The Birth and Persistence of Cities: Evidence from the Oklahoma's First Fifty Years of Urban Growth*

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December 2020

Abstract

This paper examines the influence of first- and second-nature forces on the process of city formation in Oklahoma from 1890 through 1930. The natural experiment offered by the opening up of previously unoccupied land for settlement in central Oklahoma in 1889 and the rapid initial settlement reveals that population density was highest near railroads and pre-existing sites of (modest) habitation. Persistence or second-nature forces dominate in explaining population growth over the first decade of settlement. The oil boom of 1900 to 1930 altered the productivity potential of many locations in Oklahoma. Oil shocks increased population in those areas most profoundly affected. We also find evidence that the effect of the shock is larger in areas with higher initial population density and places with a higher initial population. The adverse impact of erosion is clearly apparent in the place regressions while it has no impact on township population density.

Keywords: city formation; urban agglomerations; locational fundamentals; natural experiment

JEL Codes: N9, R1

1 Introduction

Urban economists have long been interested in understanding the origin of urban agglomerations. As Fujita et al. (1999) show, in a featureless plane, without some sort of increasing returns, there should be no reason why population would optimally choose to agglomerate in a specific location. At the same time, there is plenty of evidence that human settlements have long been very much influenced by natural advantages such as proximity to the sea or to a river or a moderate climate.

The literature has defined first nature forces (also known as *locational fundamentals*) as attributes specific to a location but not associated with human settlements that make some locations more appealing than others (Davis and Weinstein, 2002). From a different perspective, the Heckscher-Ohlin model posits that relative factor endowments (e.g. fertile soil, deposits of minerals) dictate comparative advantage and hence relative city size. Second nature forces have been defined as the advantages to a location that derive from

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an agglomeration of population and can include external economies of scale arising from localization or urbanization economies. The distinction between first-nature and second-nature forces is a crucial one for urban economists but, as we argue below, previous attempts to separate them empirically have not been very successful.

There is some limited evidence from the European colonization of America that first-nature forces mattered for initial settlements. However, this specific natural experiment is not very clean. The process of settlement extended over several centuries, which makes the task of isolating the importance of first-nature factors vis-à-vis other confounding factors a daunting one.

This paper examines the importance of first and second nature influences on the development of Oklahoma's urban system during the first 50 years of settlement by non-native people. It exploits three unusual features of that history: the extremely rapid pace of urban development during the period of initial settlement (1889 to 1907), the dramatic impact of highly localized positive productivity shocks during the oil boom years (1900 to 1930) and a third episode of negative shocks to first nature fundamentals during the Dust Bowl and erosion of roughly 1930 to 1940.

Oklahoma's history of urban development began with the Land Rush of 1889, when as many as 40,000 non-native people (mostly, but not all Euro-Americans) competed for a farmstead in the area known as the "Unassigned Lands." Figure 4 shows that this virtually uninhabited area (about the size of Rhode Island) was at the time of settlement surrounded by Indian Territory inhabited by native peoples. During the less than two decades following the first Land Rush the remaining area of Indian Territory (about 23 times the area of the original Unassigned Lands) had been opened up to Euro-American settlers following the allotment of a small share of the territory to native people. Each opening up of territory prompted a rapid in-flow of new settlers, compared with the more measured pace that characterized the settlement of neighboring states prior to the "closing" of the American frontier in 1890. By the late 1890s, the area of the Territory of Oklahoma included over almost 1,000 places (cities, towns, villages, crossroads), where there had been only a handful of isolated stagecoach stops and railroad depots prior to 1890. The subsequent two historical periods featured spatially-identifiable localized shocks to productivity: the oil boom that peaked in the 'twenties and 'thirties and the widespread degradation of farmland evident by the early 1930s.

These three periods of Oklahoma history offer several advantages for identifying the importance of first- versus second-nature influences on urban growth. During the first Land Rush period, there was no role for second nature forces of prior agglomerations since the Unassigned Lands were practically uninhabited up until mid-1889. This natural experiment allows us to estimate in a very clean way the importance of first nature forces on town formation. Second, the shock was very short-lived since most of the territory was claimed a few days after it was given over to settlement.[1] The second period (the oil boom) features spatial and temporal variation in positive shocks to local productivity in the context of what was still a very young urban system. The boom vaulted Oklahoma to the top oil-producing U.S. state for a period and resulted in remarkable urban growth in some areas, even as others showed signs of stagnation. We can also investigate the interaction of first and second nature forces by examining whether larger agglomerations benefited more in the longer term from the impact of an oil shock. The final section of the paper examines the impact of a strong negative shock to first nature—the Dust Bowl and soil erosion of the 1930s—on Oklahoma's towns

[1] For example, the settlement of the Americas by Europeans, started in the early 16^{th} century and continued for several more centuries. During that very long period of time they were likely many time-varying factors that affected the process. Bosker and Buringh (2017) consider early urbanization in Europe but again this was a very drawn-out process.

and cities up through 1940.

The rest of the paper is organized as follows. Section 2 provides some historical context for the land rush, the oil boom and the erosion crisis of the 1930s. Section 3 reviews the literature on attempts to identify the importance of first and second nature forces on the urbanization process. Section 4 presents a theoretical framework that illustrates the impact of a productivity shock on the path of urban development in the presence of agglomeration economies. Section 5 describes the data used in the analysis. Section 6 presents results on the role of first nature influences and population persistence on the density of settlement during the first decade (1890 to 1900). Section 7 examines the impacts of positive and negative productivity shocks on the urban system of Oklahoma over the 1910 to 1940 period. Section 8 concludes the paper.

2 Historical context

Our analysis of the influence of first and second nature forces on Oklahoma's urban development over the first half-century of non-native settlement takes account of three distinct periods in the state's history. The first period (1889 to 1907) includes the almost two decades of transformation that took a territory that was once the home of native peoples from across the continental United States to a state that was admitted to the Union in 1907. The second period (1900 to 1930) involves the height of the oil boom, which became most significant durin the so-called "Black Gold" era of the 'teens and 'twenties. The third period (1930 to 1940) was one of economic reversal, as drought and the consequences of destructive agricultural practices resulted in soil erosion and rural depopulation.

Between the 1820s and 1889, Oklahoma became home to as many as 40 tribes of native people by a process of successive "removals" and resettlement as mostly Euro-Americans pursued a relentless drive to settle first the area east of the Mississippi, and then lands to the north of Oklahoma (Kansas and Nebraska). The tribes came from as far east as Florida and Georgia and as far west as Oregon and Washington. Most prominent among the tribal groups were the five "civilized" tribes who had origins in the southeastern United States and who practiced agriculture with settled communities and full systems of self-governance (see Figure 5).[2] Pressure by settlers outside of Oklahoma and railroad interests intent on generating revenue from lines running through the Indian Territory led to the first of a sequence of Congressional Acts opening up land to settlement by Euro-Americans. The first area opened upon was the so-called "Unassigned Lands." Shown in Figure 4, this region was at the time of settlement unoccupied. It was settled in a very short period of time during the first Oklahoma "Land Rush." After 1889, each subsequent opening up of new land to Euro-American settlers involved allotting a share of the land as tracts to the native people inhabiting the land and then a "land run" (as in the first land rush) or a process of allocating land by lottery. Both processes resulted in rapid settlement of the territories that were opened up to non-hative people (Buck, 1907). As Figure 5 indicates, by 1900 most of the western and northern part of former Indian Territory was incorporated into the new Territory of Oklahoma. Lands in the southwest and in the northeast were added to the Oklahoma Territory by successive treaties between 1900 and 1906. The final step was the formal incorporation of territory occupied by the civilized tribes that had farmed their lands for several decades at statehood in 1907.

For the first land rush, Bunky (1890) reports that more than 40,000 waited on the borders of the "promised

[2] These five tribes were the Choctaw, Cherokee, Seminole, Chickasaw, and Muscogee(Creek).

land" on Monday, April 22, 1889 for their share of the two million acres (8,000 km^2) in the Unassigned Lands.[3] As was the practice throughout the West and Midwest since the enactment of the Ordinance of 1785, the land in the area opened up for settlement had been surveyed and divided into about 12,000 "quarter sections" of 160 acres (about 64 hectares) each. Thirty-six complete sections made up a surveyed "township" of thirty-six square miles designated by the range (east or west) and town (north or south). Figure 6 illustrates the results of this practice for the case of Garfield County. Conducted under the terms of the Homestead Act of 1862, a claim for a maximum of 160 acres could be made by any person aged 21 or older, male or female. To "prove" the claim and receive title, the settler had to build a habitation and well on the land, plow it, and live there for at least the first three years after filing the claim. The settler also had the option to buy the land after six months of residency for $1.25 per acre.[4] By the end of April 22, 1889 most of the available quarter-sections had been claimed and several thousand settlers inhabited the towns and small places of the new Oklahoma Territory.

In the wake of the land run, a few cities and town centers sprang up overnight. The future site of the state's largest city, Oklahoma City, consisted of only seven buildings on April 21: the train depot, a section house, a post office, a government building, the home of the railway agent, a boarding house, and an old stockade used by a stage company for an office. Main Street of what is today Oklahoma City was the base of operations and in a very short time the best lots on the street were taken. *"Every train brought great numbers of new citizens from all parts of the country and the new city was booming by the second night of its existence... While this adjustment of lots was going on in the southern part of the city, hundreds of citizens were settling in the north part upon the lines of the Seminole survey and those who could not find any place to settle, were talking loud, holding meetings, and denouncing everything and everybody."* (Bunky, 1890). Similar scenes played out in the larger towns of Guthrie, Kingfisher, and Norman.

The initial year or two of settlement involved substantial churning of settlers, since the land run occurred with inadequate time for a homesteader to prepare a field and then plant it. Buck (1907) reports that a drought during the summer of 1889 also meant that for the first year, settlers were dependent upon food shipments brought in by the U.S. Army. However, subsequent years were beneficial for agriculture. Bohanon and Coelho (1998) report that the average value of farmland rose from $5 to $25 per acre between 1890 and 1910. They estimate that entering one of the Oklahoma land contests could allow an unskilled laborer to obtain an asset worth between $276 and $388, or between 74% and 103% of a year's income. So it is fair to say that, while risky, there was a high payoff for those who were able to overcome the risks of homesteading.

The next period of Oklahoma's history with a profound impact on urban development was the 1900 to 1930 oil boom, during which Oklahoma rose rapidly to prominence as a leading oil-producing state (Boyd, 2002 and Northcutt, 1985). The discovery of oil first took place in 1897 in an area under control of the Osage tribe, although the first productive well was not in place until after 1900. Various parts of the then-Indian territory and a few locations elsewhere experienced discoveries. As Figure 7 illustrates, the opening up of new oil pools began in earnerst after 1910, with a remarkable surge of new discoveries of oil fields during the years around World War I. During the period 1907 to 1923, Oklahoma ranked as the number one oil-producing state.

[3]The area included all or part of present-day Canadian, Cleveland, Kingfisher, Logan, Oklahoma, and Payne counties.
[4]The three years' required habitation was less than the five years typical for areas settled under the Homestead Act.

The map in Figure 8 shows the distribution of oil discoveries during the first four intercensal periods for which population data are available. The area just north of the Indian Territory saw the first major new drilling prior to statehood. In the period from 1907 to 1909, new discoveries were primarily in the area of the former Muscogee(Creek) nation. The period 1910 to 1919 saw an expansion to much of the Muscogee nation and north into the former Osage territory. Finally, the last wave of discoveries were clustered further to the east in former Osage territory and reached for the first time into the former Seminole nation (Seminole County). Welsh et. al. (1981) provide detailed documentation of the boom in Seminole County and adjacent areas to the east in Pottawatomie County. Many communities saw their population increase up to seven-fold from 1920 to 1930. Other regional studies document similar tales of villages that experienced an extraordinary boom followed by population decline (or even extinction).[5]

The pattern of boom and then bust was not uniform. Particularly after 1920, discoveries of new fields could also have been in reality enhanced recovery of oil from a previously discovered pool using drilling techniques that allowed for drilling wells twice as deep as was previously possible. Higher efficiency of recovering oil from wells involving repressurizing the field with water or gas also made a difference in increasing yields (Stocking, 1933). Up until the late 1920s, the discovery of a new pool opened up a rush to secure leases from the landholders located in proximity to the initial site of the discovery and then the rapid drilling of wells. For example, the Seminole district, which was the last great oil district opened up in Oklahoma through the 1950s, "had many leaseholders and the size of the average lease was small, therefore, speed was absolutely necessary to keep rival producers from draining the oil from someone else's lease."(Carney, 1985, p. 61).

In the late 1920s, the development of oil fields in West Texas and the rapid exploitation of the Seminole Pool led to an unprecedented decline in the price of oil of almost 50 percent. Industry-sponsored measures to curb production in fields began to take hold. Known as proration, these measures were designed to control "output in an industry which had been allowed to run wild for more than half a century"(Stocking, 1933, p. 137). They effectively severed the long-standing link between oil exploration efforts and subsequent booms in production.

An effort to stabilize prices and stave off further price declines, proration systems involved state regulators setting limits on production from individual oil fields to "conserve" oil and to balance production with assessments of demand; quotas were then allocated to owners of a well according to the well's productive capacity. By 1931 in the wake of the price collapse of that year, the governors of both Oklahoma and Texas had invoked martial law in order to limit production from oil pools as the Great Depression and new production sites in East Texas pushed oil prices to record lows (see Figure 7). Despite the resistance of small producers, state proration systems—often with draconian enforcement mechanisms involving confiscation of any surplus above a well owner's quota—were in place by the mid-1930s. By 1935, court decisions and federal legislation reinforced state limits on production using proration (Donald, 1942, pp. 611-613). Donald (1942, p. 616) argued that the system provided a perverse incentive for oil companies to increase their drilling and exploration activity in an effort to increase their share of a fixed amount of oil production at the expense of incumbent well owners. Unlike during the period prior to 1930, the opening up of new oil pools documented in Figure 7 did not result in the boomtowns typical of what Northcutt (1985) described as the "Black Gold Era" of the Oklahoma oil industry. Despite the surge in new or re-opened pools, the annual number of new oil wells completed scarcely topped the very modest numbers of the period prior to 1910.

[5]See the series of studies led by geographers at Oklahoma State University: Carney (1981), Carney (1985) and Carney (1986).

A key issue for our understanding of this period is whether this short-term boost to local productivity interacted with existing productivity advantages (either first or second nature) to yield more lasting impacts to the productivity–and population–of a particular location.

