatment year	
	1922	1924
	(1)	(2)
A. Dependent variable: Patents by all individuals, aged 18-30		
Quota exposure × Post-treatment	0.00001*	0.00002**
	(0.00001)	(0.00001)
Dependent variable mean	0.00033	0.00031
Number of observations	229,099,190	227,839,671
Number of individuals	20,990,682	21,194,035
Number of cities	3,337	3,337
R-squared	0.2908	0.2851
B. Dependent variable: Patents by all individuals, aged 31-80		
Quota exposure × Post-treatment	-0.00003***	-0.00003***
	(0.00001)	(0.00001)
Dependent variable mean	0.00050	0.00049
Number of observations	345,670,225	362,663,553
Number of individuals	31,973,731	33,518,579
Number of cities	3,337	3,337
R-squared	0.3167	0.3172

Notes: The outcome variable is the number of patent applications per year by all individuals. The sample is partitioned into two subsamples: those aged 18-30 and those aged 31-80. The number of patents is winsorized at 10. Standard errors are clustered by individuals.

Appendix

In this section we consider several modifications to the main estimation equations (2) and (3). First, we consider the possibility that different states experienced different trends in patenting over time that might not be picked up by our individual-level indicator variables and year-level indicator variables. We therefore add a full set of state-by-year indicator variables to the estimating equations, allowing for fully-flexible time effects across different receiving states.

Second, we consider an alternative instrument for immigration inflows used by Tabellini (2019). The instrument is a modified version of the standard shift-share instrument which "predicts the number of immigrants received by US cities over time by interacting 1900 settlements of different ethnic groups with subsequent migration flows from each sending region, excluding individuals that eventually settled in a given city's MSA" (Tabellini, 2019). This alternative instrument is not directly determined by the quotas themselves, and accounts for a broader set of events which may have influenced overall migration flows from individual source countries over time.

Third, we consider an alternative dependent variable. Some patent applications constitute highly original ideas, and citations may be an inadequate measure of this originality. We thus construct a measure of the newness of the words used in each patent title, with some patent titles using no words that haven't already appeared in a previous patent title, and other patent titles using at least one word that has not already appeared in a previous patent title. We then define a dependent variable consisting of the number of patent applications containing at least one word that has not already appeared in a previous patent title.

In Tables A.1 through A.6, we report the successive effects of these modifications on the first stage and reduced form effects. The results are largely consistent with the main results reported in the body of the paper, especially for the 1919-1929 time period in which the patent match is most likely to be accurate.

Table A.1: THE EFFECT OF THE QUOTAS ON IMMIGRATION INFLOWS, STATE-YEAR FIXED EFFECTS

	Year of immigration			
	1900-1929		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: New immigrants as a fraction of 1920 population				
Quota exposure × Post-treatment	-0.0028***	-0.0029***	-0.0008***	-0.0009***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)
Dependent variable mean	0.0023	0.0022	0.0016	0.0016
Number of observations	92,190	92,190	33,803	33,803
Number of cities	3,073	3,073	3,073	3,073
R-squared	0.6401	0.6375	0.7432	0.7449
B. Dependent variable: New immigrants as a fraction of 1910 population				
Quota exposure × Post-treatment	-0.0039***	-0.0039***	-0.0012***	-0.0014***
	(0.0002)	(0.0002)	(0.0002)	(0.0001)
Dependent variable mean	0.0029	0.0028	0.0022	0.0022
Number of observations	92,190	92,190	33,803	33,803
Number of cities	3,073	3,073	3,073	3,073
R-squared	0.6387	0.6367	0.7116	0.7130

Notes: The outcome variable of new immigrants is constructed by combining information from the 1910, 1920, and 1930 U.S. Census. Specifically, new immigrants per year between the years 1900 and 1909 are obtained from the 1910 Census data, those between 1910 and 1919 from the 1920 U.S. Census, etc. We restrict data to cities that exist in all three censuses to obtain a balanced panel. State-year fixed effects are included.

