Entrepôts and Urbanization: Evidence from U.S. Railroads

PRELIMINARY AND INCOMPLETE

Hugh Montag *† Heyu Xiong ‡

April 22, 2016

Abstract

How significant are spatial frictions in determining the density and distribution of economic activities? We develop and study an economic geography model related to the existence of entrepôts, locations which intermediate trade between pairs of other locations. Entrepôt locations receive a second sector of income due to interchange, attracting more labor and economic activity. We use discontinuities in transportation induced by railroad gauge breaks in 19th century U.S. as an example of this phenomenon. Reduced form evidence indicates that counties containing rail-gauges received a substantial exogenous stimulus. We build a quantitative spatial general equilibrium model to disentangle the effects of entrepôt activity on its local economy as well as to evaluate its general equilibrium consequences.

*We thank Treb Allen and Yuta Takahashi for helpful advice, and Richard Hornbeck for comments. We are grateful to Kelsey Rydland for ArcGIS assistance.

†Department of Economics, Northwestern University.

‡Department of Economics, Northwestern University.

1 Introduction

What explains the distribution of economic activities across space? Why do people congregate in cities, and why is the observed distribution of cities so uneven? Economists have tackled questions related to economic geography dating back to at least Von Thunen (1826). A common theme in this long line of research is that transportation cost and infrastructure are integral to the spatial arrangement of development and the formation of cities.

What has been relatively unexplored is the role of trade intermediation in urbanization. Locations, such as New York City or Singapore, are strategically situated at junction and natural stopping points of trade routes. These focal points engage in productive industry, but they also captures surplus from pass through trade which require local labor.

This paper studies a natural experiment in entrepôts based on the U.S. railroads before gauge standardization. The U.S. rail network in 1861 was both extensive and surprisingly non-standardized.[1] At this time nine distinct gauge regions existed in the US railway network. At location of gauge breaks, significant labor and capital would be required for the costly interchange and transshipment of freight for through traffic.

First, we provide reduced form evidence that these gauge junctions spurred economic activity in the local railway town and counties where they were located, which attracted more people and saw more industrial production. The OLS estimates indicate these locations became more populated contemporaneously and experienced greater subsequent growth. We mitigate concerns of selection via an identification strategy based on the predicted location of gauge breaks based on origins of railroad hubs in 1840. We also control for observable pre-trends with matched differences in differences strategy.

Our finding coincides with a strand of research following Bleakley and Lin (2012) which has documented the significances of portages, or obstacles to trade, for economic development. But while the existing work emphasized the surprising persistence of these locations long after they were obsolete, our paper focuses on the contemporaneous effect.

More importantly, the prior works has studied only the local or partial equilibrium aspect of what is fundamentally a general equilibrium phenomenon. The incidences of portages are not just on the locations they occupied but the economic configuration across locations holistically and, to our knowledge, relatively little is known about their welfare implications in a general equilibrium setup.

Thus, we develop a spatial framework and embed our analysis in a structural model that captures the sentiments of contemporaneous anecdotes. We incorporate these entreôt locations in a quantitative spatial equilibrium model with realistic geography and heterogenous locations. In addition to bilateral trade and heterogeneous productivities, a subset of locations specialize in freight transfers and derive income from pass through traffic.

[1] Due to the decentralized process of railroad construction, varying engineering traditions developed. Between 1830 and 1832, four different gauges simultaneously emerged. In the subsequent fifty years, nine distinct gauges developed. Cities and railroad companies had been constructing train tracks for 40 years, so many counties had access to a railway. At the same time, the military necessities of the Civil War hadn't prompted a national pressure to standardize gauges yet. Therefore, 1861 provides the most relevant variation in the railroad network, and is the focus for remainder of the paper.

In considering entreôts, our model endogenizes iceberg trade cost by explicitly modeling the transport sector and the locations that specialize in that service. Thus in our model, the trade cost is endogenous to not only the path taken but also the cost of labor along the path. Because we consider the price indexes, endogenous trade routes, the underlying trade network, and the equilibrium bilateral flows between any pair of locations, we derive sufficient statistics for elasticity of welfare to existence and utilization of entreôts.

Ultimately, the model disentangles the effect of market access from "gauge taxes" and allow us to evaluate meaningful counterfactuals in absence of these historical "accidents".

2 Literature Review

This paper bridges at least three strands of literature. The first is the literature exploring the historical effect that railroads have had on U.S. economic development, particularly in the 19th century. This field became particularly energetic in the 60's, when papers such as Fogel (1964) and Boyd and Walton (1971) debated the overall significance of railroads, as opposed to alternatives such as canals. In recent years, digitization of maps has permitted paper such as Atack (2013), and Cervantes (2013), Donaldson and Hornbeck (2016) to model the transportation networks more thoroughly, and answer these questions in an economic geography framework. In particular, this paper draws inspiration from the market access approach of Donaldson and Hornbeck (2016), which finds significant welfare and economic losses in the absence of railroads.

The second field concerns general equilibrium economic geography models more generally. Many of these papers concern themselves with the existence of multiple equilibria, which is a strong possibility in our model. Allen and Arkolakis (2014) establish strong existence and uniqueness results in a economic geography gravity model. Davis and Weinstein (2002) explores the persistence of population distributions after a temporary shock and find strong location persistence, indicating little path dependence.

It is worth noting that this is not the first paper to look at entrepôts and port cities. Feenstra and Hanson (2004) and Ken (1978) explore how re-exporting has affected Hong Kong and Singapore, respectively. These papers are more interested how re-exporting reflects information frictions in trade, and how manufacturing activity in these cities has been affected. Both of these papers are more case studies than general models though, and do not explicitly model the affect of these entrepôts on other locations. Bleakley and Lin (2012) examine how portage locations, which are another type of entrepôt, led to the development of large towns. However, they focus on demonstrating that these large towns persisted long after the portages disappeared. Bleakley and Lin do not take these portage characteristics to a general paper.

3 Historical Settings

United States commercial railway construction began in earnest during the period of 1830 and 1832. As described by historians Taylor and Neu, the first U.S. railroads were built to serve regional enterprises and their transport needs.[2] Individual states authorized and granted charters for the construction of local railroads to facilitate trade between coastal cities and their hinterlands. Railroad construction was largely a private endeavor unfettered by national or public regulation.

The earliest examples of such charters included the Delaware and Hudson Canal Company's gravity line; and the Mohawk and Hudson Railroad, to carry freight and passengers around a bend in the Erie Canal. To link the port of Baltimore to the Ohio River, the state of Maryland in 1827 chartered the Baltimore and Ohio Railroad (B&O), the first section of which opened in 1830.

Similarly, the South Carolina Canal and Railroad Company was chartered in 1827 to connect Charleston to the Savannah River, and Pennsylvania built the Main Line of Public Works between Philadelphia and the Ohio River. By 1861, 251 railway firms had laid over thirty thousand miles of tracks across the U.S.

In early locomotive engineering, companies faced a plethora of technological decisions. Particular salient was the choice of track gauges, the distance between the inside face of a pair of rails. While some engineers learned from and imitated their British counterpart in adopting the British technological standard, the American reports of the suitable specification of gauges was imprecise and loosely interpreted.[3] The initial 1832 New York State railroad commissioner report stated "the distance between the two tracks, for wheels, should be around five feet". As a result, opinions over the optimal gauge varied greatly.

Thus railway development became a patchwork process and the technical specification for each railroad was at the discretion of the chief engineer. Without foresight of a consolidated network, distinct gauge standards were adopted by early railroads in different parts of the country, and subsequent construction tended to consider only the gauge of their immediate neighbors. As a result, over the next fifty years, nine distinct gauge region formed across the U.S and only 17 % of destinations could be reached without a change in gauge Puffert (2000).

The incentive and necessity of adopting a standardized gauge increased with the substantial volume of interregional traffic. But at that point switching cost is costly enough to deter easy transitions.

The exigent circumstances of the Civil War provided a catalyst towards standardization. The war time logistics and needs exerted pressure on Union and Confederate governments to standardize railways within their domain. The Pacific Railway Act of March 3, 1863 specified that the federal funded transcontinental railroad was to be on standard gauge. By 1880, competitive forces and consolidations in the railroad industry had resulted in a common gauge in the Northern states but the Southern states remained on a broad 5' gauge.

The final resolution to gauge diversity came with the integration of Southern railway network on May

[2] "The first railroads in the United States were built, as were most of the early turnpikes [roads] and canals, to serve nearby and local needs" Taylor and Neu (p.4).

[3] In Britain, the Stephenson gauge, 4'8.5", had prevailed as the preeminent gauge choice. British railroad practice was at first uncritically transferred onto America.

31 and June 1, 1886 when 13,000 miles of tracks were physically converted to the national gauge.

3.1 Gauge Junctions

"Where ever there is a break in gauge, there is always a large amount of business to be done and a town springs up immediately around that place."

-Senator James B. Grimes, during the Erie Gauge Wars of 1855-1856

The incompatibilities incurred by breaks of gauges were costly. Each gauge transition imposed a full-day delay on through shipments and required significant labor and capital for interchange, which was typically performed manually (Poor 1851, Taylor and Neu (2003)). Railroad companies maintained fleets of idle trains at gauge break stations for transferring freights. The most common method of service was bogie exchange whereby, aided by cranes, each rail car would be hoisted, and its chassis replaced with one of a different gauge.[4]

Historians estimate that transshipment cost at site of gauge break varied between 7 and 25 cents per ton and interchange took up to 24 hours. Boston Board of Trade reported that in 1866 such "gauge taxes" on traffic between Boston and Chicago amounted to 500,000 dollars Taylor and Neu (2003).