The final period of Oklahoma's urbanization history (1930 to 1940) was influenced by the collapse in oil prices during the Great Depression and devastation to agricultural production caused by drought and soil erosion. Cronin and Beers (1937) document the impact of a series of droughts on the Great Plains states and Lee and Gill (2015) provide a discussion of competing explanations for the severity of erosion from wind found in the areas most dramatically affected by the Dust Bowl. According to reports of the period, severe wind erosion was confined to the far western part of the state and the panhandle. Reports of the period note that soils in large swaths of central and eastern Oklahoma were also subject to "sheet erosion," which occurs when heavy rains fall on powdery soils that were already dry from extended drought and farming methods unsuited to the soil structure. Figure 9 illustrates the geographic spread and spatial hetereogeneity of soil erosion as of 1934. A large proportion of the townships on the map experienced sever erosion with some parts of the state subject to moderate erosion. Aside from areas such as Osage County in the northeast, which was primarily rangeland, the only other areas least affected by erosion were the many river valleys of the state.

Along with the direct and indirect impacts of erosion, the ability of rural areas in central and eastern Oklahoma to support large rural populations suffered from the mechanization of cotton growing that substantially reduced the requirements for labor (Holzschuh and Mills, 1939, pages 28-29.) These changes in the technology of production as well as the weather shocks contributed to the potential for rural depopulation. [6]

3 Related Literature

Our paper is directly related to several strands of the literature. First, it directly links to the literature that has quantified the importance of first-nature forces in determining location choices. Several authors have identified important first-nature variables for both consumers and firms (Rosenthal and Strange, 2004): good weather (Rappaport, 2007), factor endowments (Ellison and Glaeser, 1999; Kim 1995), ports (Bleakley and Lin, 2002), proximity to the sea (Cuberes et al., 2019), proximity to coal mines (Fernihough and O'Rourke, 2014), and locational fundamentals (Davis and Weinstein, 2002) among others. For example, Ellison and Glaeser (1999) use industry data to show that the percentage of agglomeration that is predicted by the natural advantage proxies is roughly 20%. Henderson et al. (2018) use lights data and find that geographical characteristics explain 47% of worldwide variation and 35% of within-country variation in income around the world. Most of these studies focus on firms' data whereas we use data on individual's location choices.[7] Moreover, almost no study has exploited a natural experiment to analyze the importance of first-nature forces.

The paper is also related to the literature on endogenous growth arising from agglomeration economies that predicts strong persistence and path-dependence in urban agglomerations (Davis and Weinstein, 2002; Bleakley and Lin, 2012; Liu, 2015; Desmet and Rappaport, 2015; Ahlfeldt et al, 2015; Michaels and Rauch (2018); Bazzi et al., 2019; Flückiger et al, 2019).

[6] See the results of the Farm Security Administration survey discussed in Holzschuh and Mills (1939, Fig. 3 page 20).
[7] See Rosenthal and Strange (2004) for a review of these papers.

Our examination of an exogenous positive shock to the persistence of urban agglomerations links our work to papers that have also explored productivity shocks. Their efforts focus on negative shocks to productivity, including the effects of World War II bombings (Davis and Weinstein, 2002; Brakman et al., 2004) and the effects of conflicts that took place in medieval Europe (Cuberes and González-Val, 2016).

Our paper takes advantage of the unique quasi-natural experimental circumstances of Oklahoma's early urban history. The Land Run of 1889 is the first example, since it circumvents two problems associated with work similar to Bosker and Buringh (2017). First, the issue of pre-existing population is resolved by studying the location choices of the first settlers of a vast territory (the Unassigned Lands) with virtually no human habitation. Since by historical accident there were practically no settlements, institutions or other second-nature features in this territory at the moment of the Land Run, our estimates capture pure first-nature effects. We are not aware of any other paper that can make this claim. Second, our shock, namely the Land Run of 1889 is very short-lived, in the sense that, in a matter of days or weeks at best, the totality of the Unassigned Lands became occupied. This reduces the scope of confounding variables or shocks that can explain the emergence of urban agglomerations. The second example are the oil discoveries of 1900 to 1930, which represent positive highly localized shocks to productivity in a setting that roughly holds constant many other features of the Oklahoma urban system. This example offers a contrast to other studies focused on negative shocks to productivity, which typically involve widespread wartime destruction or dislocations that were likely to have affected many aspects of the urban system aside from the productivity benefits of particular locations. Finally, the negative shock to agricultural productivity in the 1930s is both a spatially identifiable and measurable shock to the locational fundamentals of the agricultural *Umland* of the places in the Oklahoma urban system.

The history of Oklahoma's oil boom towns is replete with accounts of the rapid ascent and then collapse of towns as a the nearby oil pool that prompted the boom was exhausted. We don't know if there are circumstances when a positive productivity shock could alter a community's longer-term growth path. The next section of the paper presents an urban model that explores the impacts of a (positive) productivity shock on urban growth paths in the presence of agglomeration economies. It suggests some surprising insights that are explored in the analysis of data from Oklahoma's urban system.

4 A Theoretical Model of City Growth

4.1 Households

Consider a closed economy with $j = A, B$ cities and a continuum of atomistic households that can invest in physical capital employed in these cities to produce final goods. The sources of income of a representative household are wage earnings and the return on assets.[8] Let ω be the equilibrium wage rate in this economy.[9] The amount of assets invested by this household in city j are denoted z^j. Investment in physical capital is assumed to be irreversible. This is a reasonable assumption if one interprets physical capital - or at least a significant fraction of it- as infrastructure (buildings, urban facilities, etc.). Total population in the economy N is constant over time. For simplicity, consumption is assumed to be not city-specific so that we can define per capita consumption as $c \equiv \frac{C}{N}$. Household's capital income is given by $\sum_{A,B} r^j z^j$, where r^j represents

[8] In what follows we omit time subscripts to simplify the notation.
[9] Free labor mobility ensures that the two wages are equalized in equilibrium.

the net return to capital (net of congestion costs, introduced below) in city j and her optimization problem is therefore

$$max_{c,i^j} \int_0^\infty ln(c)dt$$

s.t

$$\sum_{j=A,B} i^j + c = \omega + \sum_{j=A,B} r^j z^j$$

$$i^j \geq 0, \forall j = A, B$$

$$z_0^j \quad given > 0, \forall j = A, B$$

where $\rho \in (0,1)$ is the discount rate. As stated above, households face the irreversibility constraints $i^j \geq 0$, $j = A, B$. Finally, z_0^j is the initial stock of assets in city j.

4.2 Firms

Each city has I identical firms that use a Cobb-Douglas technology to produce the unique good in the economy. Each firm is subject to two positive external effects à la Romer (1986). The first one is generated by an increase in the marginal product of capital of a city associated with a larger stock of capital installed in the city where it operates. The second external effect comes from the total population of the city. In this case we assume that a firm's productivity or TFP is an increasing function of the total population of the city where it is located. Both effects can be rationalized by the standard agglomeration argument that larger cities are more productive than smaller ones (see Duranton and Puga, 2004, for example). Since each firm uses a constant returns to scale production function with respect to its private inputs, the number of firms I is indeterminate.[10] More specifically, the production function of firm i located in city j is given by

$$Y^{ij} = A^{ij} \left(N^{ij}\right)^{\alpha} \left(K^{ij}\right)^{1-\alpha} \left(K^{j}\right)^{\psi} \tag{1}$$

where Y^{ij}, N^{ij}, and K^{ij}, respectively represent the firm's production, labor, and capital, and K^j is the total stock of capital installed in city j, i.e. $K^j = \sum_{i=1}^{I} K^{ij}$ and I is the number of firms operating in that city. The parameter $\psi > 0$ captures the size of the external effect of aggregate city capital on any firm that operates in the city.

In this production function $A^{ij} = \xi^j \left(N^j\right)^{\gamma}$ is a city-specific productivity parameter that has two components. The first one, ξ^j, can be interpreted as a first-nature physical attribute of the city that can be potentially affected by a shock. The second component, $\left(N^j\right)^{\gamma}$ represents the positive productivity effect associated with operating in a more populated city, where $N^j = \sum_{i=1}^{I^j} N^{ij}$ and I^j denotes the number of people living in city j. This positive effect is captured by the parameter $\gamma > 0$. These two external effects imply that each firm's production function exhibits diminishing returns to each private input but increasing returns to scale with respect to all inputs since $\alpha + \gamma + (1-\alpha) + \psi > 1$.

[10]Other models in which centripetal forces are generated by external economies of scale include Chipman (1970), Abdel-Rahman (1990) and Krugman (1992).

Firms are subject to a congestion cost $g(K^j)$ where $g(0) = 0$, $g^{'} > 0$, and $g^{''} > 0$ generated by the aggregate stock of capital operating in a given city, and pay a fraction $\frac{1}{I}$ of this cost. [11] Normalizing the price of the consumption good to one, profits, Π^{ij} of firm i located in city j, are then given by

$$\Pi^{ij} = \xi^j \left(N^{ij}\right)^{\alpha} \left(N^j\right)^{\gamma} \left(K^{ij}\right)^{1-\alpha} \left(K^j\right)^{\psi} - (r^j + \delta)K^{ij} - \frac{1}{I}g(K^j) - \omega N^{ij} \tag{2}$$

where $\delta \in (0,1)$ is the rate at which capital depreciates. Firms hire labor and capital at competitive given prices and sell their product in the market. Therefore the first order conditions of the firm with respect to labor and capital are, respectively:

$$\alpha\xi^j \left(N^{ij}\right)^{\alpha-1} \left(N^j\right)^{\gamma} \left(K^{ij}\right)^{1-\alpha} \left(K^j\right)^{\psi} = \omega \tag{3}$$

$$(1-\alpha)\xi^j \left(N^{ij}\right)^{\alpha} \left(N^j\right)^{\gamma} \left(K^{ij}\right)^{-\alpha} \left(K^{ij}\right)^{\psi} = r^j + \delta + g'(K^j) \tag{4}$$

We now impose the symmetry conditions $N^{ij} = N^j$ and $K^{ij} = K^j$, $\forall i$, $j = A, B$.[12] This gives us

$$\alpha\xi^j \left(N^j\right)^{\gamma+\alpha-1} \left(K^j\right)^{\psi+1-\alpha} = \omega \tag{5}$$

$$(1-\alpha)\xi^j \left(N^j\right)^{\gamma+\alpha} \left(K^j\right)^{\psi-\alpha} = r^j + \delta + g'(K^j) \tag{6}$$

From (7) we obtain the following condition for population in city A and B:

$$\alpha\xi^A \left(N^A\right)^{\gamma+\alpha-1} \left(K^A\right)^{\psi+1-\alpha} = \alpha\xi^B \left(N^B\right)^{\gamma+\alpha-1} \left(K^B\right)^{\psi+1-\alpha} \tag{7}$$

and so

$$\frac{N^A}{N^B} = \left(\frac{\xi^A}{\xi^B}\right)^{\frac{1}{1-\alpha-\gamma}} \left(\frac{k^A}{k^B}\right)^{\frac{1+\psi-\alpha}{1-\alpha-\gamma}} \tag{8}$$

Note that the positive effect of population on TFP, captured by $\gamma > 0$, implies that any positive productivity shock- even if temporary - will have a permanent effect on the $\frac{N^A}{N^B}$ ratio. This effect can be directly seen in the term $\left(\frac{\xi^A}{\xi^B}\right)^{\frac{1}{1-\alpha-\gamma}}$ but also indirectly in the term $\left(\frac{k^A}{k^B}\right)^{\frac{1+\psi-\alpha}{1-\alpha-\gamma}}$.

This optimality condition states that the ratio of labor between the two cities is an increasing function of their ratio of capital stocks and the ratio of their productivities. Note that since $\psi, \gamma > 0$ we have $\frac{1+\psi-\alpha}{1-\alpha-\gamma} > 1$ and so, if one assumes no productivity differences between cities, i.e. $\xi^A = \xi^B$, at each point in time the city with the largest stock of capital also has the largest population. Under this assumption, (8) also implies that increases in the (log) capital ratio are associated with more than proportional increases in the (log) population ratio.

[11] Congestion costs can also arise from consumers' disutility associated to crowded cities. To make the model tractable, we assume that these costs are originated in the production side of the economy.

[12] Since there are constant returns to scale at the firm level, the number and size of firms are indeterminate, and thus one can focus on the problem of a representative firm in each city and normalize I to one.

From (6) we have

$$r^j = f_j - \delta - g'(K^j) \tag{9}$$

where

$$f_j = (1-\alpha)\xi^j \left(N^j\right)^{\gamma+\alpha} \left(K^j\right)^{\psi-\alpha} \tag{10}$$

represents the gross marginal product of capital in city j.

4.3 Equilibrium Transition and Steady State

Since the economy is closed and the only available asset is physical capital one has $z^j = k^j, \forall j = A, B$. The equilibrium is given by equations (7)-(10) and the market clearing condition $\sum_{A,B} N^j = N$ along with the normalization $k^j \equiv \frac{K^j}{N}$, $\forall j = 1, ..., J$. In the Appendix we show that combining these equations the equilibrium net MPK in city j is given by

$$f_j = (1-\alpha)\Theta\xi^j N^{\beta-1}\Omega^{-(\alpha+\gamma)} \left(k^j\right)^{\frac{\beta}{1-\alpha-\gamma}-1} \tag{11}$$

where $\Omega(k^A, k^B, N) \equiv \Theta \left(k^A\right)^{\frac{\beta}{1-\alpha-\gamma}} + \left(k^B\right)^{\frac{\beta}{1-\alpha-\gamma}}$, $\beta \equiv 1 + \psi - \alpha$ and $\Theta \equiv \left(\frac{\xi^A}{\xi^B}\right)^{\frac{1}{1-\alpha-\gamma}}$.

Equation (11) states that the gross marginal product of capital in city j depends on the two stocks of capital, the two levels of productivity, and total population.[13] We next make the simplifying assumption that in the initial date 0, productivity in city A cannot be smaller than in city B.[14] Moreover, for now, productivity in both cities is assumed to be constant over time.

Assumption 1: $A^A(0) \geq A^B(0)$.

The following proposition shows that, due to the presence of increasing returns to scale, at any point in time, the gross MPK is strictly larger in the city with the largest stock of capital.

Proposition 1: If $k^A > k^B$ then $f_A(k^A, k^B, N) > f_B(k^B, k^B, N)$

Proof: Assume, by contradiction, that $k_A > k_B > 0$ but $f_A(k^A, k^A, N) \leq f_B(k^B, k^B, N)$. This implies $\left(k^A\right)^{\frac{\beta}{1-\alpha-\gamma}-1} < \left(k^B\right)^{\frac{\beta}{1-\alpha-\gamma}-1}$ or $\left(\frac{k^A}{k^B}\right)^{\frac{\beta}{1-\alpha-\gamma}-1} < 1$. Taking logs on both sides this implies $\left(\frac{\beta}{1-\alpha-\gamma} - 1\right) ln \left(\frac{k^A}{k^B}\right) <$

[13] It can be shown that that the decentralized equilibrium is inefficient because firms do not internalize the external effect they receive from the aggregate stock of capital in the city where they operate. Consequently, the transition to the steady state is too slow. The reason is that the gross MPK of the city that experiences the largest investment is always lower in the decentralized economy than in the planner's one. The proof follows from the fact that firms do not internalize the positive effect that their investment decision has on the rest for the firms operating in the city.