Table A.2: THE EFFECT OF THE PREDICTED QUOTAS ON IMMIGRATION INFLOWS, STATE-YEAR FIXED EFFECTS

	Year of immigration			
	1900-1929		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Dependent variable: New immigrants as a fraction of 1920 population				
Predicted quota × Post-treatment	-0.0081***	-0.0080***	-0.0048***	-0.0039***
	(0.0006)	(0.0005)	(0.0008)	(0.0006)
Dependent variable mean	0.0023	0.0023	0.0016	0.0016
Number of observations	88,080	88,080	32,296	32,296
Number of cities	2,936	2,936	2,936	2,936
R-squared	0.6453	0.6418	0.7556	0.7535
B. Dependent variable: New immigrants as a fraction of 1910 population				
Predicted quota × Post-treatment	-0.0126***	-0.0124***	-0.0094***	-0.0071***
	(0.0017)	(0.0015)	(0.0022)	(0.0015)
Dependent variable mean	0.0029	0.0028	0.0022	0.0022
Number of observations	88,080	88,080	32,296	32,296
Number of cities	2,936	2,936	2,936	2,936
R-squared	0.6449	0.6406	0.7186	0.7137

Notes: The predicted quota exposure is a modified shift-share instrument used in Tabellini (2019) that predicts the number of immigrants by interacting ethnic groups living in 1900 with immigrants from each sending country between 1910 and 1920. The outcome variable of new immigrants is constructed by combining information from the 1910, 1920, and 1930 U.S. Census. Specifically, new immigrants per year between the years 1900 and 1909 are obtained from the 1910 Census data, those between 1910 and 1919 from the 1920 U.S. Census, etc. We restrict data to cities that exist in all three censuses to obtain a balanced panel. State-year fixed effects are included.

Table A.3: THE EFFECT OF THE QUOTAS ON PATENT APPLICATIONS PER YEAR, STATE-YEAR FIXED EFFECTS

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Patent applications by inventors active as of 1919				
Quota exposure × Post-treatment	0.0010	-0.0004	-0.0052***	-0.0048***
	(0.0010)	(0.0010)	(0.0016)	(0.0014)
Dependent variable mean	0.1230	0.1184	0.0996	0.0897
Number of observations	6,577,575	6,577,575	1,573,627	1,573,627
Number of inventors	145,842	145,842	144,994	144,994
Number of cities	3,311	3,311	3,311	3,311
R-squared	0.2328	0.2328	0.4003	0.4003
B. Patent applications by inventors active as of 1910				
Quota exposure × Post-treatment	-0.0010	-0.0020	-0.0044**	-0.0045**
	(0.0016)	(0.0015)	(0.0021)	(0.0018)
Dependent variable mean	0.1419	0.1361	0.0808	0.0772
Number of observations	3,700,540	3,700,540	871,536	871,536
Number of inventors	81,308	81,308	80,632	80,632
Number of cities	3,275	3,275	3,274	3,274
R-squared	0.2656	0.2656	0.4426	0.4426

Notes: The outcome variable is the number of patent applications per year by native-born incumbent inventors who already had at least one patent as of 1919 and 1910 respectively. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals. State-year fixed effects are included.

Table A.4: THE EFFECT OF PREDICTED IMMIGRATION INFLOWS ON PATENT APPLICATIONS PER YEAR, STATE-YEAR FIXED EFFECTS

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Patent applications by inventors active as of 1919				
Predicted quota × Post-treatment	-0.0011	-0.0062	-0.0365***	-0.0306***
	(0.0050)	(0.0049)	(0.0091)	(0.0075)
Dependent variable mean	0.1231	0.1185	0.0995	0.0895
Number of observations	6,315,006	6,315,006	1,511,117	1,511,117
Number of inventors	140,087	140,087	139,259	139,259
Number of cities	3,044	3,044	3,044	3,044
R-squared	0.2318	0.2318	0.3992	0.3992
B. Patent applications by inventors active as of 1910				
Predicted quota × Post-treatment	-0.0027	-0.0066	-0.0358***	-0.0293***
	(0.0073)	(0.0072)	(0.0127)	(0.0105)
Dependent variable mean	0.1421	0.1362	0.0809	0.0773
Number of observations	3,556,604	3,556,604	837,893	837,893
Number of inventors	78,196	78,196	77,537	77,537
Number of cities	3,015	3,015	3,014	3,014
R-squared	0.2671	0.2671	0.4441	0.4441

Notes: The predicted quota exposure is a modified shift-share instrument used in Tabellini (2019) that predicts the number of immigrants by interacting ethnic groups living in 1900 with immigrants from each sending country between 1910 and 1920. The outcome variable is the number of patent applications per year by native-born incumbent inventors who already had at least one patent as of 1919 and 1910 respectively. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals. State-year fixed effects are included.