Contemporaries at the time noted the significance of gauge junctions to local development. To local merchants it was clear the forced transshipment of freights led to formation of forwarding companies and created jobs for the municipalities' workers. The most spectacular example of this parochialism was during the Erie Gauge Wars of 1855-1856 when vested local interest physically intervened to prevent conversion of gauges at Erie which would have denied the break of gauge.

As late as summer of 1871, Louisville campaigned for a stretch of 5' railroad to be built at the south of the city, in consideration of the gauge interchange at the nexus of North South trade traffic.

4 Data Description

The main sources of data are historical county boundary files from NHGIS and railroad data from University of Nebraska. County-level shape files are standardized to 1860 county borders, using the county-intersection procedure described in Donaldson and Hornbeck (2016).

The railroad data from University of Nebraska is digitized from maps provided in Taylor and Neu (2003) which contains detailed information on ownership of individual railway tracks as well as their gauge width. Figure 2 depicts a visual representation of the railway network in the the United States as of 1861. The different shades of lines correspond to different railroad gauges. We coded locations of gauge breaks and junctions between railroad companies and calculated number of these junctions enclosed by counties.

[4]Several alternative adapters developed such as transporter cars (which carried cars of a different gauge), adjustable-gauge wheels, and multiple-gauge track. No method was completely satisfactory and each had its own deficiencies.

We recover locations of known railroad towns from Taylor and Neu (2003) and label these nodes in the railroad data. This provides us a sample of 590 known railroad towns in 1861. We then match these towns to city level data from the 1850 and 1860 population census tabulated and digitized in Fishman (2009). This provide us with suitable outcome variables at the city level.

Locations of railroad gauge breaks and trade routes are calculated using ArcGIS software. Information regarding freight costs, transshipment cost, and wagon routes are taken from Donaldson and Hornbeck (2016).

We gather economic and demographic county-level data before and after the march from the US Census, 1850-1920. Haines Michael (2010) provides decadal, county-level, agri- cultural production and asset value data, as well as demographic information for each county, from the Census of Population, the Census of Agriculture, and the Census of Manufactures.

5 Reduced Form Evidence

According to the historical context, gauge breaks should encourage economic activity in the towns where they are located. This is the case because firms shipping across gauge breaks need to hire local labor from these towns to unload goods from one type shape of train and load them onto another. This additional source of labor demand should drive up wages, and encourage people to migrate to these towns. To test this prediction empirically, I first estimate the reduced form effect of gauge breaks on contemporaneous population and manufacturing.

5.1 OLS Estimates: County Level Results

We organize our analysis at two geographic levels, the county and the railroad towns/cities themselves. This section presents the county specification and OLS results. The estimating equation is:

$$y_{c,s,1860} = \beta \# \text{ of Gauge Breaks}_{c,1860} + \alpha_s + \lambda \mathbf{M}_c + \gamma \mathbf{X}_{c,1860} + \epsilon_c \tag{1}$$

where $y_{c,s,1860}$ is the economic outcome (such as log population, log manufacturing establishments, share of population in manufacturing, and log railroad employment) of county c in state s and the decade 1880. $\mathbf{M}_c$ is a vector of time-invariant controls, and $\mathbf{X}_{c,1860}$ is a vector of initial conditions in 1860, α_s is a state fixed effect, and ϵ_c is an error term. The coefficient of interest, β, is on the number of gauge breaks enclosed in county c.

The vector of time-invariant controls, $\mathbf{M}_c$, comprises a rich set of variables. First, I control for a host of geographic variables. We include distance to major urban centers and waterways measured in logs. These distances could affect the market access of industrial production and the flow of trade, and thus including them as controls is important to avoid omitted variable bias. We also control for ecological characteristics such as terrain ruggedness, elevation, latitude and longitude which can feasibly affect development.

To mitigate concerns of selection, we restrict our analysis to only counties that had railroad access by 1860. This leaves us with a sample of 869 counties. And among the set of initial conditions, $\mathbf{X}_{c,1860}$, we include railroad specific controls. Specifically, we control for the log miles of railroad enclosed in the county in 1860.

Since gauge breaks only occur at intersection of railway lines owned by different companies, the estimate could be conflating the effect of having multiple railroad companies or the density of railroad ownership within the county. To address this concern directly, we include the number intersecting railway companies within the county. These junctions resemble the gauge breaks with the exception than the fact they do not contain a transfer of gauge, thus they are potential confounders and their inclusion rules out competing explanations.

Lastly, we include an array of socio-economic controls such as lagged population size, urbanization rate, lagged manufacturing, etc. The state fixed effects absorb any shocks common to all counties within a state such as changes in the state-specific business cycles or state policy changes.

Table 1 provides the OLS estimate of the number of gauge breaks and the number of intersection between railroad companies which are not gauge breaks. We see for the set of outcome variables, the coefficient on gauge break is positive and significant. In particular, gauge break counties were more populous, had higher number of railroad workers, more manufacturing establishments, and greater share of population in manufacturing employment. The table reports robust standard errors clustered at the state level.

Table 1: OLS Results: County Level Analysis

	Log 1860 Population		Log Railroad Employment		Manufacturing Establishment		Manufacturing Employment	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Gauge Breaks	0.089***	0.090***	0.192**	0.187**	0.036**	0.031*	0.071***	0.058***
	(0.027)	(0.027)	(0.081)	(0.084)	(0.018)	(0.017)	(0.020)	(0.020)
# of Railroad Companies	0.019***	0.019***	0.039***	0.037***	-0.023	-0.020	-0.023	-0.016
	(0.004)	(0.004)	(0.013)	(0.013)	(0.015)	(0.014)	(0.020)	(0.019)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Population Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Socioeconomic Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	829	829	826	826	799	799	799	799
Clusters	30	30	30	30	30	30	30	30
R^2	0.889	0.897	0.208	0.213	0.492	0.508	0.555	0.585

Note: * $p < .10$, ** $p < .05$, *** $p < .01$

5.2 IV Construction and 2SLS Results

The estimations presented in the previous section reveal a suggestive relationship, but they cannot be interpreted as causal. The primary concern is that measuring the differences between gauge break and non gauge break counties can potentially result in biased estimates because counties selected to possess a gauge break could possibly differ along unobservable dimensions that are correlated with economic growth.

One especially compelling competing explanation is that because local interests recognized the significance of gauge breaks, the more politically connected locations were able to politically lobby for gauge breaks to be allocated to their town. Thus the results reflect consequences of political capital rather than gauge breaks themselves. To address these threats to identification, we pursue an instrumental variables strategy.

The purpose of the instrument is to identify plausibly exogenous variation in the determinants of gauge breaks. To construct the instrument, we predict the locations of gauge breaks based on the configuration of railroad network in its initial infancy, decades priors to the actual realization of an integrated network.

Rail networks tended to originate form a hub-city, such as New York City or Philadelphia, and expand outwards. Without political influence or intervention, if railroad clusters simply grew concentrically and organically, we would expect an intersection to occur midway between two hubs. And if these railway clusters were built on differing gauges, we would anticipate their junction to result in a gauge break.

Our approach was to find the centroid of each rail network in 1840, of which there were roughly 20. We treated these centroids as "railroad hubs", and found the midpoints between each centroid-pair that possessed different gauges. This would indicate spots where we would expect these gauges to meet and break, conditional on railroad networks growing radially from their origin, if they ended up meeting. The instrument is the distance of a county from the nearest midway spots, which we would expect to be exogenous.

For each county in our sample, we calculated how far away they were from one of these theoretical gauge breaks, which was the instrument. For an example of this process, see figure 5, which draws the line between a centroid-pair.

The key intuition is we are isolating and utilizing variation in the existence of gauge breaks that is attributable only to their distance from the predicted location of junctions. Because these predicted locations do not affect economic development through any other channels, the exclusion restriction is plausibly satisfied.

Table 2 reports the IV estimates of the effect of gauge breaks on outcomes considered in the previous section with the same corresponding specification. The IV estimates indicate positive and significant effects of gauge breaks on the contemporaneous population size of the county

Unfortunately the instrument is relatively weak with a F-statistics hovering around 10 across the different specifications. This leads to the large and imprecise standard errors on several of the other coefficients.

However, the point estimates themselves are unanimously larger than their respective OLS counterparts. Since weak instruments tend to bias IV estimates toward the OLS, this would indicate we might be underestimating the actual effect. A negative bias in the OLS estimates is explained by omitted variables that are negatively correlated with gauge break status and positively associated with subsequent economic performances.