[14] Alternatively, we could make the milder assumption that initial productivity in city B cannot be much larger than in city A.

0. Since, by assumption $k^A > k^B$ this also means $\left(\frac{\beta}{1-\alpha-\gamma} - 1\right) < 0$. But this is a contradiction since we assumed $\psi, \gamma > 0$, Q.E.D.

Assumption 2 establishes that in the in initial date 0 investment is potentially profitable in both cities, while Assumption 3 ensures that investment is still potentially profitable in city B once city A becomes too congested.

Assumption 2:

$$r^A(0) > r^B(0) > \rho$$

Assumption 3:

$$r^B(\hat{t}) > \rho$$

The qualitative features of the unique equilibrium in this economy are displayed in Figures 1-5. Figure 1 shows the evolution of capital in each city for the case in which the catch-up case i.e. the case where both cities have the same productivity $A^j = A$, $\forall j = A, B$. As stated above, k^A increases between dates 0 and $\hat{t}$. The period $\hat{t}$ is the one in which the two MPKs become equal. During this period the stock of capital in city B declines as a result of the depreciation. Non-arbitrage implies that, after period $\hat{t}$, capital accumulation in the two cities is such that this equality holds. Since city A is relatively large and city B relatively small this can only happen if the stock of capital increases faster in city B than in city A. Therefore, for some periods, investment is larger in city B than in city A. At some point, the stocks of capital are equalized in the two cities. Let $\tilde{t}$ be the period in which this occurs. Note that this period is well defined because it is impossible to attain the steady state unless the two cities have already reached a critical level of congestion costs.[15] Also note that in this last transition the common net MPK will eventually reach its maximum value (at period t_B). However, the lack of a better investment alternative makes the stock of capital in each city continue growing to its steady state level k^*.

4.4 The effect of a temporary productivity shock

Suppose that city A experiences a one-time increase in its productivity, A^A, before it has reached its critical size. This will increase its MPK, f_A and so it will increase its growth rate until city A reaches its critical size, i.e. the critical period at which investment in city B starts will now we lower than before. Note that, due to the positive external effect of a city's population on the city's productivity, the steady-state population of city A is now permanently larger than before the shock. This is illustrated in the following Figure 3:

With this framework we can also analyze whether a temporary productivity shock of a given size will have a bigger effect in the large city or in the small one. Suppose, for now that these shocks occur before the cities reach the critical size where the net MPK starts decreasing. In particular, suppose city A is shocked

[15] Unlike in the standard neoclassical growth model, the presence of convex congestion costs implies that this steady state is reached in finite time so that t^* is also well defined. Once the two stocks of capital are the same, they grow together until the economy reaches its steady state (at period t^*).

between $[0, \hat{t}]$.[16] The following proposition shows that the big city benefits more than the small city from such a shock.

Proposition 2: A temporary productivity shock of a given size during the time interval of fast investment in a city affects the big city more than the small one.

Proof: The effect if a one-period productivity shock in city A is given by

$$\frac{\partial f_A}{\partial A^A} = (1-\alpha)\Theta N^{\beta-1}\Omega^{-(\alpha+\gamma)} \left(k^A\right)^{\frac{\beta}{1-\alpha-\gamma}-1}$$

The effect if a one-period productivity shock in city B is given by

$$\frac{\partial f_B}{\partial A^B} = (1-\alpha)\Theta N^{\beta-1}\Omega^{-(\alpha+\gamma)} \left(k^B\right)^{\frac{\beta}{1-\alpha-\gamma}-1}$$

Given Assumption 1 we know that $k^A > k^B$ and so it follows that $\frac{\partial f_A}{\partial A^A} > \frac{\partial f_B}{\partial A^B}$. Q.E.D.

5 Data Description

The data used for this paper include estimates of population for two geographies of Oklahoma for the period 1890 to 1940 (townships and places), geo-referenced information on the first nature forces that existed prior to the first wave of settlement in 1889, geo-referenced data on all discoveries of oil pools for the period through 1939 and a unique mapping of the damage to Oklahoma's soils from the Dust Bowl and destructive agricultural practices preceding it. Since census data for smaller administrative units of Oklahoma Territory are not available until 1900, this study tapped three sources of information on population that are for the first time compiled into consistent geographies suitable for analysis. The first source draws on the individual observations from the extant manuscripts of the 1890 territorial census that was conducted in conjunction with the establishment of formal territorial government in the Unassigned Lands. For subsequent years (1900, 1907, 1910, 1920, 1930 and 1940), data for the population of towns (places) and townships (rural unincorporated areas) are available from the territorial censuses of 1900 and 1907, a special census of the Indian Territory in 1907, and the decennial censuses of 1910 through 1940.

This study uses three ways of organizing the geography of population agglomeration. First, all of the population data have been mapped into a spatially-consistent GIS of about 700 "administrative townships." The GIS is based upon the 988 civil townships that existed in 1934 and constructed so that the population data applies to the same geographic region across time. Since the GIS allows a calculation of the area of the administrative townships, the most relevant measure that covers all of the state of Oklahoma is the population density of each township.[17] The data on population available from incorporated towns and cities are mapped in a separate "place" GIS. There were about 515 such places ca. 1930. Finally, a third

[16] This is empirically the most relevant case since Oklahoma cities were very small in the period we analyze.

[17] We note also that for a place to become incorporated and thus included in the census involved a political process and was often a response to population growth. Many small town centers would never appear in the census.

township-based GIS was developed for the unique circumstances of the 1890 census, for which data could only be geo-referenced according to the town-range surveyed townships required by the Ordinance of 1785.

The manuscript 1890 Oklahoma census was based on a comprehensive index of homestead files and was taken in June of 1890. The data in the manuscripts are arranged by the county and then the enumerators notation of the town and range or the place of residence of each enumerated individual. As Womack(1986) documents, this census was not without its shortcomings. Multiple towns and ranges are given on several of the 1200-plus pages of the census, and it appears that manuscripts for two or three survey townships have gone missing. To fill in these gaps, we used two directories published by James W. Smith in 1890 that covered places (the "urban directory") and all of the homesteads recorded as of August, 1890. In addition, the homestead patents available from the Bureau of Land Management allowed identification of the town and range of households.[18].

Our specification of first-nature forces includes three variables descriptive of the physical geography of Oklahoma that may have influenced patterns of settlement and agglomeration. Table 1 provides the descriptive statistics for these variables based upon the 1930 panel of administrative townships. The first is the rivers, which served as both transportation routes (to the extent they were navigable) as well as points of trans-shipment. About one-half of townships had a river passing through them. The second is the soil suitability index for maize developed by Galor and Özak (2016). The index provides a measure of the potential crop yields for what was the most important crop planted by settlers in Oklahoma, since it was used for both food and as a feed grain. The variation observed in the table (from 30 to about 3) reflects the southeast-northwest gradient of agricultural productivity in the state. The northwest and the panhandle were generally viewed as marginal for farming and best suited as rangeland. The third variable is the terrain ruggedness index developed at one kilometer of resolution and published by Amatulli, et. al. (2018).The index is highest in the far southeast (near the Ozarks).We would expect that a more uneven topography is less-suited to farming.[19] The map of the Unassigned Lands found in Figure 10 illustrates the east-west course of the main rivers and as well as the moderate east-west gradient of soil suitability in central Oklahoma.

First nature also includes the results of human interactions with the geography that took place prior to the settlement of Oklahoma by non-native people. For Oklahoma as a whole, this measure (termed human geography) includes the presence of or planned expansion of a railroad within the boundaries of what became an administrative township. Both are found on a detailed map of Oklahoma from 1887. As Table 1 indicates, perhaps 18 percent of the townships would have had prior or planned railroad service. Our specification of human geography for the Unassigned Lands also includes transportation routes and nodal points that existed prior to April, 1889. The trails and roads in Figure 10 include a major north-south stage coach route along the western edge of the unassigned lands and three well-known cattle trails for driving cattle from pastureland in the northern part of the United States down to Texas: the Abilene trail, Chisholm trail, Shawnee trail).[20]

[18]See Smith(1890) and U.S. Department of the Interior, Bureau of Land Management, General Land Office Records (http:/www.glorecords.blm.gov/default.aspx) for the homestead patent records. In the small number of cases where the original 104 survey townships could not be directly mapped into the 71 administrative townships for the Unassigned Lands, we prorated the population by area

[19]These variables were projected onto the maps of the survey and administrative townships. The median value from the projection was assigned to the township.

[20]Cattle drive trails were routes that were used for moving cattle from pastureland in northern areas of the United States down to Texas; they had been present in Oklahoma well before 1890. We have identified three main cattle trails that cross the state from North to South: the first one (the one to the left in Figure 3) is the Abilene Cattle trail. This trail run from Kansas to Texas and was founded in 1867 by Joseph McCoy. The second one (in the middle), is the 1,200-mile historic Chisholm

In the eastern part of the Unassigned Lands, the Sante Fe railroad had built a rail line connecting Kansas with Texas that was completed in 1887. We georeferenced the roads, trails, and railroads using several contemporary maps based upon the surveys of United States Geological Survey.[21] Finally, we include initial minor points of human habitation in the Unassigned Lands. These were a few railroad depots spaced evenly along the Sante Fe railroad to serve as watering stations for steam locomotives, a few stage coach stations and Fort Reno (which was the site of an Indian Agency and lay just outside of the Unassigned Lands.) With the exception of Fort Reno, these places had at most few non-native inhabitants.[22] As we can see from Table 2, column (1), about one-half of the Unassigned Land townships had a (shallow) river flowing them. The ruggedness of terrain varied across the area. The variation in maize productivity was relatively limited. Only about ten percent of survey townships had access to a railroad depot, although the network of roads and trails apparently served the area well.

Our specification of the two shocks to the productivity of locations in Oklahoma focused on the geographic distribution of discoveries of new oil pools and on the impact of soil erosion. Bullard (1928) is the main source for the data and an accompanying map of pools, which we were were able to georeference. Several periodical publications referenced by Bullard provided data on new oil pool discoveries from 1927 to 1939.[23]

Along with the location of the discovery, the sources typically provide the initial output of the discovery wells in the field either as an average or a minimum and maximum. We used the maximum production to estimate the amount that the discovery would enhance local productivity. For each intercensal period (1900 through 1906, 1907-1909, etc.) we developed a surface for the state of Oklahoma that used the geolocated log of the production of the discoveries as the "height." We used InverseDistanceWeighted spatial interpolation methods in GIS to create a catchment for the areas within a distance of 30 miles that could have been influenced by a discovery. We used a decay parameter of 2, which means that the impact of a discovery on productivity would diminish over space. As Figure 8 suggests, discoveries (and the potential impact on local productivity) were concentrated in north and central Oklahoma with other lesser discoveries in the south central region. As the summary data in Table 1 suggests, most of the 700 or so townships in the state had small amounts or no positive productivity shock. As the map indicates, the shocks affected townships at different times during the early and "Black Gold" years of Oklahoma's oil industry. We used the maximum value of the interpolated shock present in an administrative township as our indicator of a positive economic shock. For places, we used the maximum value of the interpolated productivity in the survey township where the place was located.

The data on soil erosion included 24 classifications of differing degrees of erosion due to wind or sheet erosion that varied by severity (from little or no erosion up to severe sheet erosion and severe wind erosion) and the extent to which gullies traversed the landscape.[24] We focused on the proportion of land subject to

Trail and is known as the world's greatest cattle trail. The Chisholm Trail, founded by Jesse Chisholm, a Scottish-Cherokee cattleman, operated between 1867 and 1885 and it ran from Abilene, Kansas to South Valley, Texas. The third trail (the one on the right) is Shawnee Cattle Trail, which was in operation between 1840 and 1872.

[21] As asserted in Glaeser and Kolhase (2004), "Because roads and rail were rare and costly, every large city in 1900 was located on a waterway."

[22] Our analysis distinguishes between railroad depots and the "other" places of human habitation present in 1889 prior to the Land Rush.

[23] The sources included the Bulletin of the American Association for Petroleum Geologists, the weekly *Oil and Gas Journal* (published in Tulsa) and various reports of from the annual meetings of the American Institute of Mining, Metallurgical and Petroleum Engineers.

[24] See United States, Soil Conservation Service (1934) and United States, Soil Conservation Service, et. al. (1935).

severe and very severe erosion of either variety, which typically meant that 75 percent or more of the land surface was influenced by erosion. This degree of erosion meant the loss of a few more inches of topsoil. The geographic variation in this variable is also significant, with an average value of a bit over one-half of the area of a township affected by such erosion. The erosion measure for the place location was assigned directly to the place. About one-half of places were located in an area that had experienced severe erosion.

6 First- and Second Nature during the First Land Rush Period: 1890-1900

We are interested in exploring two main questions: first, what was the initial pattern of settlement and early town formation for the first wave of settlers in 1889? Did they settle in areas with favorable first nature characteristics (rivers, railroads, cattle trails, etc.), or did they mostly chose their location without taking these factors much into account? Second, how did the urbanization process evolve in the following decade? Did new migrants and towns locate near where the first settlers resided?

Our empirical strategy to answer these questions consists of two stages. First we use the cross-section data on from the first two available census of population (1890 and 1900) in Oklahoma after the land rush of 1889 to explore the spatial pattern of population for the territory of the Unassigned Lands in 1890 and 1900 and to estimate the extent two which it can be explained by specific geographic features. Then we explore the persistence of this dispersion between 1890 and 1900 for the 71 administrative townships of the Unassigned Lands.

6.1 The importance of first-nature forces or physical and human geography

We begin by documenting the spatial distribution of population in the Unassigned Lands as of 1890, a few months after the first Oklahoma Land Rush. Our assumption is that by and large, variation in population across townships results from the presence or absence of urban agglomerations, whether they be a small city such as Guthrie or a small crossroads settlement or village.[25] In the regressions reported in Tables 2 and 3, we focus on the importance of the human and physical geographical contributions to first nature.

We study the effect of first-nature forces by estimating the following regression in 1890:

$$ln(Density_{i,1890}) = \alpha + \gamma' X_i + \varepsilon_i \tag{12}$$

We estimate this equation for the survey townships for 1890 only and the "panel-consistent" administrative townships for 1890 and 1900. Table 2 shows the results of estimating this equation using OLS for the 104 survey townships and and Table 3 shows the results using the 71 administrative townships. As a quick review of the coefficients estimated for both geographies suggests, physical geography accounted for a maximum of eight percent of the density of population observed in 1890. The presence of a river was the strongest influence. Human geography variables accounted for about 17 percent of the variation in population density. Access to a railroad depot was the most important influence. As column (4) suggests, "First

[25]We also plausibly assume that in the first years of settlement, the initial distribution of land was equal since each homestead had 160 acres and that the size of households occupying a homestead did not vary systematically across the Unassigned Lands given similarities in farming technologies.