Table A.5: THE EFFECT OF THE QUOTAS ON ORIGINAL PATENT APPLICATIONS PER YEAR, STATE-YEAR FIXED EFFECTS

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Original patent applications by inventors active as of 1919				
Quota exposure × Post-treatment	-0.0007***	-0.0008***	-0.0021***	-0.0015***
	(0.0003)	(0.0003)	(0.0005)	(0.0004)
Dependent variable mean	0.0236	0.0218	0.0108	0.0082
Number of observations	6,577,575	6,577,575	1,573,627	1,573,627
Number of inventors	145,842	145,842	144,994	144,994
Number of cities	3,311	3,311	3,311	3,311
R-squared	0.0612	0.0612	0.0791	0.0791
B. Original patent applications by inventors active as of 1910				
Quota exposure × Post-treatment	-0.0012***	-0.0013***	-0.0022***	-0.0018***
	(0.0004)	(0.0004)	(0.0007)	(0.0005)
Dependent variable mean	0.0317	0.0294	0.0084	0.0066
Number of observations	3,700,540	3,700,540	871,536	871,536
Number of inventors	81,308	81,308	80,632	80,632
Number of cities	3,275	3,275	3,274	3,274
R-squared	0.0826	0.0826	0.0924	0.0924

Notes: The outcome variable is the number of original patent applications per year by native-born incumbent inventors who already had at least one patent application as of 1919 and 1910 respectively. An original patent application is defined as a patent application with new one/two/three word phrases in its title that did not exist in patent applications in previous years. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals. State-year fixed effects are included.

Table A.6: THE EFFECT OF PREDICTED IMMIGRATION INFLOWS ON ORIGINAL PATENT APPLICATIONS PER YEAR, STATE-YEAR FIXED EFFECTS

	Year of patent application			
	1900-1950		1919-1929	
	Post-treatment year			
	1922	1924	1922	1924
	(1)	(2)	(3)	(4)
A. Original patent applications by inventors active as of 1919				
Predicted quota × Post-treatment	-0.0033***	-0.0039***	-0.0075***	-0.0073***
	(0.0013)	(0.0012)	(0.0022)	(0.0019)
Dependent variable mean	0.0236	0.0218	0.0108	0.0081
Number of observations	6,315,006	6,315,006	1,511,117	1,511,117
Number of inventors	140,087	140,087	139,259	139,259
Number of cities	3,044	3,044	3,044	3,044
R-squared	0.0617	0.0617	0.0801	0.0801
B. Original patent applications by inventors active as of 1910				
Predicted quota × Post-treatment	-0.0050**	-0.0057***	-0.0108***	-0.0105***
	(0.0020)	(0.0019)	(0.0030)	(0.0028)
Dependent variable mean	0.0317	0.0294	0.0084	0.0066
Number of observations	3,556,604	3,556,604	837,893	837,893
Number of inventors	78,196	78,196	77,537	77,537
Number of cities	3,015	3,015	3,014	3,014
R-squared	0.0832	0.0832	0.0939	0.0939

Notes: The predicted quota exposure is a modified shift-share instrument used in Tabellini (2019) that predicts the number of immigrants by interacting ethnic groups living in 1900 with immigrants from each sending country between 1910 and 1920. The outcome variable is the number of original patent applications per year by native-born incumbent inventors who already had at least one patent application as of 1919 and 1910 respectively. An original patent application is defined as a patent application with new one/two/three word phrases in its title that did not exist in patent applications in previous years. The number of patent applications per inventor per year is winsorized at 10. Standard errors are clustered by individuals. State-year fixed effects are included.