Table 2: 2SLS Results: County Level Analysis

	Log 1860 Population		Log Railroad Employment		Manufacturing Establishment		Manufacturing Employment	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Gauge Breaks	0.055**	0.054**	0.523	0.488	0.275	0.260	0.066	0.104
	(0.026)	(0.026)	(0.892)	(0.437)	(0.412)	(0.251)	(0.265)	(0.073)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Population Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Socioeconomic Controls	No	Yes	No	Yes	No	Yes	No	Yes
Observations	829	829	826	826	799	799	799	799
Clusters	30	30	30	30	30	30	30	30
R^2	0.889	0.897	0.208	0.213	0.492	0.508	0.555	0.585
F	10.693	11.018	10.693	11.018	7.974	8.099	7.974	9.667

Note: * $p < .10$, ** $p < .05$, *** $p < .01$

5.3 Township Level Results

Next, we repeat our analysis at a finer geographic level. The higher degree of spatial frequency allow us to concentrate on measuring the effect at the location where it would be most salient. We compare population of railroad cities situated at break of gauges to neighboring railroad cities elsewhere in the county. Our baseline specification is the following:

$$y_{t,c,1860} = \beta \mathbb{1}\{GaugeBreak\} + \delta_c + \lambda \mathbf{X}_t + \epsilon_t \tag{2}$$

where $y_{t,c,1860}$ is the log population of town t in county c in the decade 1860. $\mathbf{X}_t$ is a vector of baseline city level controls that include lagged 1850 population, gender ratio, and the white population of the town t in 1850.

The inclusion of the county fixed effect, δ_c, accounts for unobservables characteristics at the county level, the residual variation captured by β is within county differences in population between cities.

Additionally, we examine the extensive margin. We define as dependent variable a dummy, $\mathbb{1}\{\text{Incorporated Township}\}$, for if a incorporated town existed at the railroad junction using the same regression specification above. Positive estimates of β would imply that junctions involving a gauge break were more likely to have an incorporated township.

As before, we instrument for the gauge break status of a city with the distance of that city to the nearest location of predicted gauge break.

Table 3 displays the results. As expected, the effect is much larger at city level.

5.4 Differences in Differences Specification

To further address concerns regarding endogeneity and selection, we move beyond the static setting and augment the cross sectional analysis with panel variation. We use a differences-in-differences estimation strategy, exploiting the timing and the geographical variation in the introduction of gauge breaks.

Intuitively, we compare the difference in outcomes of counties before and after the introduction of

Table 3: Town Level Results: OLS and IV

	OLS					IV			
	$\mathbb{1}$\{Incorporated Township\}		Log (1860 Population)			$\mathbb{1}$\{Incorporated Township\}		Log (1860 Population)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathbb{1}$\{Gauge Break\}	0.163**	0.148*	0.975***	0.750***	0.671**	0.567	0.399	2.647*	2.616*
	(0.077)	(0.083)	(0.300)	(0.277)	(0.314)	(0.634)	(0.409)	(1.595)	(1.454)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County Fixed Effects	No	Yes	No	Yes	Yes	No	Yes	No	Yes
Township Controls	No	No	No	No	Yes	No	No	No	Yes
Observations	590	590	335	335	203	590	590	314	175
R^2	0.013	0.201	0.268	0.321	0.558	590	590	333	314
F	–	–	–	–	–	11.175	10.362	12.450	9.667

Note: * $p < .10$, ** $p < .05$, *** $p < .01$

gauge breaks in a given locality, with the difference in outcomes within localities that never had gauge breaks in the same period of interest. This strategy accounts for the unobserved level differences between localities.

However, the credibility of the DiD approach hinges crucially on the identifying assumption that in absence of gauge breaks the treated counties would have experienced the same changes in outcome variable as the untreated, conditional on covariates. This assumption is potentially violated in our setting where selection on trends is a possible confounding factor.

To reduce the scope for omitted variable bias and correct any unobserved pre-treatment trends, we follow the approach of Abadie and Imbens (2006) and Abadie and Imbens (2011) to impute counterfactual observations by matching treated houses with similar houses from a control group. Thus, we employ an empirical approach of differences in-differences technique combined with a nearest-neighbor matching algorithm

The key to matching procedures is to restrict the sample so that unobservable county attributes are not correlated with treatment status. We do so here by limiting the control and treatment sample by requiring approximate matches in certain dimensions. In particular, we match gauge counties to non-gauge counties that are similar along the observed baseline log population in 1790, 1800, 1810, and 1820, with the idea that these matched counties would otherwise be expected to change similarly.

Ultimately, we exclude 9 gauge counties and 188 non gauge counties from subsequent analysis because they do not have a nearest neighbor within the specified caliper. With this restricted sample of substantially more comparable counties, we employ a traditional differences in differences framework. We estimate the following fully flexible equation:

$$y_{it} = \sum_{t=1790}^{2010} \beta_t \mathbb{1}\{GaugeBreak\} * I_t + \sum_{t=1790}^{2010} \gamma_t I_t + \sum_c \rho_c I_t^c + X_{ict}\beta + \epsilon_{ict} \quad (3)$$

where i indexes countries and t indexes decades, which span 1790 to 2010. The equation includes county and year fixed effects, $\sum_c \rho_c I_t^c$ and $\sum_{t=1790}^{2010} \gamma_j I_t$. The county controls include a set of time invariant variables interacted with the year fixed effect.

The variable $\mathbb{1}\{GaugeBreak\}$ is a time invariant indicator for if a county i had gauge breaks in 1861. It is interacted with the time period fix effects. The estimated vectors of β_t reveal the correlation between gauge break status and the outcomes of interest in each time-period. If, for example, the gauge breaks increased local population then we would expect β_t to be positive and significant only after their introduction circa 1860.

The dependent variables we will be considering are log population, manufacturing employment, and log total investment in manufacturing. These variables were chosen because we have consistent measure of them in the pre-gauge years for us to match and assess pre-trends.

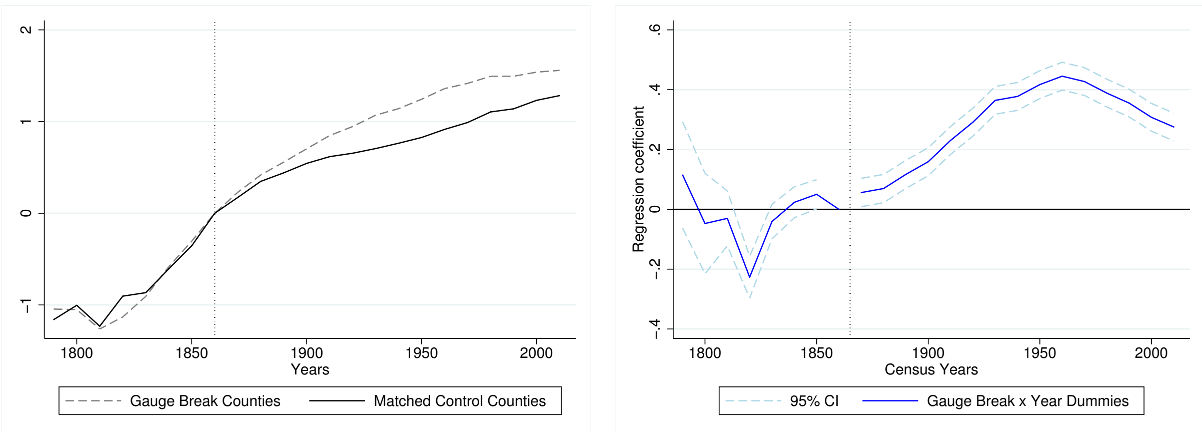
The patterns in the data is visualized most clearly by plotting the coefficients of the interaction terms over time. Figures 1 and 2 plot the point estimates of β_t and their 95 percent confidence intervals for log population, manufacturing employment, and log total investment in manufacturing. A clear pattern emerges. The growth in gauge break counties occur only after the existence of gauge breaks and we do not observe any clear trends of the estimated interaction effects during the time periods immediately prior.

Altogether the totality of the evidence is consistent with our hypothesis that gauge breaks had a causal impact on local development.

Figure 1: Differences in Differences: Population

(a) Log population in matched gauge and control counties

(b) Event study of log population



Note:

6 Model

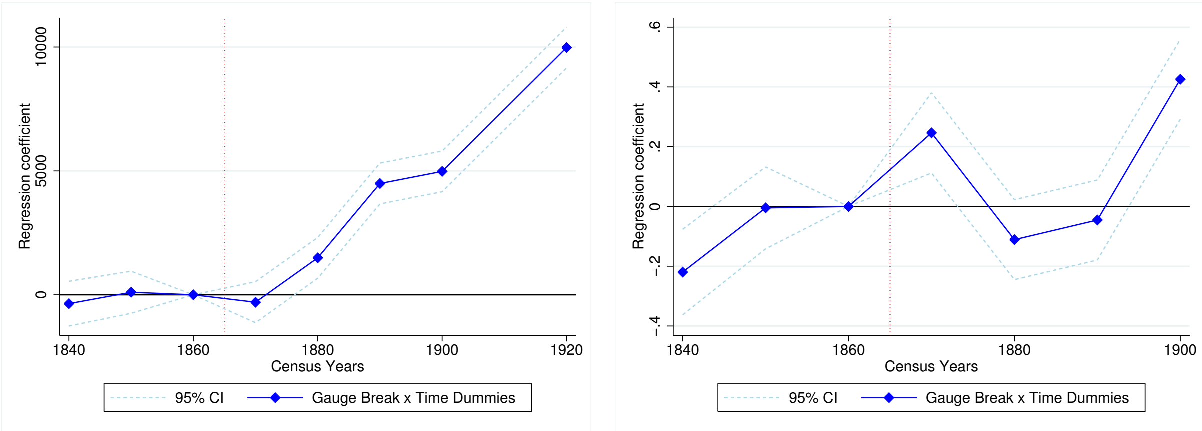
6.1 Transportation Costs

Entrepots will influence the cost of trade between locations by introducing endogenous transhipment costs for certain routes. This section introduce the framework developed by Allen and Arkolakis (WP)

Figure 2: Differences in Differences: Manufacturing Outcomes

(a) Manufacturing employment

(b) Log total manufacturing investment



Note:

for endogenizing trade costs across a transportation network. We will also present a method to calculate the probability that a shipment travels through a given entrepot, which will allow us to assess how much income a gauge break earns through freight transfers.