Nature" accounted for about one-fifth of the variation in population density." The result on railroad depots is even stronger in columns (2) and (3) of Table 3, which uses data on the 71 administrative townships present in the Unassigned Lands. Other urban "places" (stagecoach stops) also had an influence. These results are consistent with Anas et al (1998), who show that major cities, such as Oklahoma City, Denver, Omaha, and Salt Lake City, grew up around rail nodes and developed compact CBDs centered on rail terminals. Since the railroad depots were built in the Unassigned Lands prior to settlement, they can can be considered first-nature. The size of their estimated contribution to population density is suggestive of causality leading from transportation access to population growth.This result is also consistent with Bairoch (1988), who claims that transportation advantages were by far the most important first nature force to explain the spatial pattern of urbanization in Europe, rather than defensive advantages, climate, or resource abundance. Interestingly, terrain ruggedness contributed positively to township population density as well. Most surprising is the negligeable impact of agricultural productivity potential.

6.2 First-nature vs. second-nature influences in 1900

By 1898, the area of the Unassigned Lands alone included approximately 92 crossroads, towns, villages, or cities. In this section we study the extent to which first nature forces rather than centers of population existing in 1890 reinforced the tendency for further urban development. To examine this question, we estimate the following regression between 1900 and 1890:

$$ln(Density_{i,1900}) = \alpha + \beta ln(UnexplainedDensity_{i,1890}) + \gamma' X_i + \varepsilon_i \tag{13}$$

We estimated this regression for the all of the 71 administrative townships that had existed since 1890. Those results are found in columns (4) through (6) of Table 3. Our measure of "Second Nature" is the residual from the estimation of equation (12). The results suggest that by 1900, first nature influences would still account for about one-quarter of the variation in population density. What is surprising is the strong influence of the Second Nature variable, which accounts for almost two-fifths of the variation in population in 1900. A 10 percent higher population density in 1890 is associated with six to seven percent higher density in 1900. The presence of a railroad depot has an even stronger influence on population density by 1900 as the economy in the Unassigned Lands matured. First and second nature forces in these regressions account for almost two-thirds of the variation in population by 1900.

Our initial examination of the influence of first nature forces on early urban development in the Oklahoma Territory suggests that the main influences were the creation of transport nodes, rather than natural features. The substantial persistence exhibited suggests that the initial decisions on those areas with urban development in 1890 continued to exert a strong influence on subsequent town formation. The focus on the Unassigned Lands is not without drawbacks. The degrees of freedom are limited, and it is possible that the geography displays inadequate variation to reveal impacts on urban development. Fortunately, Oklahoma's early settlement history was characterized by an identifiable and dramatic series of productivity shocks after 1900. The local productivity shocks arising from the discovery and exploitation of oil fields in locations across large parts of the south and eastern allow us to explore further interactions between first and second nature and the path of urban growth.

7 Productivity Shocks, First-, and Second-Nature During the Oil Boom and the Erosion Crisis: 1900 to 1940

In this section we use the structure of the theoretical model of Section 4 to inform our study of the effect of localized technology shocks. To do so we exploit cross-sectional and time variation in the discovery of oil in Oklahoma and the erosion crisis of the 1930s. There is a wide range of theoretical models showing how transport costs and agglomerations of population interact. The models do not always have the same prediction. In theory, lower transport costs can contribute to further agglomeration and hence divergence in populations in the urban system, or they can work for convergence.[26]

As the model presented in Section 4 suggests, in the presence of increasing returns to population, cities hit by a large productivity-induced population shock can reallocate to a different equilibrium. Additionally, the role of increasing returns can interact with changing fundamentals. Advantages of a location can lock in cities at locations with long-defunct advantages as Bleakley and Lin (2012) found in their study of portages and urban development in the USA. Alternatively, a shock to first nature fundamentals could facilitate urban populations to spatially reallocate as they adapt to new configurations of locational advantages. One such example is that cities after the collapse of the Western Roman Empire in Britain reconfigured in coastal areas (Michaels and Rauch, 2018).

The historical literature on Oklahoma suggests that such a reallocation may have taken place as localities developed industries and skills complementary to the initial shock of oil discovery, but this hypothesis has not been subject to rigorous testing.[27] As the map in Figure 8 reveals, the productivity as well as spatial distribution of these fields varied widely over time and space. This section exploits this spatial and temporal variation to examine the impacts of shocks to productivity of localities and explore the hypothesis that second nature forces (population) may have interacted with shocks to magnify their impact on subsequent growth.

Our treatment of the adverse productivity shock to the rural *Umland* of the towns and cities in Oklahoma focuses on assessing whether the areas identified as eroded in 1934 had any influence on population counts in 1940, when we first see the overall impacts of the agricultural crisis of the 1930s. The empirical analysis focuses on the period 1910 to 1940 and looks at the experience of the 700+ administrative townships and over 300 places. We estimate two versions of regressions of this basic structure:

$$ln(D_{i,t}) = \alpha + \beta_1 ln(D_{i,t-1}) + \beta_2 Oil_{i,t-1} + \beta_3 Oil_{i,t-2} * ln(Den_{i,t-2}) + \gamma' X_i + \varepsilon \tag{14}$$

where lnD_t is the (log of) the current population density in census year t, lnD_{t-k} is the population density or population in the year t-k (k=1,2), $\text{Oil}_{i,t-k}$ (k=1,2) is the (log of) the spatially averaged productivity of nearby oil fields, and X_i is the vector of first nature influences defined in section 5. We interpret the discovery of oil as a shock to the first nature productivity potential of a township or place. As noted above, measure the presence and intensity of the oil productivity shock (Oil_{t-1}) over the intercensal period prior to the census year ($t-1$ up to but not including t). We lag the oil shock-population interaction by one

[26]See See Fujita et. al. (1999), Baldwin and Martin (2004), and Desmet and Rossi-Hansberg (2014).

[27]See most notably Stacey(1956). Oil boomtooms experienced rapid expansions of services, but also activities ancillary to oil extraction including refineries prior to the building of oil pipelines from the Oklahoma fields to cities such as Chicago in the 1930s.

period (to $t-2$) in the interaction term, which we designate $\text{Oil}_{t-2}\text{xLDen}_{t-2}$, in order to overcome the high correlation of the impact of the shock in $t-1$ with an interaction term including the same shock and the population density. The lagged value also allows us to test Proposition 2 of the model: the longer-term impacts of the productivity shock are augmented by the presence of an agglomeration. The test is essentially whether an oil boom brought about by the discovery of a pool in 1914 in a larger urban area has a larger impact that persists through to 1930.

In brief, the specification allows use to assess the short-run "level" effect of a shock on township population as oil drilling and exploration attract capital and a population of additional workers. In addition, the formulation permits a direct test of Proposition 2: the longer-term impacts of a positive productivity shock are augmented by the presence of an agglomeration. For the first set of regressions presented in Tables 4 and 5 (for administrative townships and for places), the full specification thus becomes

$$\begin{aligned} ln(D_{i,1910}) = \alpha + \beta_1 ln(D_{i,1907}) + \\ \beta_2 Oil_{i,1907-1909} + \\ \beta_3 Oil_{i,1900-1906} * ln(Den_{i,1900}) + \gamma' X_i + \varepsilon \end{aligned} \tag{15}$$

We also recognize that the locational fundamentals can be viewed as fixed effects within the context of panel estimation. The organization of our data into a geographically consistent panel spanning the period 1900 to 1940 allows us to estimate a version of (15) using panel methods. The period of our analysis is confined to the years 1910 to 1940 for the full model, which incorporates the two-period lags in population(density) and the productivity shock. The first year for which population data are available for all of the 700 administrative townships is 1910; the sample for 1900 includes only 242. Thus there is sample attrition for the full model and sample sizes will vary depending upon the year of analysis.[28]

Consider first the results for townships found in Table 4. Consistent with the finding in Table 2 for the townships in the Unassigned Lands, a measure of second nature (prior population density) plays an important role in predicting current population density.[29] Given the importance of persistence in accounting for population in both geographies, the R^2s rise substantially when the specification moves from the first column for each year, with its focus on first-nature influences (X_i), to the second column, when the specification includes the (lagged) log of population or population density. It is noteworthy that when all the 693 township for which complete data are available are analyzed, first-nature influences can account for from 18 to 28 percent of the variation in population density. Presence of a railroad in the township exerts a positive influence regardless of the time period. The presence of a river is strongest in the first two periods, which were also periods of peak agricultural prosperity. The pattern of coefficients on Ruggedness and Maize vary in an expected fashion. The years 1910 to 1919 reflected optimal production and demand conditions, which enhanced the importance of a township's agricultural productivity (the coefficient on Maize) for predicting population. The negative coefficient on ruggedness in 1940, a period of the most reduced agricultural productivity, is consistent with this interpretation. Once persistence is accounted for, the coefficient on Erosion drops in importance with the sole exception of the census year 1940.

[28]Specification test results were ambiguous. We present random effects estimates here for the township panel and fixed effects for the place panel.

[29]We plan on applying the estimation strategy used in Table 2 to get a "clean" estimate of second nature influences in the regressions for the entire dataset in Tables 4 and 5.

The oil productivity shock is strongly positive in all three years (cols. (3), (7), and (11)) prior to the shift in the management of oil pools to proration. Consistent with production limits in the 1930s, discovery of an oil pool has a fraction of the influence on population density when compared with the "Black Gold" years. Recalling that the oil shock is measured in logs, the point estimates suggest an elasticity of 0.05 to 0.07 with respect to the size of the initial discovery. The coefficients on the interaction of the lagged shock and population density ($\text{Oil}_{t-2}\text{xLPopDen}_{t-2}$) suggest that during at least some of the boom years of the 'teens and 'twenties townships with a larger initial population would be more likely to continue to receive benefits from the productivity shock. The only year for which the interaction term is not significant is 1910, which could reflect the fact that the early discoveries for the most part took place in townships for which population data are not available in 1900.[30]

The results on the population of places presented in Table 5 are in general in line with those presented in Table 4. The variables expressing first nature forces alone generally perform poorly, although the impact of rugged terrain on population loss by 1940 is consistent with the results for administrative townships. The only other first nature variable that stands out is the positive impact of highly suitable land for growing maize in 1940, which is also consistent with the results seen in Table 4.

The coefficients on the oil shock terms are very close to those estimated for administrative townships. The interaction term is only significant for population in 1920 and is of a smaller magnitude. This could be reflective of the sample selection issues inherent in using population data for places, many of which would not have been large enough to achieve incorporation prior to a local oil boom.[31]

The results of panel analysis found in Tables 6 and 7 largely reinforce the conclusions from the cross-sectional regressions. By definition, the five first nature forces employed in the analysis are time invariant. Since the cross-sectional regressions suggested there may be some scope for time-varying influences of these variables, the panel analysis allowed for some variation in the coefficients on these variables over the final three years of the panel. Note that the contribution of the townships that were formed after 1900 means that the composition of the panels changes with the inclusion of the interaction term ($\text{Oil}_{t-2}\text{xLPopDen}_{t-2}$). The results in both tables exhibit the pattern of varying fortunes of the agriculture economy evident in the cross-sectional results. Townships and places with the greatest productivity potential (land with a good potential for raising maize) saw a positive impact on population in the 'teens (resulting in higher 1920 population) with a reversal of fortune in the 1920s and to a lesser extent in the 1930s that is most evident in the results for places. Townships exhibit a recovery in the 1930s. The adverse impact of erosion is clearly apparent in the place regressions while it has no impact on township population density. One reason for the strength of the result may be that approximately one-half of places were located in areas designated as severely eroded. The predicted decline in population was 7 to 11 percent in 1930 and again in 1940.[32]. The lagged influence of population was positive in all cases for townships and places.

In both sets of regressions, the impact of the oil productivity shock is positive and significant. For both townships and places, the magnitude is about two-thirds that reported in Tables 4 and 5 from the cross-sectional regressions. The time-varying coefficient on the shock is suggestive. The impact was largest in the

[30]The only exception appears to be the discoveries in Tulsa.

[31]The table in Welsh, et. al. (1981, page 12) illustrates several cases.

[32]This result is roughly consistent with Hornbeck(2012), who found a 12 percent reduction in population between 1930 and 1940 for counties of the Great Plains states experiencing "high erosion" as of 1934. His study does not investigate the possibility that the intensification of production and concomitant damage to soil structures starting the late 'teens of which the so-called "Dust Bowl" era was a consequence may have had the impacts prior to 1930 documented in Table 7

first two decades of significant oil exploration (the 'teens and the 'twenties). As expected, the enforcement of proration dampened the impact of the discovery oil on population growth during the 1930s. The impact of the interaction term ($\text{Oil}_{t-2}\text{xLPopDen}_{t-2}$) is largest for both townships and places in 1920, and would reflect the fact that the impact of discoveries during the relatively short 1907-1909 period had a larger impact in relatively larger townships or places. The coefficients for 1930 and even for 1940 for places suggests that the discoveries during the 'teens and the 'twenties continued to have a larger impact on places that started out with a larger population.

8 Conclusions

This paper uses three natural experiments that affected the urbanization of Oklahoma to explore the importance of first- and second-nature forces in influencing the pattern of urban settlement and growth. The first was the extraordinary and sudden pattern of settlement that resulted from the 1889 Oklahoma Land Run. It allowed us to examine how the process of town and city formation works in a previously unpopulated area. This natural experiment is an ideal environment to study city formation since, as of 1889, most of Oklahoma's Unassigned Lands were unoccupied and because the migration to this territory occurred in a very short period of time. We found that second nature forces, or the power of persistence, played a key role in accounting for population growth during the first decade of settlement.

The second natural experiment was the rapid emergence of a highly productive oil industry in the state during the first three decades of the 20^{th} century. Our analysis of highly localized shocks to productivity revealed strong impacts from the oil shocks, even as the evidence also suggested an important, if secondary, role for the first nature forces of Oklahoma's topography. The analysis also uncovered a statewide influence of persistence. The population of a township or place in one census year was highly predictive of its population in the next year. This persistence is consistent with our theoretical model where locations with an initial advantage keep attracting both population and capital until congestion is too severe. Also consistent with the model, a positive exogenous shock (the oil shock) increases a city's population: our estimates suggest an elasticity of 0.05 to 0.07 with respect to the size of the initial discovery. Negative shocks (the Dust Bowl) have a substantial negative impact, up to ten percent in the places most strongly affected. There is also some evidence in favor of the second proposition of our theoretical framework: second nature forces (a location's population) enhanced the impact of positive productivity shocks that altered the locational distribution of first nature advantages. A key question that we cannot answer here is whether the shock exerted a sustained negative impact on the subsequent growth path of Oklahoma's cities and towns.[33]

[33]Hornbeck(2012, 1494) focuses on the impact of the erosion crisis of the 1930s (termed in his paper as the "Dust Bowl") on agricultural productivity. He offers evidence that counties in the U.S. Plains states that were most severely affected by the erosion crisis of the 1930s (termed in his paper "Dust Bowl") experienced longer-term reductions in population through the 1950s. Since these declines were not restricted to the rural or on-farm population, he ascribes them to a general process of labor market adjustment to the rural productivity shock.

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Figure 1: Capital per capita

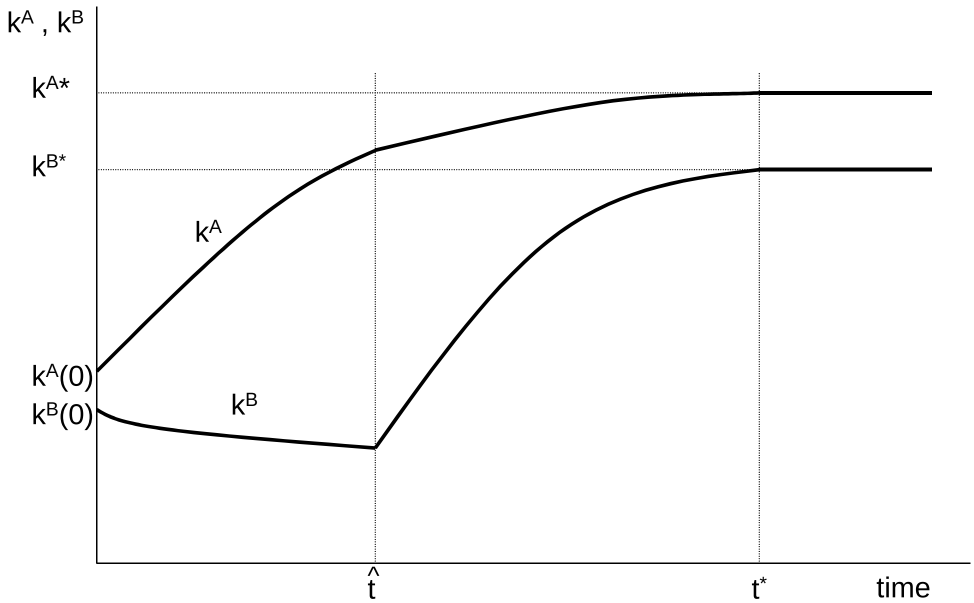


Figure 2: Population shares

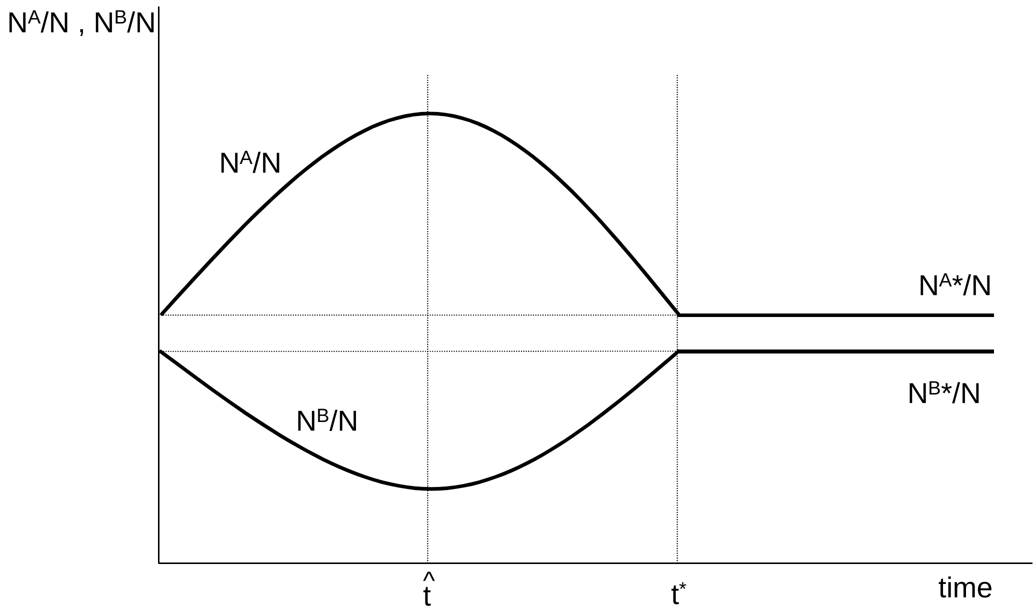


Figure 3: Population shares with temporary productivity shock in city A

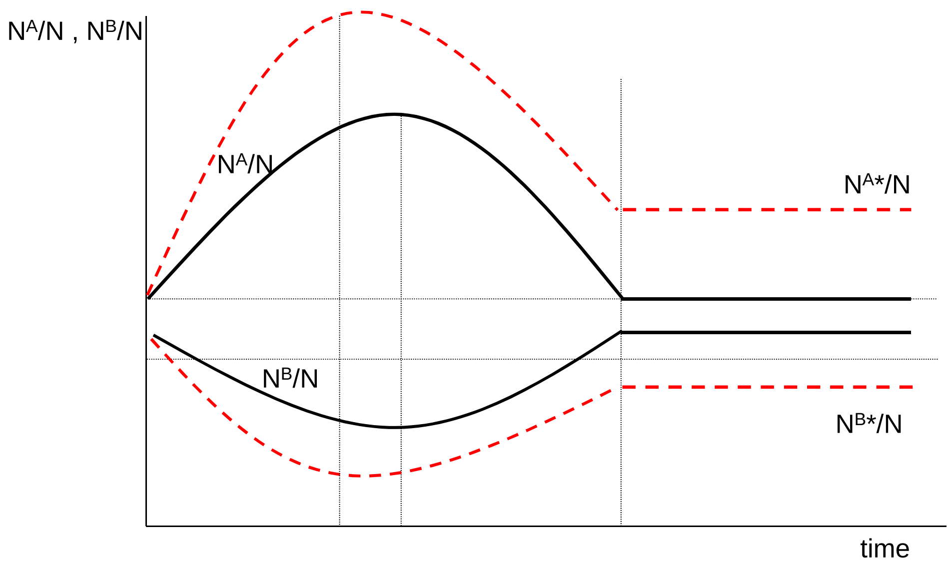


Figure 4: The Unassigned Lands

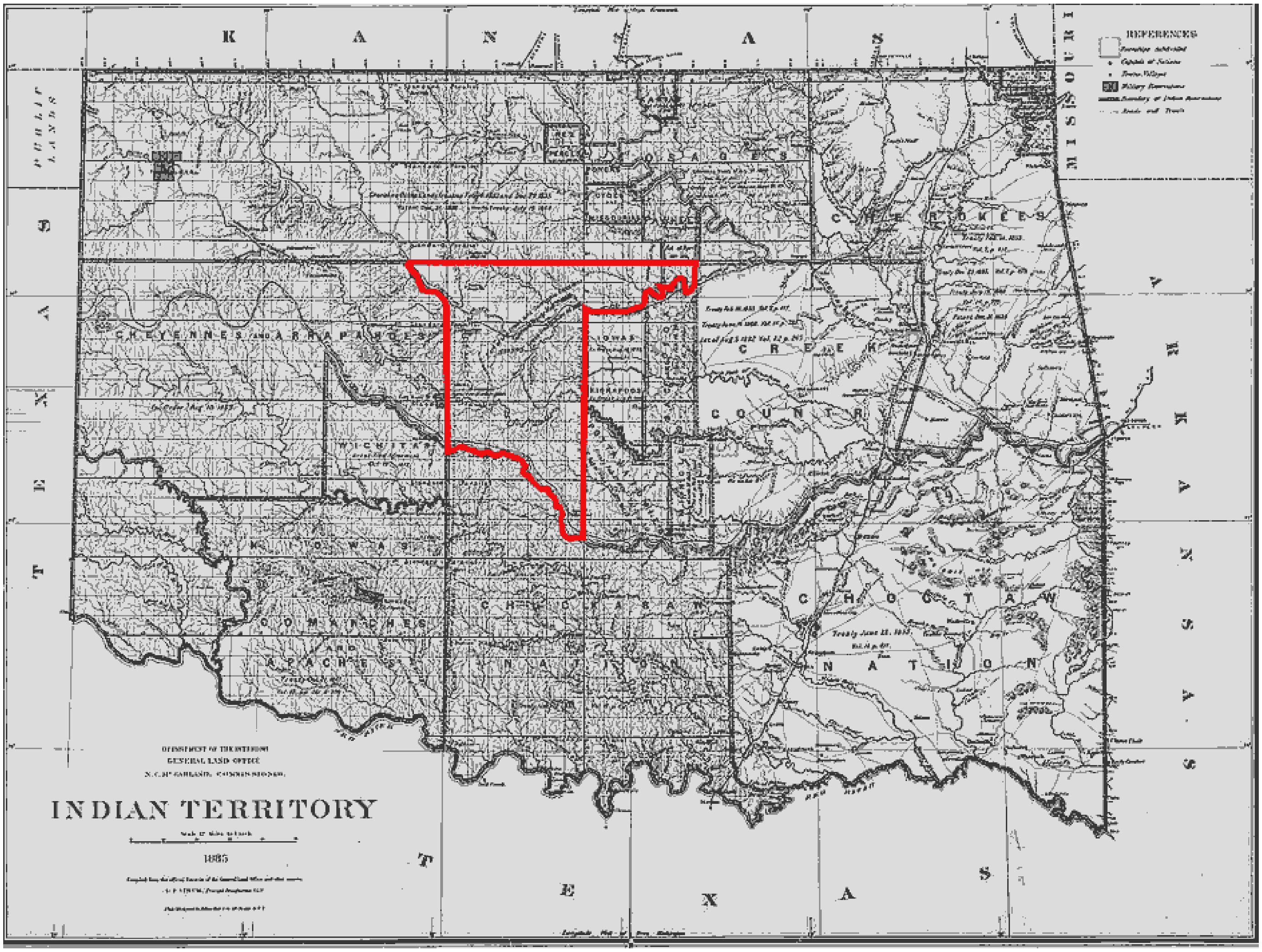
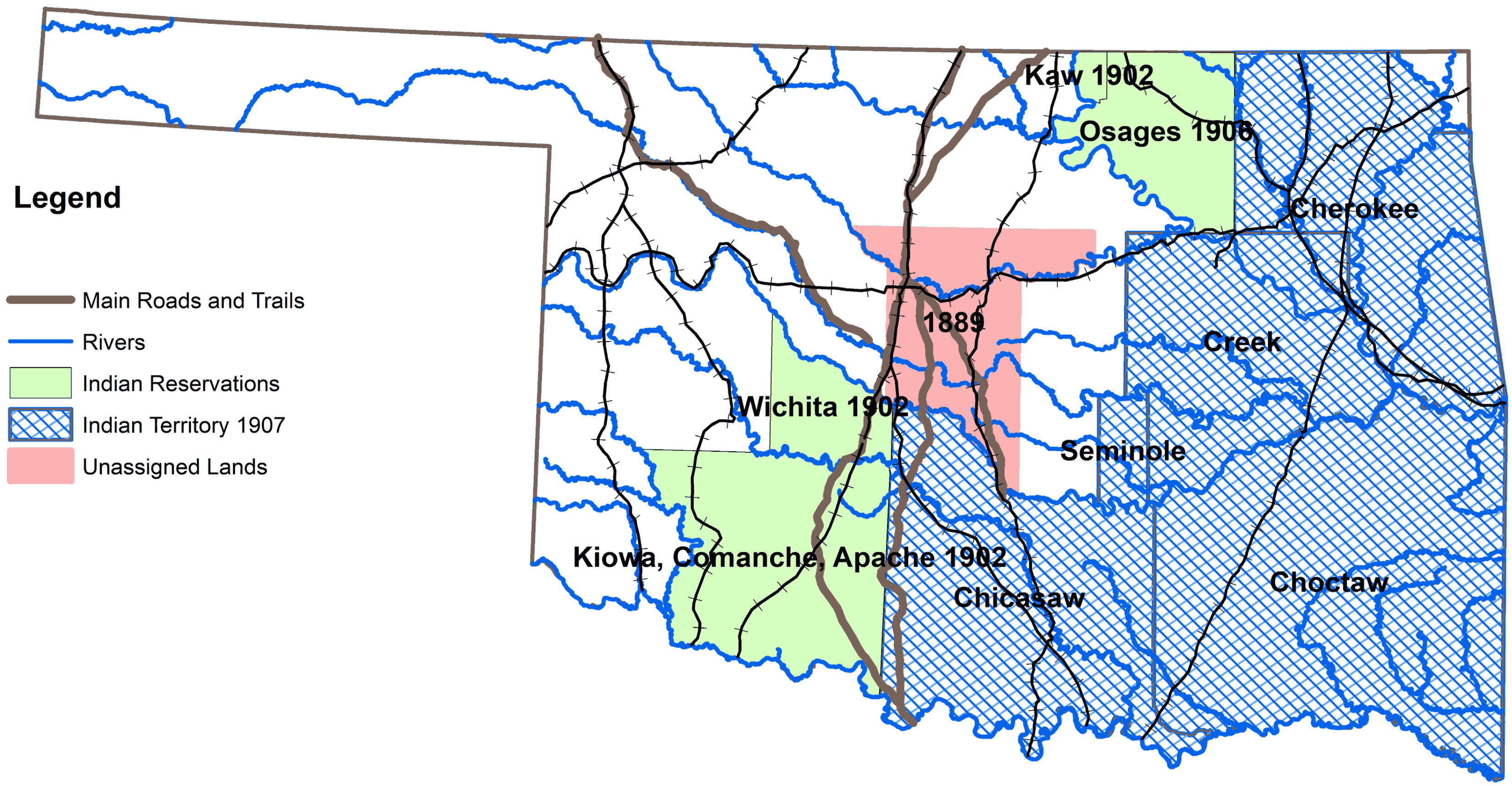
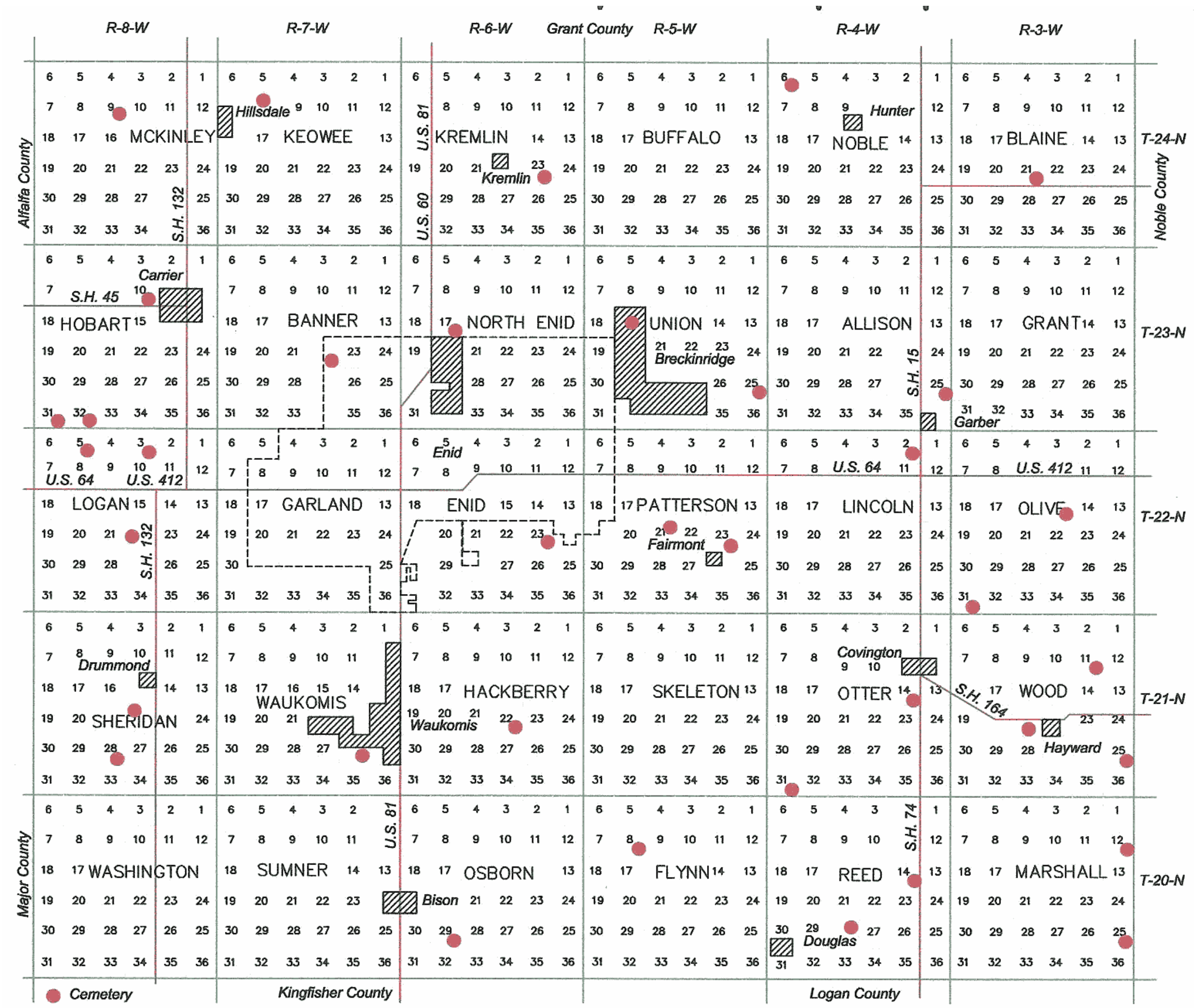