6.1.1 Setup

Locations are organized on a weighted, directed graph with an associated transportation matrix T=$[t_{i,j}]$, where $t_{i,j} \geq 1$. Vertices on the graph correspond to locations, and any two locations that are directly adjacent are connected by an edge. The term $t_{i,j} \geq 1$ corresponds to the iceberg cost of traveling along the edge *i*-*j*, where $t_{i,j} = \infty$ if i and j don't share an edge.[5]

The iceberg cost of an edge has two components potentially. If j is not an entrepot location, then the trade cost is an exogenous distance-based component, $\bar{t}_{i,j}$. Edges ending at an entrepot have an additional multiplicative entrepot cost t^j, such that $t_{i,j} = \bar{t}_{i,j}(1 + t^j)$. The entrepot cost is endogenous and paid to the entrepot as income in a process which will be explained in the next section.

Trade between locations i and j is undertaken by a continuum of heterogenous traders $\nu \in [0, 1]$ who travel along paths from origin i to destination j. A *path* from i to j a sequence of vertices, $p = (p_0, p_2, p_3, ..., p_K)$ where $p_0 = i$ and $p_K = j$. The subscript K refers to the path's length, and P_K refers to the set of all paths with length K.[6] The base trade cost of a path from origin i to destination j

[5] As in Allen and Arkolakis (WP), we do not include an edge from a location to itself, i.e. *i*-*i*. Hence, the diagonal of the transportation matrix is infinity, $t_{i,i} = \infty$. This condition is required to a coherent solution to the cost of shipping between two locations; without this assumption, we must consider routes where the goods stay at a location for an indefinite amount of time.

[6] Unlike the standard definition of a path, these paths may visit the same vertex more than once and may travel over the same edge multiple times. It's even possible that a path will arrive at j and fail to terminate. In practice, traders will

of length K is given by the expression:

$$\bar{\tau}_{i,j}(p) = \prod_{k=1}^{K} t_{p_{k-1},p_k}$$

Each trader incurs a path-specific shock $\epsilon_{i,j}(p,\nu)$, which is drawn from a Frechet distribution with shape parameter $\theta > 1$. Trader ν's cost of traveling along path p from i-j is $\tau_{i,j}(p,\nu) = \bar{\tau}_{i,j}(p)\epsilon_{i,j}(p,\nu)$. Traders choose the path which minimizes their trade cost subject to their idiosyncratic shocks, such that

$$\tau_{i,j}(\nu) = \min_{p \in P_K, K \geq 0} \bar{\tau}_{i,j}(p)\epsilon_{i,j}(p,\nu)$$

The path shock term captures the extent to which traders may choose different routes due to mistakes, idiosyncratic preferences, or other quirks. The amount of variation in paths will depend on the shape parameter θ for the shocks. As $\theta \to \infty$, the shocks converge to a degenerate distribution, which implies that all traders will pick the least cost route (according to the base trade costs). On the other hand, a small value of θ will result in a greater variance in the paths taken. Permitting variation in paths allows us to calculate the endogenous trade costs more efficiently. As trade costs change, the least cost paths can suddenly shift discretely. Since entrepots capture income from shipments that pass through them, this means that a small change in trade costs could lead to large swings in entrepot incomes. Introducing an amount of trader noise ensures that wages and incomes at entrepots are a continuous function of trade costs.

6.1.2 Average trade costs

As in Eaton and Kortum (2002), the use of the Frechet distribution yields a tractable solution to the trader's problem. The *expected trade cost* of traveling from i to j is:

$$\tau_{i,j} \equiv E[\tau_{i,j}(\nu)] = E[\min_{p \in P_K, K \geq 0} \bar{\tau}_{i,j}(p)\epsilon_{i,j}(p,\nu)] = c\left(\sum_{K=0}^{\infty} \sum_{p \in P_K} \bar{\tau}_{i,j}(p)^{-\theta}\right)^{-\frac{1}{\theta}}$$

where $c = \Gamma(\frac{\theta-1}{\theta})$. Substituting in the definition for $\bar{\tau}_{i,j}(p)$ yields

$$\tau_{i,j}^{-\theta} = c^{-\theta} \sum_{K=0}^{\infty} \sum_{p \in P_K} \prod_{k=1}^{K} t_{p_{K-1},p_K}^{-\theta} = c^{-\theta} \sum_{K=0}^{\infty} \sum_{p \in P_K} \prod_{k=1}^{K} a_{p_{K-1},p_K}$$

where $a_{i,j} = t_{i,j}^{-\theta}$. $a_{i,j}$ lies between 0 and 1, and is equal to 0 if there is no direct connection between i and j. We define the *modified adjacency matrix* as $[A_{i,j}] = a_{i,j}$. We can rewrite the summation over paths as:

$$\tau_{i,j}^{-\theta} = c^{-\theta} \sum_{K=0}^{\infty} \left(\sum_{k_1=1}^{N} \sum_{k_2=1}^{N} \dots \sum_{k_{K-1}=1}^{N} (a_{i,k_1} * a_{k_1,k_2} * \dots a_{k_{n-1},j}) \right)$$

where the subscript k_n refers to the n vertex arrived at on a particular path. Note that if vertices m and n are non-adjacent, then $a_{m,n} = 0$, which ensures that only legitimate paths of length K included

very rarely repeat their steps in our estimation, due to the added cost it imposes.

in the parantheses.

Using properties of matrix powers, we can express the term in the big parantheses as the (i, j)th entry of the modified adjacency matrix to the Kth power, $A^K_{i,j}$. Thus,

$$\tau_{i,j}^{-\theta} = c^{-\theta} \sum_{K=0}^{\infty} A^K_{i,j}$$

If spectral radius of A is less than one, then the sum of powers of a matrix converges, and is $\sum_{K=0}^{\infty} A^K = (I - A)^{-1}$. Define $B = (I - A)^{-1}$ and $b_{i,j} = [B_{i,j}]$. The expected cost of shipping a good from i to j is[7]

$$\tau_{i,j}^{-\theta} = c^{-\theta} b_{i,j}$$

6.1.3 Entrepot Centrality

An entrepot that is located in the middle of the network will experience more traffic across it than one at the periphery, and thus more income. We present below a method, developed by Allen and Arkolakis (WP), for finding the probability that a trader ships over a specific edge. This can be easily expanded to find the probability that the shipment goes through a specific entrepot.

Let $\pi_{i,j}(p)$ denote the probability of taking a specific path p of length K from i to j, subject to the random Frechet shock. The expression is $\pi_{i,j}(p) = P(\bar{\tau}_{i,j}(p)\epsilon_{i,j}(p) \leq \bar{\tau}_{i,j}(p')\epsilon_{i,j}(p'), \forall p')$. Using a similar analysis as Eaton and Kortum (2002), we can rewrite this as

$$\pi_{i,j}(p) = \frac{\tau_{i,j}(p)^{-\theta}}{\sum_{K=0}^{\infty} \sum_{p' \in P_{i,j,K}} \tau_{i,j}(p')^{-\theta}} = \frac{1}{b_{i,j}} \prod_{k=1}^{K} a_{p_{k-1},p_k}$$

where a_{p_{k-1},p_k} and $b_{i,j}$ are defined above. We are interested not in whether a specific path is taken though, but with the set of paths that pass through a given edge. Consider the edge k-l, where l corresponds to an entrepot location. Denote the set of paths of length K traveling over this edge as $P^{k,l}_{i,j,K}$ and the probability that a shipment from i to j travels over this edge is as $\pi^{k,l}_{i,j}$. By summing over the set, we find that

$$\pi^{k,l}_{i,j} = \sum_{K=0}^{\infty} \sum_{p \in P^{k,l}_{i,j,K}} \pi_{i,j,K}(p) = \frac{1}{b_{i,j}} \sum_{K=0}^{\infty} \sum_{p \in P^{k,l}_{i,j,K}} \prod_{k=1}^{K} a_{p_{k-1},p_k}$$

Following the analysis of Allen and Arkolakis (WP), we can rewrite this term as

$$\pi^{k,l}_{i,j} = \frac{b_{i,k} a_{k,l} b_{l,j}}{b_{i,j}} = \left(\frac{\tau_{i,j}}{c \tau_{i,k} t_{k,l} \tau_{l,j}} \right)^{\theta}$$

[7] If j is an entrepot, then this term includes the transhipment cost charged by j. This runs counter to the phenomenon we are attempting to explain, and raises the trade costs of j. To compensate for this, we divide out the entrepot cost for the last leg for all terms where j is an entrepot.