Figure 5: Oklahoma in 1900



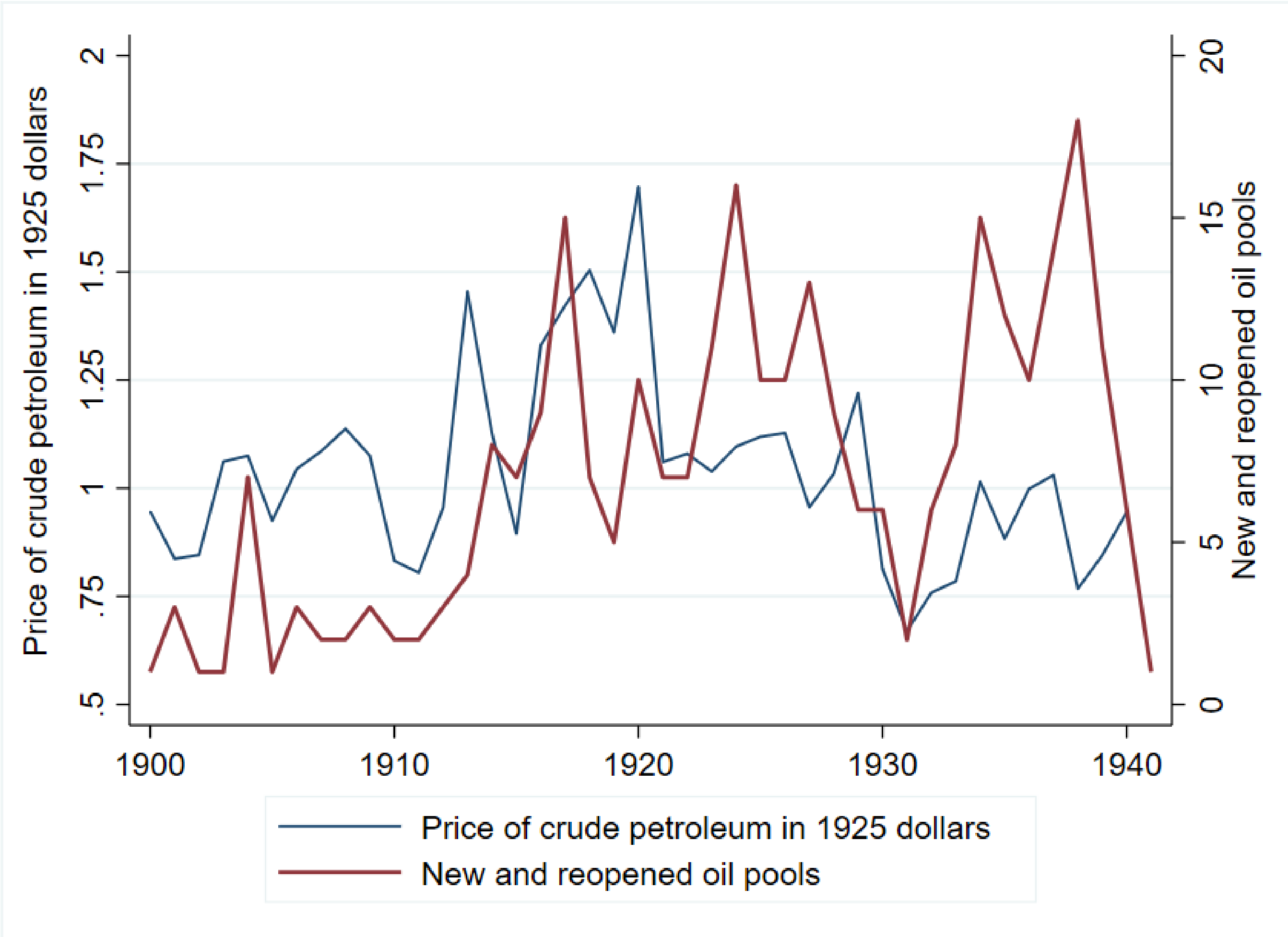
Notes: The area in white and light red constituted the Oklahoma Territory. Areas in green were tribal lands incorporated into Oklahoma Territory from 1902 to 1907. The areas in blue were the territories of the five civilized tribes, which were incorporated into the State of Oklahoma in 1907 at statehood.

Figure 6: Survey and Administrative Townships in Garfield County, Oklahoma



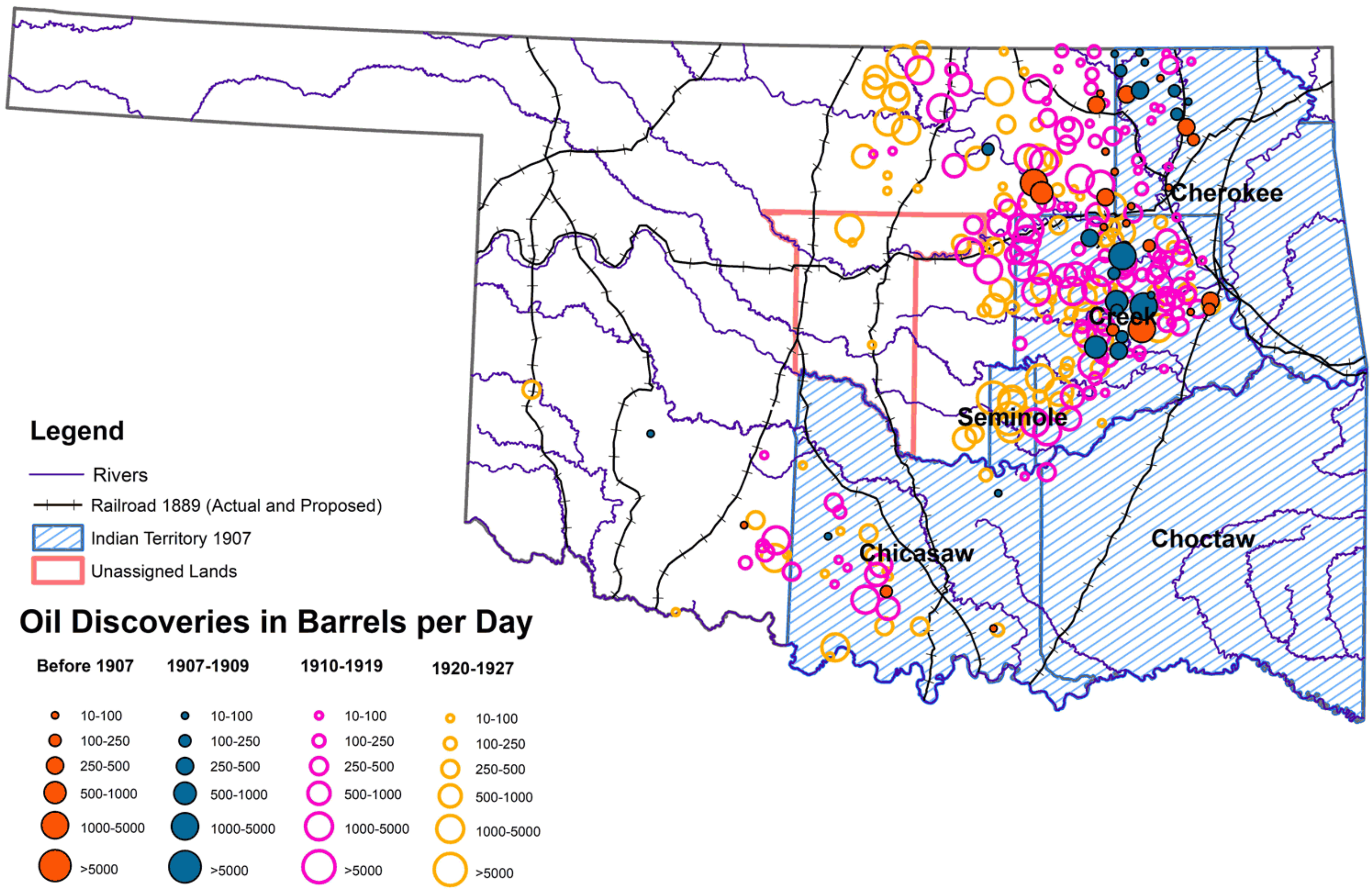
Notes: The map shows the division of the county into survey townships of 36 sections of 640 acres each. A homesteader could lay claim to one-quarter of such a section, or 160 acres or about 64 hectares. Administrative townships could be larger or smaller than 640 acres.

Figure 7: The Oil Discoveries and the Price of Oil: 1900-1940



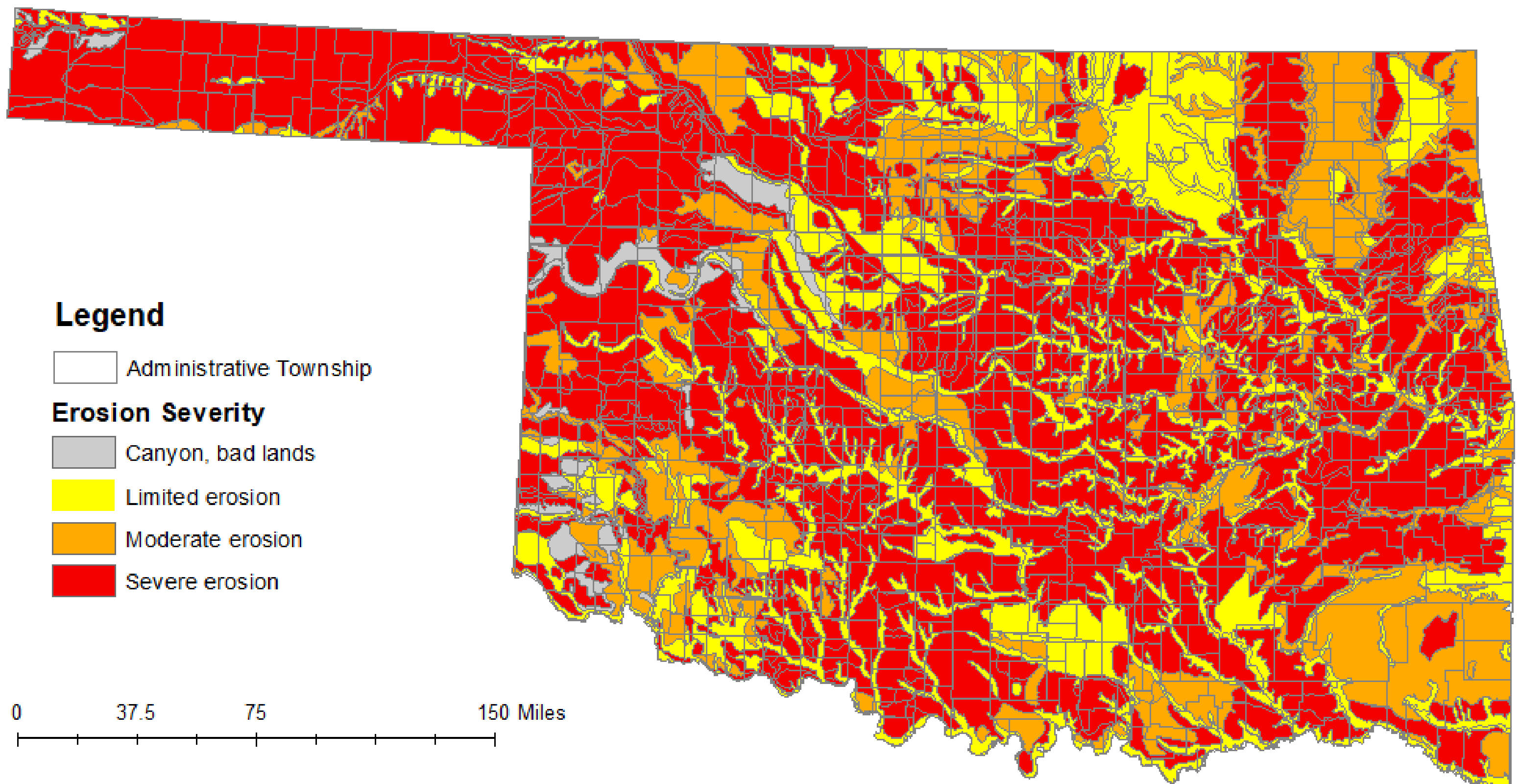
Source: Bullard, B. M. (1928) and Oklahoma Geological Survey (2019)

Figure 8: The Geography and Timing of Oil Field Discoveries: 1900-1940



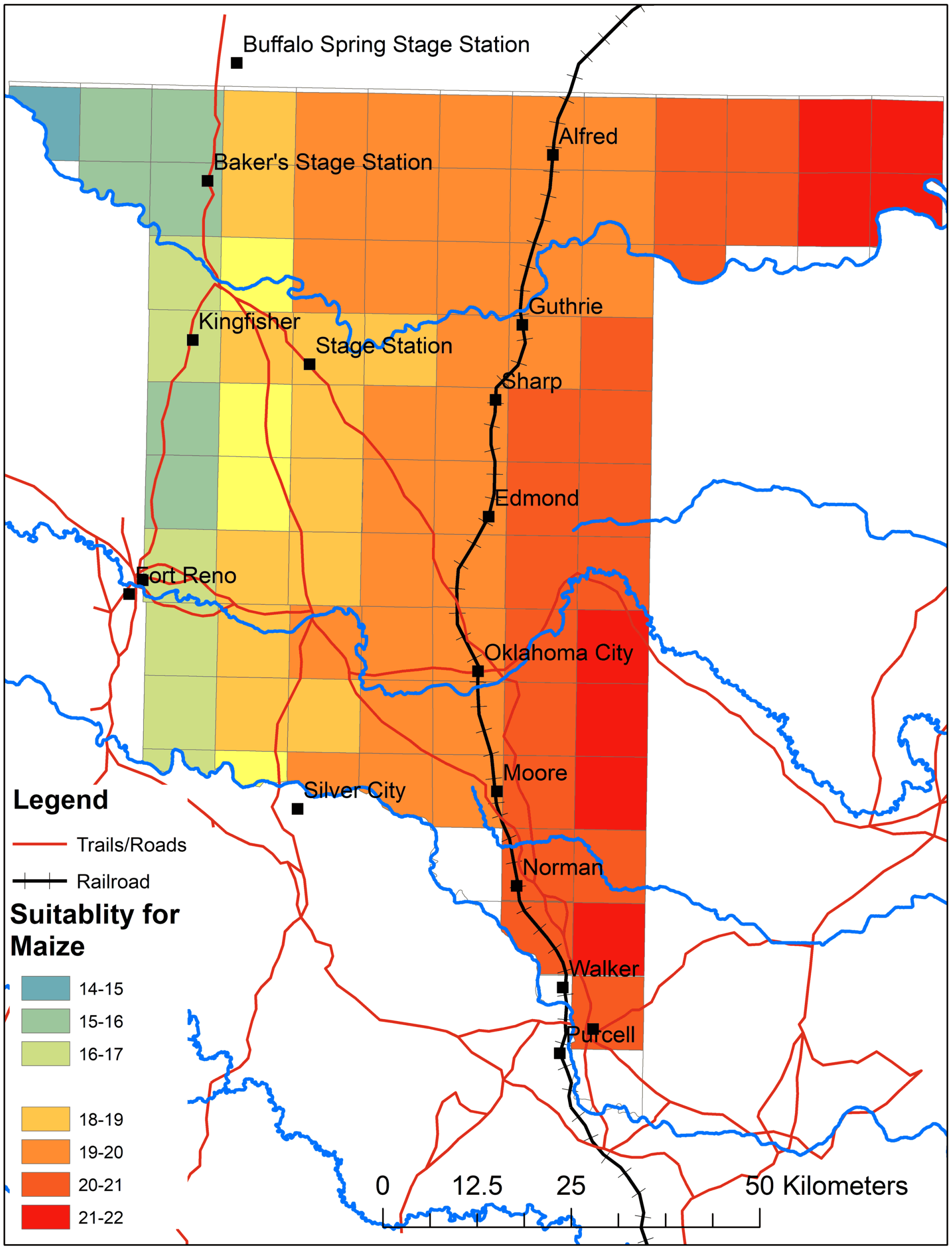
Source: Bullard, B. M. (1928) and Oklahoma Geological Survey (2019)

Figure 9: The Severity of Erosion in Oklahoma by 1935



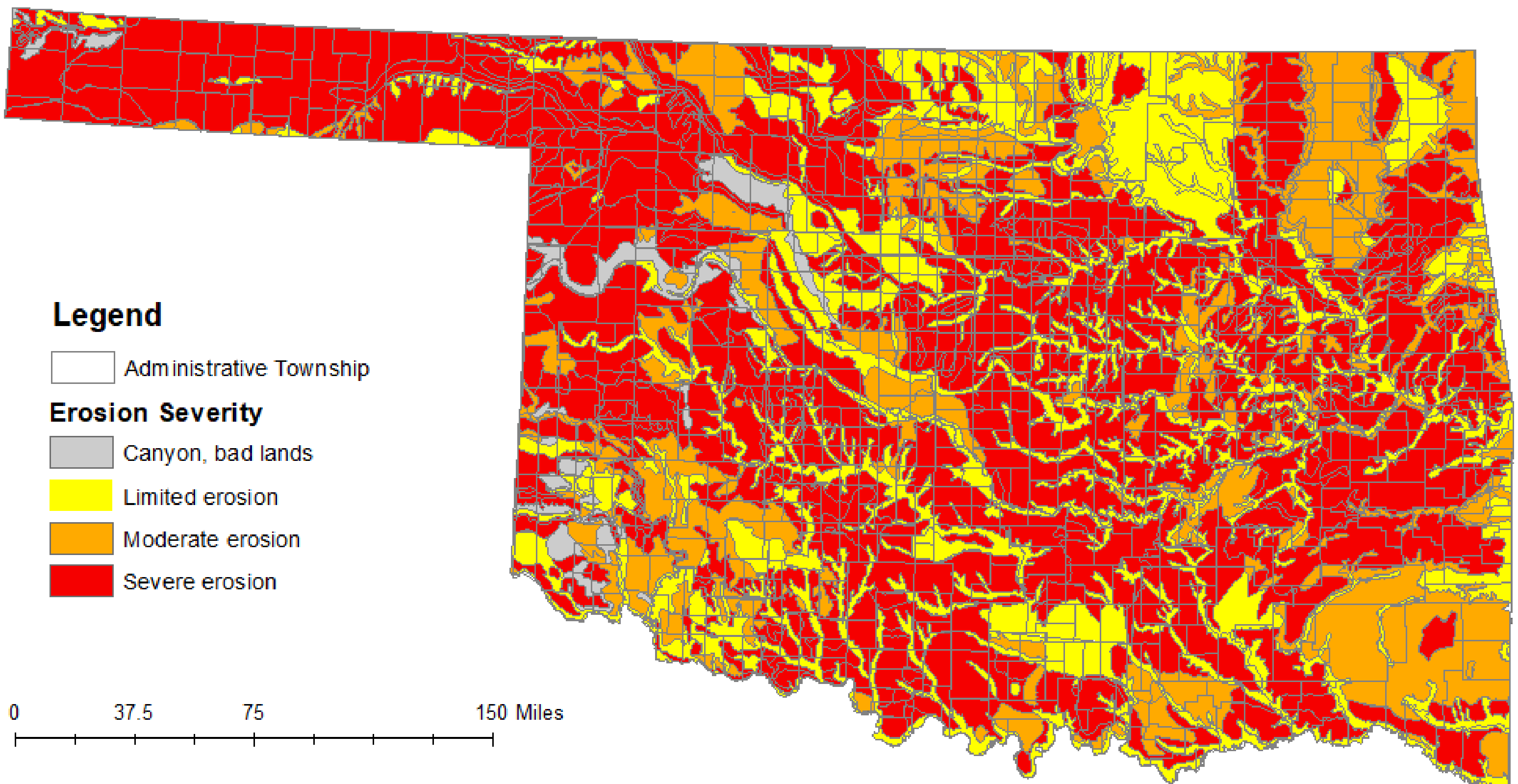
Source: United States (1934). Reconnaissance Erosion Survey of the State of Oklahoma. Washington, D.C., Soil Conservation Service.

Figure 10: First nature in the Unassigned Lands



Source: The map shows the railroads, roads or trails, railroad depots, stage stops, and forts in the Unassigned Lands prior to settlement by Euro-Americans in 1889. The soil suitability indices for Maize are from Galor and Özak (2016).

Figure 11: The Severity of Erosion in Oklahoma by 1935



Source: United States (1934). Reconnaisance Erosion Survey of the State of Oklahoma. Washington, D.C., Soil Conservation Service.

Table 1: Descriptive statistics of Variables

VARIABLES	Definition	N	Mean	Standard deviation	Minimum	Maximum
LPopDen	Log of population density	705	2.171	0.854	-1.714	6.075
LPopDen_{t-1}	Log of population density in the previous census year	705	2.136	0.846	-5.216	5.378
Oil_{t-1}	Interpolated maximum of well production in log of barrels per day within township in period prior to census year	705	0.965	1.844	0	9.221
$\text{Oil}_{t-2}\text{LPopDen}_{t-2}$	Oil_{t-1} from one period earlier multiplied by LPopDen from two periods earlier	705	2.173	4.879	-1.398	31.30
Rail	Railroad in township in 1887	705	0.176	0.381	0	1
River	River runs through township	705	0.545	0.498	0	1
Maize	Suitability of land for cultivation of maize (median in township)	705	18.82	7.076	3.285	30.42
Ruggedness Index	Terrain ruggedness index (median in township)	705	0.353	0.228	0.0813	2.244
Erosion	Proportion of area with severe erosion	705	0.555	0.302	0	1

Table 2: First Nature and the Population Density of Survey Townships

VARIABLES	(1) Mean (s.d.)	(2) Physical Geography	(3) Human Geography	(4) First Nature
Road/trail in township in 1887	0.481		0.075	0.102
	(0.052)		(0.560)	(0.743)
Railroad in township in 1887	0.144		0.330	0.223
	(0.0.353)		(1.081)	(0.733)
Railroad depot in township in 1887	0.092		0.630	0.664
	(0.296)		(1.731)	(1.851)
Other place	0.0385		0.337	0.363
	(0.296)		(0.970)	(1.054)
River in township	0.471	0.274		0.188
	(0.502)	(2.005)		(1.427)
Maize Suitability	19.07	0.059		0.041
	(1.946)	(1.348)		(0.983)
Ruggedness of Terrain	2.806	0.035		0.065
	(1.131)	(0.465)		(0.883)
Constant		0.271	1.474	0.418
		(0.369)	(15.765)	(0.602)
N		104	104	104
R^2		0.081	0.173	0.227
Adj. R^2		0.0530	0.139	0.171
F-test		2.920	5.171	4.030

t-statistics in parentheses

Note: The dependent variable is the Log(Population Density)$_{1890}$. The mean population density was 6.9 persons per km^2. An other place was defined as a stage coach stop or fort. For other variable definitions, please see the text.

Table 3: First Nature and the Population Density of Administrative Townships

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Pop Density 1890			Log Pop Density 1900		
VARIABLES	Physical Geography	Human Geography	First Nature	First Nature	Second Nature	First & Second
Road/trail in 1887		-0.039	0.051	-0.046		-0.046
		(-0.298)	(0.365)	(-0.358)		(-0.501)
Railroad in 1887		0.257	0.119	-0.012		-0.012
		(1.049)	(0.464)	(-0.049)		(-0.069)
Depot in 1887		0.498	0.625	0.788		0.788
		(1.656)	(2.038)	(2.787)		(3.899)
Other in 1887		0.465	0.519	0.230		0.230
		(1.446)	(1.601)	(0.768)		(1.075)
River	0.113		0.027	0.094		0.094
	(0.822)		(0.211)	(0.786)		(1.100)
Maize	-0.008		-0.025	0.010		0.010
	(-0.288)		(-0.915)	(0.413)		(0.578)
Ruggedness	0.890		1.332	0.343		0.343
	(1.256)		(1.817)	(0.508)		(0.710)
2nd Nature 1890					0.650	0.650
					(6.401)	(7.830)
Constant	1.492	1.550	1.582	1.787	2.209	1.787
	(3.109)	(17.880)	(3.524)	(4.317)	(44.194)	(6.040)
N	71	71	71	71	71	71
R^2	0.041	0.193	0.237	0.251	0.373	0.623
Adj. R^2	-0.00207	0.144	0.152	0.167	0.363	0.575
F-test	0.952	3.946	2.790	3.011	40.97	12.82

t-statistics in parentheses

Note: Dependent variable: Log(Population Density). The 2nd Nature variable is the residual from column (3). For other variable definitions, please see the text.