In order to obtain the probability that a shipment from i-j passes through entrepot l, we simply sum over all k[8]:

$$\pi^l_{i,j} = \sum_k \pi^{k,l}_{i,j} = \sum_k \frac{b_{i,k}a_{k,l}b_{l,j}}{b_{i,j}} = \sum_k \left(\frac{\tau_{i,j}}{c\tau_{i,k}t_{k,l}\tau_{l,j}}\right)^\theta$$

6.2 Production and Consumption

We now introduce a spatial economic framework where a subset of locations obtain additional income by interdicting trade flows. Trade transhipment will require local labor, transforming this in to a de facto second sector. What distinguishs this approach from other models is that we do not only consider *bilateral* relationships, i.e. size of trade flows from i to j, but *trilateral,* i.e. size of trade flows from i to j *and* wages at entrepot k in between them.

Much of the model's form is taken from Armington (*zzz)*, particular regarding trade flows. Beyond endogenizing trade costs, the entrepot firms will not affect the optimization problems of the households and production firms. We present the setup below.

6.2.1 Households

Let there be $i \in S$ locations, with $|S| = N$. Each location produces a unique consumer good that is sold to all locations. Consumers at location i have a CES utility function of consumption goods, which they purchase using the wage w_i that they earn from labor. Consumers must contract with a trader to ship goods to them. Consumers are randomly matched with traders, and pay the full cost of shipment.

Each consumer supplies one unit of labor inelastically, which does not enter into the utility function. Let $p_{j,i}$ denote the price of good j in consumer market i, such that the optimization problem is:

$$U_i = \max_{q_{j,i}} \left(\sum_{j\in S} q_{j,i}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \text{ s.t. } \sum_{j\in S} p_{j,i}q_{j,i} \leq w_i$$

Aggregate demand for variety j is $Q_{j,i} = p_{j,i}^{-\sigma} E_i P_i^{\sigma-1}$, where P_i refers to the Dixit-Stigliz price aggregator.[9] The value of trade from j to i is $p_{j,i}Q_{j,i} = X_{j,i} = p_{j,i}^{1-\sigma} E_i P_i^{\sigma-1}$.

The indirect utility function is $W_i = \frac{w_i}{P_i}$. We allow consumers to move between locations frictionless in order to maximize their utilities. In practice, each consumer solves $argmax_i W_i$ to determine where to live. In equilibrium, welfare is equalized at all places, $W_i = \bar{W}$. In our estimation we will assume that the total population in the network is fixed, such that economy-wide welfare fluctuates in response to shocks.

[8] A trader may travel over vertex l multiple times, since they are permitted to repeat their steps. It is entirely possible that $\pi^l_{i,j} > 1$, a bizzare result. In this sense $\pi^l_{i,j}$ denotes the *average number of transverals over* l, instead of the probability of using that edge. It's generally rare for this value to be above $1 + 10^{-5}$, indicating that inefficient traders are rare.

[9] We assume that $\sigma > 1$, such that consumer goods are substitues.

6.2.2 Firms

There is a continuum of identical competitive production firms at each location. Firms at location i produce their final good with technology $Q_i = A_i L_i^F$, using labor L_i^F and a constant location-specific exogenous productivity A_i and pay their workers the local wage w_i.

As goods are shipped from location i to j, an endogenous fraction $\tau_{i,j}$ of it melts or is captured by entrepots. The melted portion reflects the distance-based cost of shipping goods, while the captured cost indicates the amount paid to gauge break locations. The price of goods from location i sold to j is:

$$p_{i,j} = \tau_{i,j} \frac{w_i}{A_i}$$

The value of bilateral trade is thus:

$$X_{i,j} = \tau_{i,j}^{1-\sigma} (\frac{w_i}{A_i})^{1-\sigma} E_j P_j^{\sigma-1}$$

Trade between two locations increases with the productivity of the original location and with the expenditure in the destination. As the price index P_j increases, trade between i and j increases, indicating that consumers in location j are switching into the now relatively cheaper option in i.

6.2.3 Entrepot Income

Entrepot income depends on two factors: the number of shipments passing through a location, and the amount of value it captures from each shipment. We've presented a framework for calculating the former above, and will now set up a model for how the entrepots tranships goods, and thus how the endogenous entrepot cost is determined.

Entrepots provide a complementary service to trade flows passing through them, in the form of freight transfers. Let $X^*_{j,k,i}$ denotes the value of goods shipped from origin j through entrepot i on the way to destination k, measured before the goods pass through the entrepot. The traders must hire local labor $L^H_{j,k,i}$ from entrepot i to tranship the goods, according to the production process

$$X_{j,k} = min\left(X^*_{j,k}, \frac{\tau_B L^H_{j,k,i}}{A_i} \right)$$

This produces post-transhipment goods of value $X_{j,k}$, which are subsequently shipped further to the final destination k. If the origin firm does not hire sufficient entrepot labor, any leftover good $X^*_{j,k}$ is wasted (i.e. stuck at the entrepot and decays). Traders must pay local labor the prevailing wage w_i, which is jointly determiend by the entrepot sector and the production sector. The cost of transferring one unit across a junction is $\frac{\tau_B w_i}{A_i} p_{j,k}$, which results in an entrepot cost of $(1 + \frac{\tau_B w_i}{A_i})$. This entrepot cost enters the transportation network in a multiplicative fashion like the iceberg trade cost, which will make our analysis tractable.

To visualize this, imagine an iceberg which departs the origin, melts at a constant rate as it travels, and then arrives at its destination. In our approach icebergs lose a fraction of their size suddenly when they pass over an entrepot; this corresponds to the entrepot cost captured by the location. This imagry illustrates a drawback of our approach, namely that the amount of income captured by the entrepot-the magnitude of ice that melts-depends on how big the iceberg is when it arrives at the entrepot. If we neglect this, then we will end up double-counting income, since the entrepots will capture a greater share than the shipments will lose. To compensate for this, we deflate the value of any shipment going through an entrepot by the trade cost it's already incurred. For example, if goods of value $X_{j,k}$ are being shipped from j to k through entrepot i, the amount processed by i is deflated by $\tau_{j,i}$ when calculating entrepot income to account for iceberg trade costs that have already occured.

The total entrepot income earned by location i depends on the probability that it is used for trade, the amount that shipped, and it's prevailing wage and technology. This expression is:

$$Y_i^H = \frac{\tau_B w_i}{A_i} \sum_{(j,k) \in S \times S} \frac{\pi_{j,k}^i X_{j,k}}{\tau_{j,i}}$$

6.3 Equilibrium Conditions

This model is similar to the standard gravity model, although the entrepots add a significant twist. We will use the notation for origin- and destination-effects (see Allen and Arkolakis (2014)) to make the equations more conside.

Define $\gamma_i = (\frac{w_i}{A_i})^{1-\sigma}$, $\delta_j = P_j^{\sigma-1} E_j$, and $K_{i,j} = \tau_{i,j}^{1-\sigma}$. The value of trade between two locations can be written as:

$$X_{i,j} = K_{i,j} \gamma_i \delta_j$$

6.3.1 Equations

In equilibrium, three equations will hold:

1. Total expenditure on all consumption goods is equal to labor income:

$$E_i = w_i L_i \to \sum_j X_{j,i} = \gamma_i^{\frac{1}{1-\sigma}} A_i L_i$$

2. Welfare is equalized across all locations:

$$\bar{W} = \frac{w_i}{P_i} = \frac{\gamma_i^{\frac{1}{1-\sigma}} A_i}{\delta^{\frac{1}{\sigma-1}} E^{\frac{1}{1-\sigma}}}$$

3. Expenditure is equal to income earned by final goods production and income from providing entrepot services:

$$E_i = Y_i^F + Y_i^H \to \sum_j X_{j,i} = \sum_j X_{i,j} + \tau_B \gamma^{\frac{1}{1-\sigma}} A_i \sum_{(j,k) \in S \times S} \frac{\pi_{j,k}^i X_{j,k}}{\tau_{j,i}}$$

This equilibrium provides 3N equations to determine 3N+1 variables: $\overrightarrow{\gamma}$, $\overrightarrow{\delta}$, $\overrightarrow{A}$, and welfare $\bar{W}$. There is one degree of freedom in the setup, which we use to normalize $\bar{W} = 1$ for any baseline analysis.

6.3.2 Stylized Example

Imagine that there is a continuum of locations located on a real number line, $[0, 1]$. Like in the setup above, each location $i \in [0, 1]$ produces a differentiated good and consumes a basket of all goods with a constant elasticity of substitution. Workers move between locations frictionlessly, such that welfare is equal at every point. Productivity is identical and equal to 1 at all locations.

The top of figure 8 presents a case where the iceberg trade cost of trading between any two points i, j is exp(—i-j), that is, it's increasing in distance. Locations closer to the center have larger populations, since they are closer to other population-weighted locations. Central spots have lower price indices, which attract workers and push down the wage.

The second case introduces a gauge break, where shipments of goods that pass the location $x = \frac{1}{2}$ must pay an additional iceberg trade cost of exp(c). For example, to ship a good from $i = \frac{1}{4}$ to $j = \frac{3}{4}$, the firm in location i must produce $e^{\frac{1}{2}+c}$ units of the good. In this example the gauge break cost is lost to the economy, and not captured by workers at location $i = \frac{1}{2}$. This case demonstrates the market access benefit of locating at a gauge break, as opposed to nearby.

This second case is depicted in the bottom graph of figure 8, where the red dot indicates the population at $i = \frac{1}{2}$. It's apparent that the introduction of this junction cost attracts workers from other regions to this county, distorting the distribution of labor. This result is present, although weaker, if the gauge break is not located in the direct middle of the line segment.

6.3.3 Existence & Uniqueness

Because of the nonlinearities in the equilibrium system, the model of this paper cannot be subsumed under the general framework of universal gravity, Allen & Arkpolaksi (2014), and thus existence and uniqueness of equilibrium cannot be taken for granted. In this section we appeal to results from Allen, et al (2015) and show the existence and uniqueness of the equilibrium as described in the previous section.

Our strategy in this section will be rewriting the equilibrium conditions as *scaffold* functions as described in Allen, et al (2015) and demonstrating the necessary conditions are satisfied in order to invoke the theorems. For this purpose we can evaluate each of the equilibrium equations separately. For example consider:

$$\delta_i \sum_j K_{j,i}\gamma_j = \gamma_i \sum_j K_{i,j}\delta_j + \tau_B \sum_{(j,k)\in T_i} K_{j,k}\gamma_j\delta_k$$

which we rewrite as:

$$\delta_i = \frac{\gamma_i \sum_j K_{i,j}\delta_j + \tau_B \sum_{(j,k)\in T_i} K_{j,k}\gamma_j\delta_k}{\sum_j K_{j,i}\gamma_j}$$

Here we treat γ_j as given and $K_{i,j}$ are given positive model parameters. Then the equation clearly satisfies conditions in Lemma 1 and Theorem 2 of Allen, et al (2015) and we know there is a unique set of δ_i that satisfy the equation.

Then by same argument we use the other equations to show γ_j and w_i exist and are uniquely determined.

7 Conclusion

This paper assembles a novel dataset on the existence and effect of entrepôts in 19th century U.S. railroads. This dataset demonstrates that entrepôt status encouraged economic activity and attracted more people, which matches the historical evidence provided by people living in the time period. We also show that this effect is persistent long after the gauges have been standardized, which touches upon an ongoing debate about the persistence of local shocks.

This paper continues to adopt a simple model of economic geography to entrepôts, and develops an estimation strategy to find underlying county-level parameters. The greatest hindrance to this portion is the lack of a concrete proof of the existence of a equilibrium, much less an unique equilibrium. However, this strategy still hints at the possibility of estimating counterfactual situations which could remain quite relevant.

This paper is still very much a work in progress. There are several interesting questions that can be tackled in the future using a fully constructed dataset. For example:

1. How does the model behave once productivity and amenity spillovers are incorporated? Are entrepôt locations more productive in addition to having better market access. Since the U.S. Census of Manufacturers is available in 1860, this question is achievable.

2. In the light of productivity spillovers, do multiple equilibria exist? Is there path-dependence, i.e. initial entrepôt status raises productivity enough to be self-sustaining?

3. Is it possible to use the labor market version of the structural model, iterating over optimal paths as well as underlying parameters?

4. How much value is added by incorporating traffic into an economic geography problem, where congestion acts a dispersion force?

References

Abadie, A. and Imbens, G. W. (2006). Large sample properties of matching estimators for average treatment effects. *econometrica*, **74** 235–267.

Abadie, A. and Imbens, G. W. (2011). Bias-corrected matching estimators for average treatment effects. *Journal of Business & Economic Statistics*, **29** 1–11.

Ahlfeldt, G., Redding, S., Sturm, D. and Wolf, N. (2015). The Economics of Density: Evidence from the Berlin Wall. *Econometrica*, **83** 2127–2189.

Allen, T. and Arkolakis, C. (2014). Trade and the Topography of the Spatial Economy. *The Quarterly Journal of Economics* 1085–1139.

Allen, T., Arkolakis, C. and Takahashi, Y. (2014). Universal Gravity. *NBER Working Paper No. 20787*.

Armington, P. (1969). A Theory of Demand for Products Distinguished by Place of Production. *Staff Papers (International Monetary Fund)*, **16** 159–178.

Atack, J. (2013). On the Use of Geographic Information Systems in Economic History: The American Transportation Revolution Revisited. *The Journal of Economic History*, **73** 313–338.

Atack, J., Bateman, F., Haines, M. and Margo, R. (2010). Did Railroads Induce or Follow Economic Growth?: Urbanization and Population Growth in the American Midwest, 1850-1860. *Social Science History*, **34** 171–197.

Bartelme, D. (2014). Trade Costs and Economic Geography: Evidence from the U.S.

Bleakley, H. and Lin, J. (2012). Portage and Path Dependence. *The Quarterly Journal of Economics*, **127** 587–644.

Boyd, J. and Walton, G. (1971). The Social Savings from the Nineteenth-Century Rail Passenger Services. *Explorations in Economic History*, **9** 233–254.

Breinlich, H. (2006). The Spatial Income Structure in the European Union- What Role for Economic Geography? *Journal of Economic Geography*, **6** 593–617.

Cervantes, F. P. (2013). *Railroads and Economic Growth: A Trade Policy Approach*. Ph.D. thesis, The University of Chicago, Ann Arbor.

Davis, D. and Weinstein, D. (2002). Bones, Bombs, and Break Points: The Geography of Economic Activity. *The American Economic Review*, **92** 1269–1289.

Donaldson, D. (2017). Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. *forthcoming The American Economic Review*.

Donaldson, D. and Hornbeck, R. (2016). Railroads and American Economic Growth: A "Market Access" Approach. *The Quarterly Journal of Economics*, **131** 799–858.

Eaton, J. and Kortum, S. (2002). Technology, Geography, and Trade. *Econometrica*, **70** 1741–1779.

Feenstra, R. and Hanson, G. (2004). Intermediaries in Entrepot Trade: Hong Kong Re-Exports of Chinese Goods. *Journal of Economics and Management Strategy*, **13** 3–35.

Fishman, M. J. (2009). Population of counties, towns, and cities in the united states, 1850 and 1860. icpsr09424-v2. *Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor]* 02–17.

Fogel, R. (1964). *Railroads and American Economic Growth: Essays in Economic History*. Baltimore: Johns Hopkins Press.

Haines Michael, R. (2010). Inter-university consortium for political and social research. historical, demographic, economic, and social data: The united states, 1790–2002. *Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor]* 05–21.

Ken, W. (1978). Singapore: Its Growth as an Entrepot Port, 1819-1941. *Journal of Southeast Asian Studies*, **9** 50–84.

Krugman, P. (1998). What's New About the New Economic Geography. *Oxford Review of Economic Policy*, **14** 7–17.

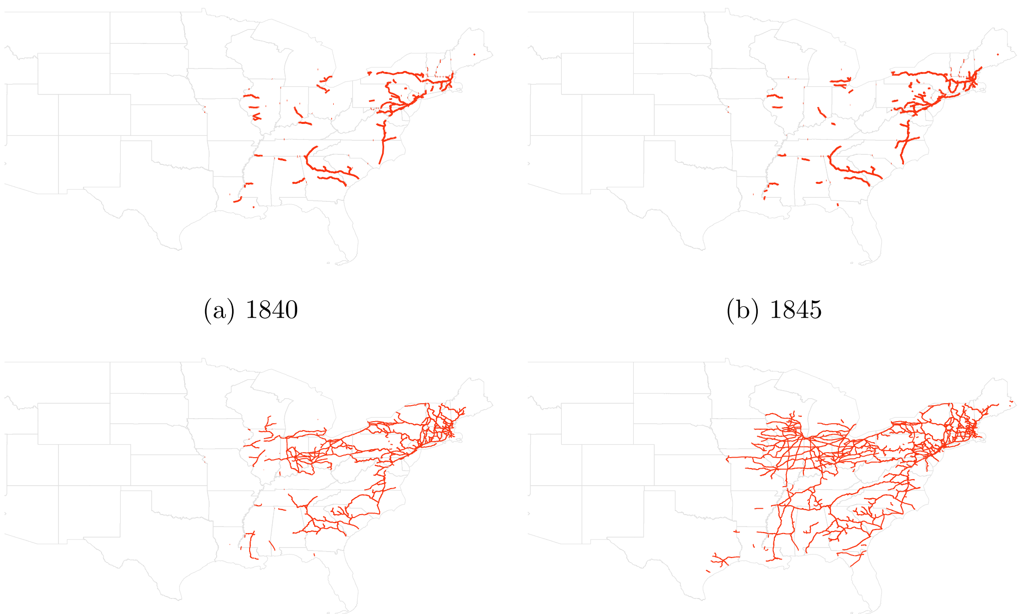
Masahisa, F. and Mori, T. (2005). Frontiers of the New Economic Geography. *Papers in Regional Science*, **84** 377–405.

Puffert, D. (2000). The Standardization of Track Gauge on North American RailRail, 1830-1890. *The Journal of Economic History*, **60** 933–960.

Taylor, G. and Neu, I. (2003). *The American Railroad Network, 1861-1890*. Urbana: University of Illinois Press.