Table 4: Productivity Shocks and Township Population Density: 1910-1940

VARIABLES	Log Density 1910				Log Density 1920				Log Density 1930				Log Density 1940			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$LDen_{t-1}$		0.817	0.826	1.041		0.984	0.982	0.976		0.797	0.769	0.761		0.917	0.915	0.931
		(47.954)	(49.291)	(69.370)		(31.403)	(31.820)	(30.164)		(31.145)	(30.523)	(29.757)		(71.786)	(70.993)	(66.769)
Oil_{t-1}			0.068	0.896			0.051	0.042			0.069	0.060			0.005	0.010
			(5.500)	(1.095)			(4.741)	(3.632)			(6.517)	(5.163)			(1.053)	(1.986)
$Oil_{t-2}LDen_{t-2}$				-0.433				0.029				0.009				-0.007
				(-1.088)				(2.532)				(1.808)				(-2.990)
Rail	0.214	0.050	0.063	0.056	0.155	-0.055	-0.025	-0.033	0.212	0.088	0.141	0.145	0.246	0.052	0.056	0.049
	(3.516)	(1.737)	(2.249)	(2.520)	(1.990)	(-1.097)	(-0.500)	(-0.646)	(2.616)	(1.687)	(2.738)	(2.809)	(3.112)	(1.897)	(2.039)	(1.766)
River	0.117	0.049	0.044	-0.005	0.219	0.104	0.090	0.100	0.239	0.065	0.066	0.061	0.253	0.034	0.035	0.035
	(2.551)	(2.261)	(2.098)	(-0.306)	(3.729)	(2.748)	(2.416)	(2.658)	(3.917)	(1.620)	(1.714)	(1.575)	(4.247)	(1.638)	(1.676)	(1.695)
Maize	0.037	0.007	0.005	-0.008	0.054	0.018	0.013	0.014	0.045	0.002	-0.002	-0.003	0.064	0.023	0.023	0.023
	(10.707)	(3.912)	(2.762)	(-3.799)	(12.180)	(5.715)	(4.172)	(4.431)	(9.681)	(0.494)	(-0.539)	(-0.786)	(14.115)	(13.724)	(13.529)	(13.734)
Ruggedness	-1.268	-0.218	-0.180	-0.224	-1.084	0.164	0.227	0.223	-1.025	-0.162	-0.095	-0.085	-1.042	-0.102	-0.098	-0.101
	(-11.931)	(-4.020)	(-3.368)	(-2.870)	(-7.956)	(1.713)	(2.381)	(2.308)	(-7.236)	(-1.695)	(-1.020)	(-0.908)	(-7.538)	(-2.082)	(-1.994)	(-2.057)
Erosion	0.380	0.042	0.028	-0.020	0.365	-0.009	-0.027	-0.045	0.309	0.019	0.033	0.023	0.347	0.063	0.059	0.054
	(4.897)	(1.108)	(0.758)	(-0.698)	(3.672)	(-0.136)	(-0.428)	(-0.679)	(2.993)	(0.280)	(0.510)	(0.357)	(3.436)	(1.806)	(1.681)	(1.552)
Constant	1.531	0.379	0.381	0.160	1.144	-0.362	-0.329	-0.337	1.347	0.436	0.449	0.477	0.886	-0.349	-0.348	-0.374
	(18.933)	(8.200)	(8.409)	(4.885)	(11.045)	(-4.419)	(-4.060)	(-3.935)	(12.504)	(5.782)	(6.140)	(6.388)	(8.430)	(-8.720)	(-8.709)	(-9.188)
N	693	678	678	242	693	693	693	678	694	693	693	693	694	694	694	693
R^2	0.251	0.830	0.837	0.970	0.230	0.684	0.694	0.681	0.180	0.660	0.680	0.682	0.285	0.916	0.916	0.917
adj. R^2	0.246	0.828	0.836	0.969	0.224	0.681	0.691	0.677	0.174	0.657	0.677	0.678	0.279	0.915	0.915	0.916
F	46.09	545.7	492.5	933.9	40.97	247.5	222.0	178.4	30.20	222.2	208.0	183.0	54.74	1246	1068	945.3

t-statistics in parentheses

Note: The dependent variable is the log(population density of the civil township in the respective year. $LDen_{t-1}$ is the log of population density in the prior census year (e.g., for 1910 from 1907). For other variable definitions, please see the text.

Table 5: Productivity Shocks and the Population of Places: 1910-1940

VARIABLES	Log Density 1910				Log Density 1920				Log Density 1930				Log Density 1940			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$LPopulation_{t-1}$		0.995	0.995	1.022		1.034	1.032	1.039		1.050	1.042	1.053		1.005	1.007	1.013
		(56.223)	(56.945)	(44.670)		(53.570)	(56.416)	(55.301)		(57.039)	(58.746)	(62.437)		(120.975)	(120.371)	(121.292)
Oil_{t-1}			0.061	0.081			0.077	0.068			0.083	0.086			-0.010	0.006
			(3.104)	(2.237)			(6.574)	(5.727)			(6.217)	(6.707)			(-1.651)	(0.953)
Oil_{t-2}x$LPop_{t-2}$				0.001				0.008				-0.000				-0.006
				(1.482)				(2.388)				(-0.129)				(-5.695)
Rail	-0.001	0.001	0.001	-0.001	0.001	0.002	0.002	0.003	0.001	0.001	0.001	0.001	-0.000	-0.001	-0.001	-0.001
	(-0.386)	(0.695)	(0.673)	(-0.413)	(0.270)	(2.077)	(2.031)	(3.336)	(0.278)	(1.616)	(0.942)	(1.119)	(-0.121)	(-3.292)	(-3.104)	(-2.596)
River	0.001	0.001	0.001	-0.000	0.002	0.000	0.001	0.001	-0.006	-0.009	-0.008	-0.007	-0.005	-0.000	-0.000	0.000
	(0.158)	(0.304)	(0.592)	(-0.119)	(0.304)	(0.117)	(0.579)	(0.320)	(-0.958)	(-3.631)	(-3.688)	(-3.131)	(-0.791)	(-0.100)	(-0.187)	(0.230)
Maize	0.007	-0.008	-0.010	-0.008	0.020	0.011	0.005	0.008	-0.000	-0.026	-0.029	-0.030	0.009	0.008	0.008	0.009
	(0.776)	(-2.875)	(-3.420)	(-1.513)	(2.342)	(3.143)	(1.568)	(2.351)	(-0.020)	(-7.877)	(-8.988)	(-9.066)	(1.059)	(4.867)	(4.963)	(5.755)
Ruggedness	0.254	-0.021	0.026	0.161	0.522	0.162	0.238	0.113	0.491	0.250	0.286	0.366	0.316	-0.164	-0.162	-0.171
	(0.693)	(-0.180)	(0.227)	(1.050)	(1.462)	(1.175)	(1.820)	(0.866)	(1.278)	(1.766)	(2.104)	(2.803)	(0.824)	(-2.319)	(-2.297)	(-2.482)
Erosion	-0.034	-0.001	-0.004	0.005	-0.049	-0.041	-0.053	-0.054	-0.029	-0.005	0.001	-0.051	-0.033	-0.006	-0.005	-0.001
	(-0.311)	(-0.028)	(-0.124)	(0.104)	(-0.453)	(-0.983)	(-1.352)	(-1.374)	(-0.252)	(-0.124)	(0.029)	(-1.305)	(-0.277)	(-0.263)	(-0.214)	(-0.067)
Constant	6.321	0.379	0.381	0.092	6.030	-0.340	-0.315	-0.399	6.418	0.172	0.215	0.164	6.271	-0.130	-0.138	-0.185
	(33.173)	(2.950)	(3.008)	(0.466)	(32.541)	(-2.408)	(-2.349)	(-2.789)	(31.937)	(1.299)	(1.679)	(1.309)	(31.198)	(-2.016)	(-2.127)	(-2.867)
N	388	335	335	124	466	384	384	332	505	461	461	381	511	498	498	455
R^2	0.005	0.907	0.909	0.951	0.025	0.886	0.898	0.908	0.006	0.879	0.889	0.919	0.007	0.968	0.968	0.972
adj. R^2	-0.00813	0.905	0.907	0.947	0.0145	0.884	0.896	0.906	-0.00380	0.878	0.887	0.917	-0.00266	0.967	0.968	0.972
F	0.376	530.5	468.0	276.3	2.368	488.9	472.1	398.9	0.618	550.4	516.4	527.6	0.730	2460	2116	1954

t-statistics in parentheses

Note: The dependent variable is the log of the population of a town or city in the respective year. $LPop_{t-1}$ is the log of the population in the prior census year (e.g., for 1910 in 1907).For other variable definitions, please see the text.

Table 6: Productivity Shocks and Township Population Density: 1910-1940

VARIABLES	(1)	(2)	(3)	(4)	(5)
LPopDensity_{t-1}		0.880	0.871	0.884	0.886
		(81.447)	(81.315)	(69.247)	(69.72)
Oil_{t-1}			0.038	0.034	
			(8.457)	(6.621)	
1910xOil_{t-1}					-0.266
					(-0.0881)
1920xOil_{t-1}					0.0412
					(4.208)
1930xOil_{t-1}					0.0557
					(5.795)
1940xOil_{t-1}					0.00977
					(1.247)
$\text{Oil}_{t-2}\text{xLPopDen}_{t-2}$				0.001	
				(0.475)	
$\text{1910xOil}_{t-2}\text{xLPopDen}_{t-2}$					0.129
					(0.0878)
$\text{1920xOil}_{t-2}\text{xLPopDen}_{t-2}$					0.0326
					(3.403)
$\text{1930xOil}_{t-2}\text{xLPopDen}_{t-2}$					0.00490
					(1.136)
$\text{1940xOil}_{t-2}\text{xLPopDen}_{t-2}$					-0.00387
					(-1.154)
1920xRail	-0.018	-0.033	-0.009	-0.024	-0.0116
	(-0.390)	(-0.797)	(-0.219)	(-0.564)	(-0.271)
1930xRail	0.039	0.075	0.104	0.100	0.118
	(0.862)	(1.817)	(2.520)	(2.349)	(2.777)
1940xRail	0.073	0.060	0.093	0.089	0.0618
	(1.614)	(1.434)	(2.266)	(2.078)	(1.450)
1920xRiver	0.125	0.116	0.107	0.114	0.110
	(3.637)	(3.709)	(3.451)	(3.528)	(3.430)
1930xRiver	0.145	0.046	0.046	0.042	0.0375
	(4.223)	(1.472)	(1.475)	(1.314)	(1.174)
1940xRiver	0.159	0.043	0.048	0.043	0.0443
	(4.631)	(1.361)	(1.537)	(1.348)	(1.389)
1920xMaize	0.024	0.022	0.019	0.019	0.0173
	(9.306)	(8.935)	(7.699)	(7.450)	(6.460)
1930xMaize	0.015	-0.003	-0.005	-0.006	-0.00817
	(5.683)	(-1.186)	(-2.117)	(-2.291)	(-3.127)
1940xMaize	0.034	0.024	0.023	0.022	0.0244
	(12.989)	(10.064)	(9.449)	(8.826)	(9.671)
1920xRuggedness	-0.059	0.033	0.070	0.077	0.109
	(-0.737)	(0.441)	(0.965)	(1.006)	(1.431)
1930xRuggedness	0.000	-0.071	-0.027	-0.015	0.0295
	(0.003)	(-0.971)	(-0.371)	(-0.193)	(0.390)
1940xxRuggedness	-0.017	-0.140	-0.104	-0.091	-0.137
	(-0.214)	(-1.913)	(-1.435)	(-1.208)	(-1.827)
1920xErosion	0.058	0.031	0.019	0.007	-0.00563
	(0.998)	(0.577)	(0.372)	(0.131)	(-0.102)
1930xErosion	0.002	-0.012	-0.006	-0.013	-0.0165
	(0.040)	(-0.218)	(-0.114)	(-0.231)	(-0.306)
1940xErosion	0.040	0.074	0.042	0.041	0.0664
	(0.682)	(1.402)	(0.804)	(0.761)	(1.228)
Constant	2.096	0.365	0.375	0.284	0.282
	(74.464)	(13.820)	(14.355)	(7.527)	(7.498)
N	2,774	2,758	2,758	2,306	2,306
N townships	694	694	694	693	693
R^2 within	0.0951	0.0508	0.0583	0.000451	0.000908
R^2 overall	0.138	0.766	0.772	0.768	0.772
R^2 between	0.164	0.965	0.966	0.970	0.970

Note: t-statistics in parentheses. Results of random effects panel estimation. Year dummies are included. For other variable definitions, please see the text.

Table 7: Productivity Shocks and the Population of Places: 1910-1940

VARIABLES	(1)	(2)	(3)	(4)	(5)
$LPopulation_{t-1}$		0.403	0.402	0.325	0.322
		(18.205)	(18.610)	(12.662)	(11.695)
Oil_{t-1}			0.042	0.037	
			(7.730)	(6.303)	
$1910xOil_{t-1}$					0.042
					(1.204)
$1920xOil_{t-1}$					0.039
					(3.536)
$1930xOil_{t-1}$					0.087
					(7.815)
$1940xOil_{t-1}$					0.010
					(1.213)
$Oil_{t-2}xLPopulation_{t-2}$				-0.000	
				(-0.754)	
$1910xOil_{t-2}xLPopulation_{t-2}$					-0.001
					(-1.163)
$1920xOil_{t-2}xLPopulation_{t-2}$					0.007
					(2.478)
$1930xOil_{t-2}xLPopulation_{t-2}$					0.005
					(2.849)
$1940xOil_{t-2}xLPopulation_{t-2}$					0.003
					(1.739)
1920xRailDistance	0.002	0.003	0.003	0.003	0.002
	(2.010)	(3.016)	(2.990)	(1.544)	(1.511)
1930xRailDistance	0.004	0.004	0.003	0.004	0.003
	(3.615)	(4.204)	(3.791)	(2.125)	(1.768)
1940xRailDistance	0.002	0.002	0.001	0.001	0.001
	(2.180)	(1.885)	(1.339)	(0.843)	(0.874)
1920xRiverDistance	0.001	-0.000	-0.000	-0.002	-0.002
	(0.500)	(-0.193)	(-0.126)	(-0.782)	(-0.648)
1930xRiverDistance	-0.007	-0.008	-0.008	-0.009	-0.009
	(-2.739)	(-3.498)	(-3.668)	(-3.086)	(-2.964)
1940xRiverDistance	-0.007	-0.004	-0.004	-0.006	-0.006
	(-2.775)	(-1.839)	(-1.728)	(-1.999)	(-2.151)
1920xMaize	0.010	0.016	0.015	0.008	0.008
	(2.727)	(4.860)	(4.440)	(1.450)	(1.411)
1930xMaize	-0.015	-0.013	-0.014	-0.020	-0.024
	(-4.072)	(-4.008)	(-4.272)	(-3.561)	(-4.265)
1940xMaize	-0.006	0.004	0.005	-0.004	-0.004
	(-1.740)	(1.269)	(1.508)	(-0.677)	(-0.670)
1920xRuggedness	0.239	0.041	0.057	0.122	0.145
	(1.534)	(0.305)	(0.434)	(0.728)	(0.893)
1930xRuggedness	0.508	0.327	0.324	0.428	0.483
	(3.296)	(2.482)	(2.518)	(2.568)	(2.982)
1940xRuggedness	0.317	0.104	0.067	0.204	0.222
	(2.049)	(0.783)	(0.521)	(1.220)	(1.362)
1920xErosion	-0.079	-0.036	-0.041	-0.090	-0.080
	(-1.686)	(-0.880)	(-1.021)	(-1.625)	(-1.493)
1930xErosion	-0.080	-0.080	-0.075	-0.127	-0.111
	(-1.727)	(-1.993)	(-1.909)	(-2.288)	(-2.071)
1940xErosion	-0.087	-0.071	-0.072	-0.116	-0.098
	(-1.874)	(-1.760)	(-1.821)	(-2.094)	(-1.823)
Constant	6.372	3.913	3.913	4.436	4.458
	(380.823)	(27.993)	(28.702)	(26.475)	(24.761)
N places	526	510	510	460	460
N	1,870	1,678	1,678	1,292	1,292
R^2 within	0.132	0.351	0.383	0.335	0.382
R^2 between	0.00489	0.923	0.921	0.902	0.892
R^2 overall	0.00251	0.877	0.875	0.849	0.837
F	11.17	32.76	35.70	19.45	18.45

Note: t-statistics in parentheses. Results of fixed effects panel estimation. Year dummies are included. For other variable definitions, please see the text.