A Maps

Figure 3: Historical Rail Networks



(a) 1840 (b) 1845

(c) 1850 (d) 1860

Figure 4: 1860 Rail Gauges Network

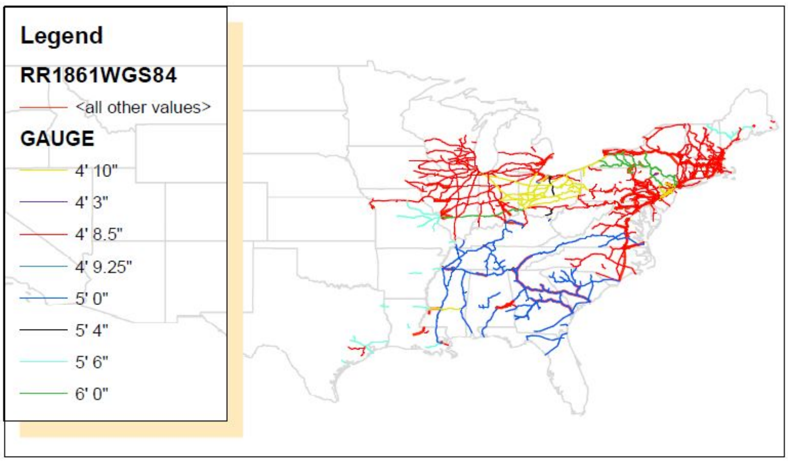


Figure 5: Network with Railroads and Rivers

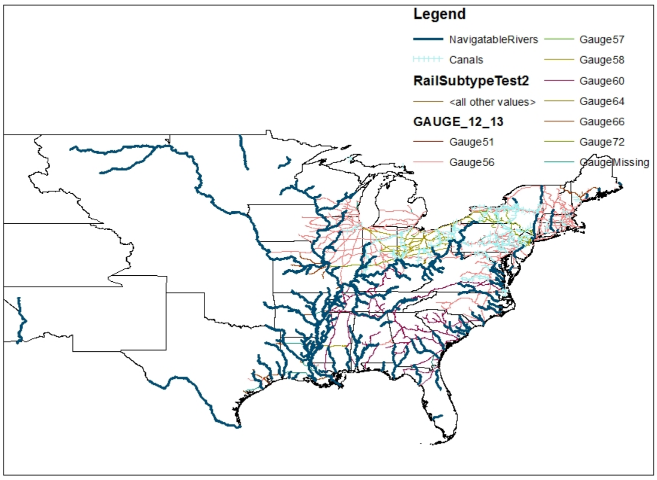
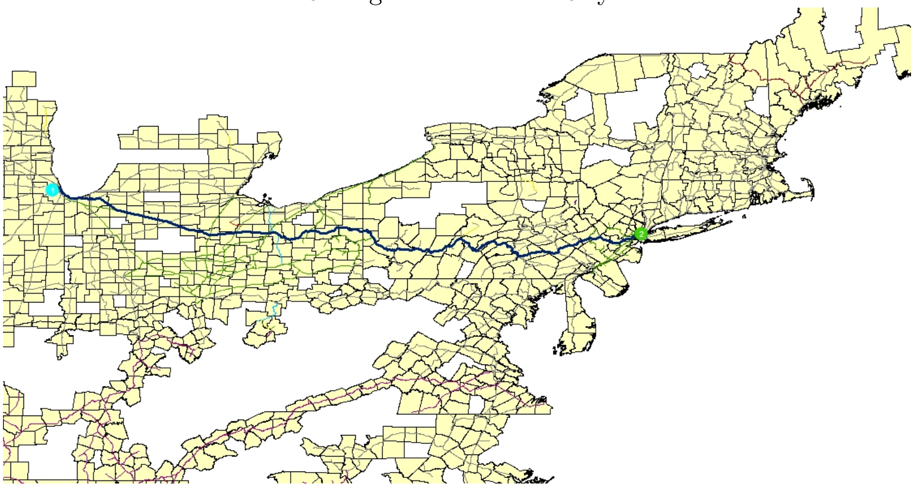


Figure 6: Sample Optimal Paths: U.S. 1860

Chicago to New York City



Chicago to Richmond

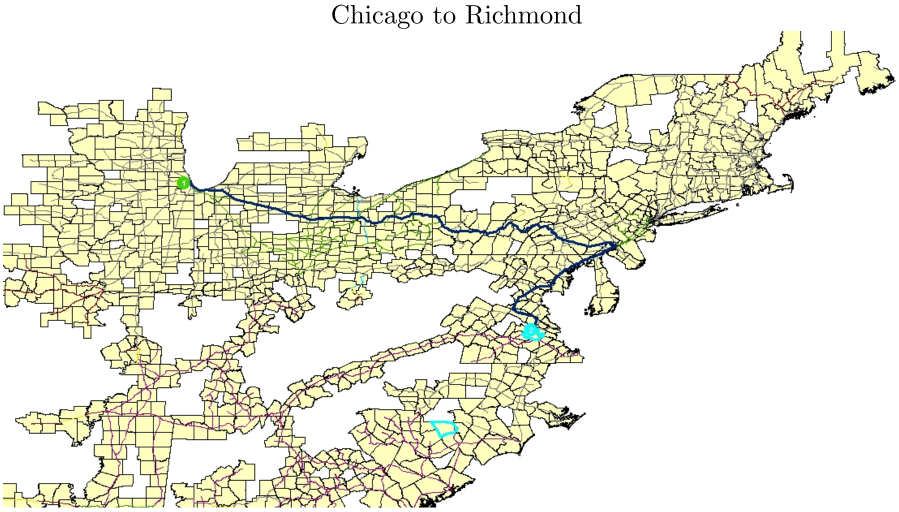


Figure 7: Instrumental Variable Example

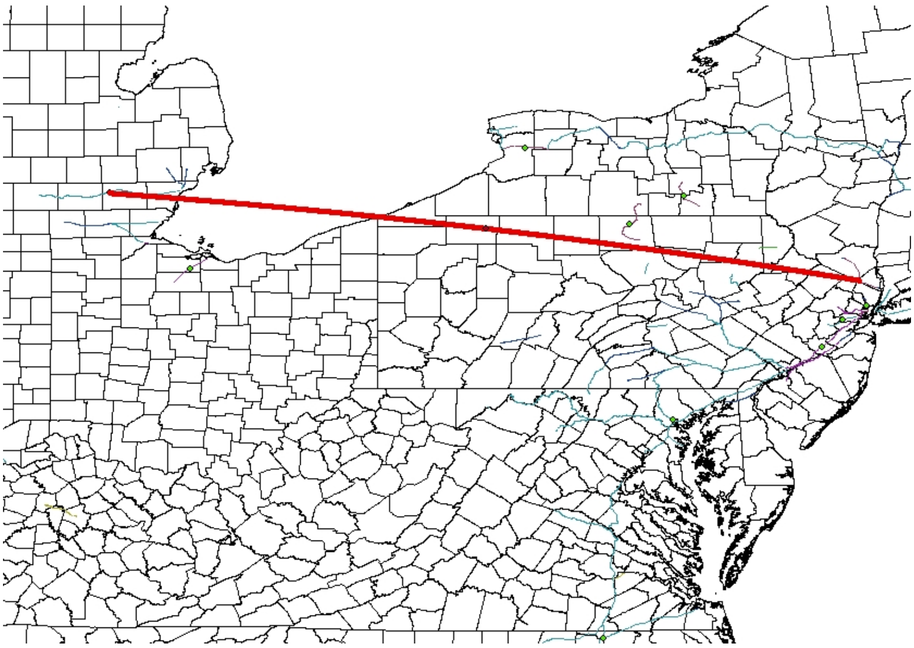
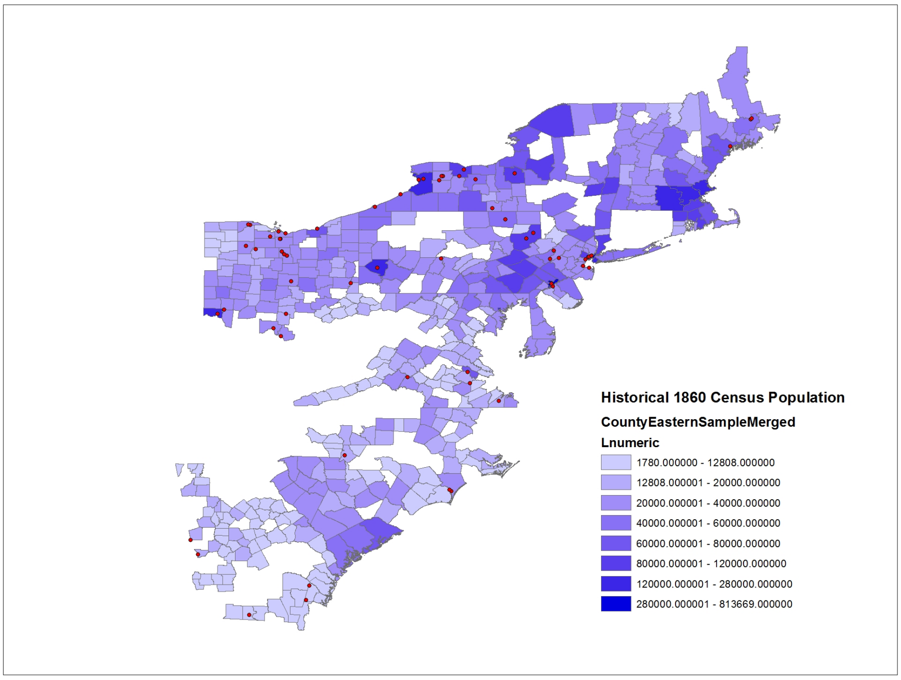


Figure 8: Population Distribution

Historical Population Distribution



Counterfactual Population Distribution

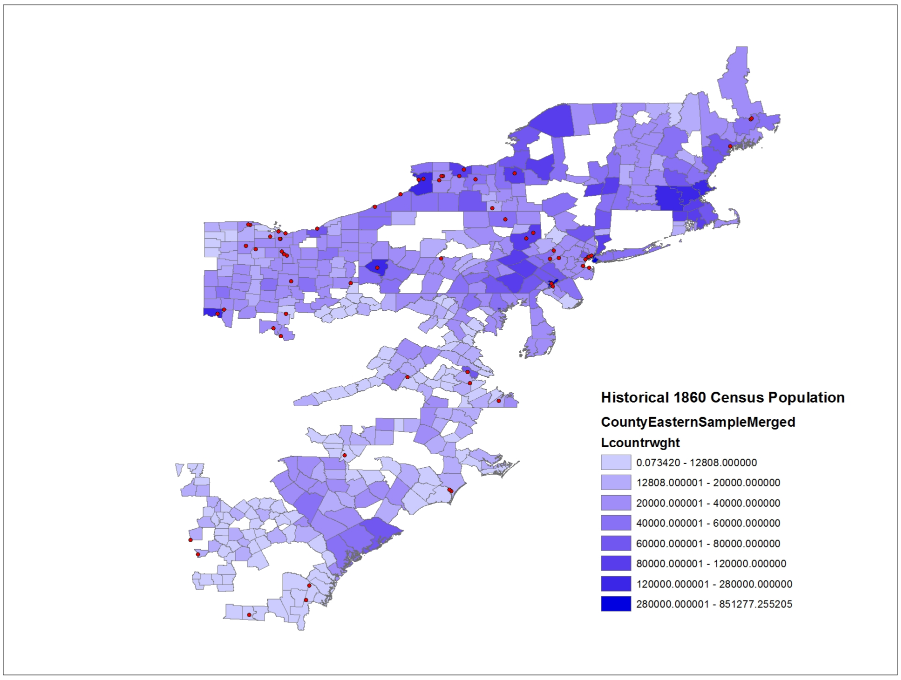


Figure 9: Top 10 counties with the largest percentage change in population

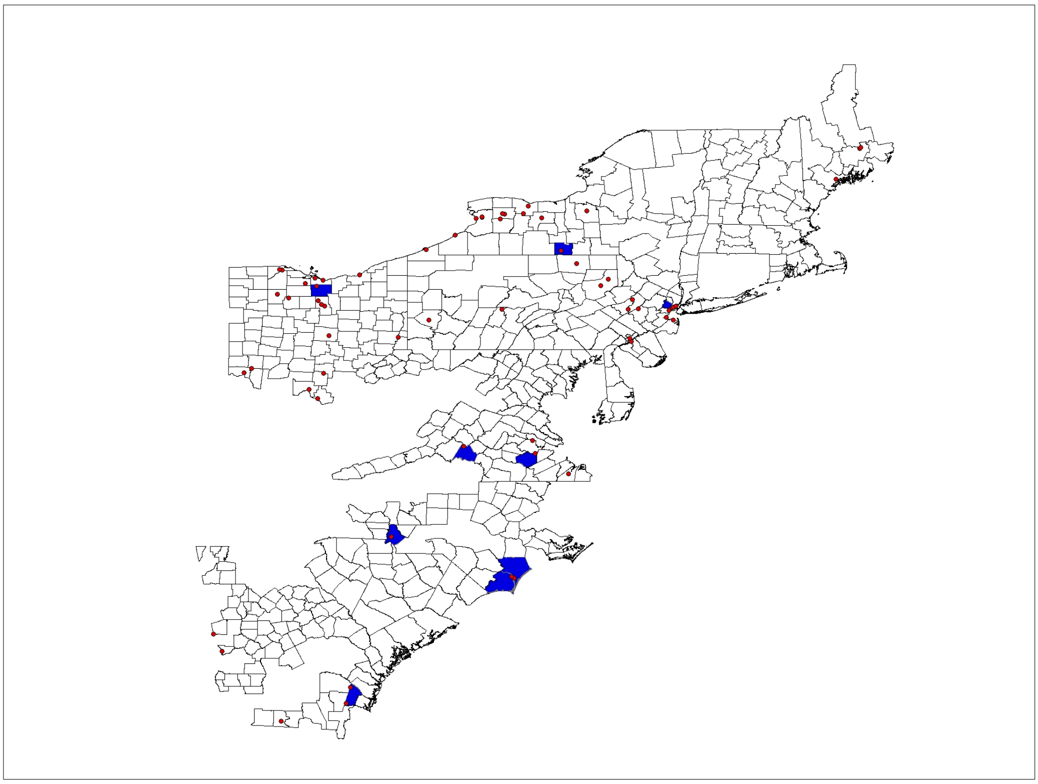
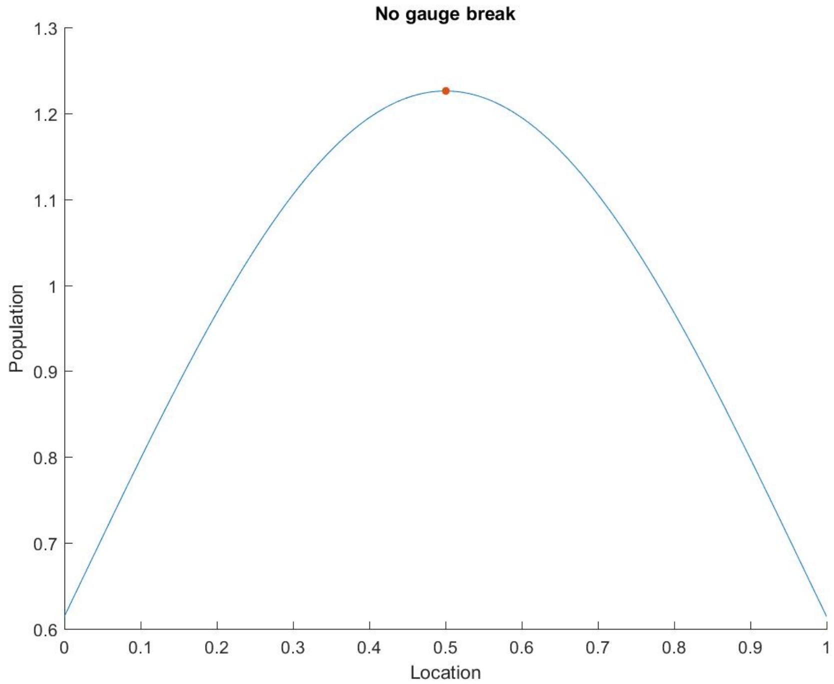
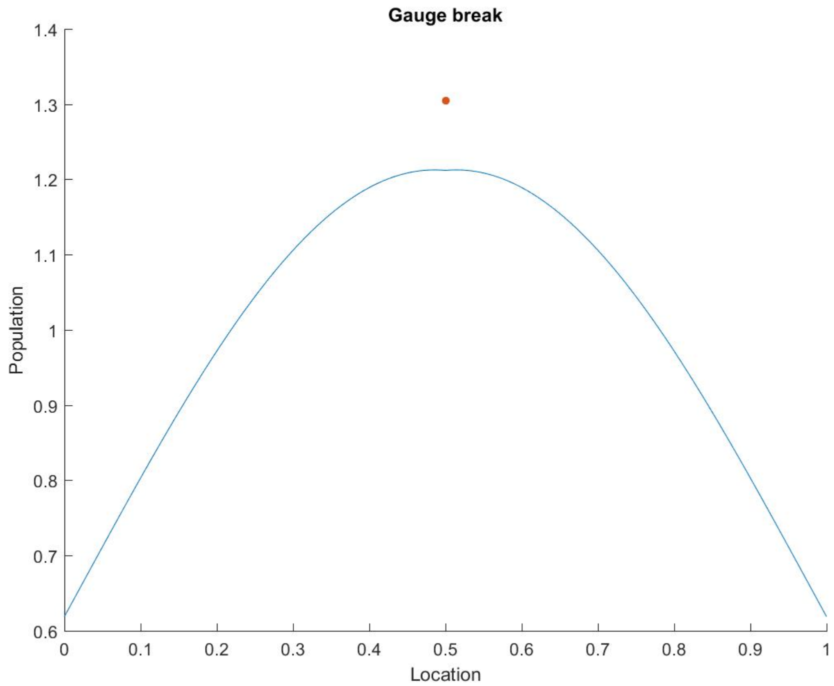


Figure 10: Stylized example

Frictionless line scenario



Gauge break line scenario



B Tables & Figures

Table 5. Top ten counties with largest change in population

County	State	Historical Pop.	Counterfactual Pop.	Percentage change	Number of Gauges
Wayne	Georgia	2268	0.07	-99%	2
Hudson	New Jersey	62717	17840	-71%	2
Brunswick	North Carolina	8406	2714	-67%	1
Campbell	Virginia	26197	9397	-64%	1
Chemung	New York	26917	15739	-41%	1
Dinwiddie	Virginia	30198	18975	-37%	1
Mecklenburg	North Carolina	17374	12044	-30%	1
New Hanover	North Carolina	21715	15576	-28%	1
Essex	New Jersey	98877	71303	-27 %	1
Huron	Ohio	29616	22318	-24 %	2