How do Neighbor Effects influence Institutional Change?

Evidence from Turnpike Trusts in Eighteenth-Century England

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Abstract

Turnpike trusts were private organizations that improved and maintained toll roads in eighteenth century England. They contributed to economic growth by increasing road investment and lowering transport costs. Turnpike trusts were adopted slowly before the 1750s and 1760s when they came to control large portions of the road network. Turnpikes were also adopted in particular regions within a short time period. This paper shows that neighbor effects can explain this diffusion pattern. The results suggest that individuals learned about the benefits of turnpikes through a demonstration of their effects in neighboring locations. They also suggest that the benefits increased as more neighboring cities adopted turnpike trusts. More generally, the paper provides an example of how neighbor effects influence the process of institutional change.

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Neighbor effects are believed to influence a wide range of social and economic phenomenon, such as poverty, educational attainment, and technology adoption (see Durlaf, 2004). The idea is that individuals are more likely to take a particular action, if more of their neighbors also take the same action. The presence of neighbor effects implies that aggregate behavior can differ across space, even when conditions are otherwise similar. For instance, if one individual adopts a new technology then their neighbors may want to adopt as well, resulting in a high level of technology diffusion. By contrast, if an individual does not adopt a technology, then their neighbors may not either, resulting in a low level of diffusion.

Neighbor effects have been studied in a variety of settings, but less is known about how they affect institutional changes, such as the adoption of legal or regulatory structures. As in the case of technologies, there may be network externalities in which the benefits or the costs of an institution decrease with the number of individuals who adopt or follow it. There could also be demonstration effects, in which individuals learn about the benefits and costs by observing the experiences of others. In either case, the adoption of an institution in one location can influence its adoption in neighboring locations.

In this paper, I show that neighbor effects contributed to the passage of turnpike Acts in eighteenth century England. Turnpike Acts had an important impact on the economy by increasing road investment and reducing transport costs (Bogart, 2005). Each Act created an organization known as a turnpike trust. The trustees were granted authority over a roadway previously maintained by local governments. They were also given the right to levy tolls and issue bonds. However, trustees were required to keep the tolls below a maximum schedule, and they were not allowed to earn profits.

Turnpike Acts were initiated by local landowners and merchants who submitted petitions to Parliament. The petitions usually stated that communications and transport would be improved if a turnpike trust was allowed to levy tolls along a road. Initially, Parliament was resistant to the idea, and many petitions failed. Over time Parliament changed its attitude, and began passing large numbers of turnpike Acts, especially during the 1750s and 1760s. By the early nineteenth century, turnpikes formed the largest toll road network in history with nearly 1000 turnpike trusts managing 20,000 miles.

Many turnpike trusts were adopted in neighboring locations around the same time period. I analyze whether neighbor effects contributed to the adoption of turnpikes by studying their diffusion along the road network connecting London with all major cities in 1700. I identify the first year when each major city had a turnpike trust managing its segment of the London road network. I also define a set of neighbors as all major cities that shared a common route to London. Last, I collect data on the characteristics of major cities, such as their distance to London, whether they had water transport to London, and the number of weekly wagon and coach services to London. My main finding is that cities were more likely to have turnpikes established along their segment of the London network when neighboring cities did the same.

I also study the adoption of turnpike trusts along any road leading into a major city. Here I define the set of neighbors as all major cities that lie within a 50-mile radius. The results produce a similar conclusion, namely that cities were more likely to adopt turnpike trusts when more of the neighbors did the same.

The preceding findings could reflect unobserved characteristics that were shared by neighboring cities, rather than neighbor effects per se. I address this issue by using an instrumental variable approach. In particular, I first predict whether neighboring cities had turnpike trusts using characteristics, such as their number of weekly wagon and coach services to London. I then use the predicted values to identify the whether neighboring adoption made cities more likely to have turnpikes. The results are consistent with the earlier findings and show that neighbor effects were present.

I interpret these results as evidence of demonstration effects or network externalities. Demonstration effects occurred when local groups learned about the benefits of levying tolls by observing the experiences of their neighbors. Network externalities were different because they did not involve learning. Instead they occurred when the benefits increased (or the costs decreased) as more turnpikes were adopted in neighboring areas.

My findings add to the literature on turnpike trusts in eighteenth century England. In particular, they provide new evidence supporting William Albert's (1972) argument that demonstration effects influenced the adoption of turnpike trusts. My analysis also extends the literature by analyzing the role of network externalities. I show that cities often adopted turnpike trusts along their London segment, after their neighbors closer to London. This finding suggests that the benefits increased when turnpikes were adopted on connecting road segments.

More generally, the results illustrate how neighbor effects influence institutional change. It is often observed that more efficient institutions are slow to emerge (see North, 1990). Neighbor effects provide one explanation for this phenomenon. If individuals believe that others will not change their institutions, then the status quo becomes self-enforcing, and the efficiency gains associated with the new institution are lost. Turnpike trusts provides one example of this phenomenon. Local landowners and merchants were slow to adopt turnpike trusts because not enough of their neighbors adopted. As a result, it took over 100 years for the turnpike network to fully develop, and for roads to be improved.

The paper is organized as follows. Section 1 presents an overview of the English economy and the rise of turnpike trusts. Section 2 discusses the data. Section 3 examines whether neighbor effects influenced the adoption of turnpike trusts. Section 4 interprets the results. Section 5 concludes.

1. Overview

In 1700 the English economy was already undergoing the early stages of economic development. Agricultural output per worker was rising, as were real wages (Allen, 2001; Clark, forthcoming). Higher agricultural productivity and real wages were caused, in part, by greater urbanization. Cities provided markets for agricultural goods, which gave farmers an incentive to adopt new techniques. Cities also produced manufacturing goods which they exported to farmers in their hinterland. As the eighteenth century progressed, cities began to specialize in particular manufacturing products. For instance, Leeds became specialized in woolen textile production, Birmingham in metalworking, and Manchester in cotton textiles (Corfield, 1983).

Specialization led to increasing trade between cities. The most significant trade occurred between London and major provincial cities (Chartes and Turnbull, 1983). The growth in long distance trade led to a higher demand for road investment, but the existing institutions were not well-suited to meet this higher demand. In 1700, most roads were maintained by local governments, known as parishes. Parishes were required by law to pay for road improvements in their jurisdiction. They were given the authority to claim labor services from their residents, or levy taxes on property income, but they could not levy tolls on road-users.

Parishes were generally ineffective in providing road maintenance and investment. The problem was that parishes were small, and therefore, most of the benefits went to through-travelers (Pawson, 1977; Bogart, 2005). The through-traffic problem was especially relevant along the highways leading into London, where wagons and carriages often passed through dozens of parishes along their route. In such cases, parishes had to pay for all the costs. Moreover, their expenditures would increase through traffic, which lowered prices in the London market or added to congestion.

The reluctance of parishes to finance road improvements led to higher transportation costs and less internal trade. Lost trade was detrimental for a number of groups in the economy, and in particular cities whose manufacturing production was growing. Some cities addressed this problem by submitted petitions to Parliament. The petitions stated that a local road was in poor condition, and that a turnpike Act was necessary to improve the road.

A turnpike Act transferred authority from parishes to a body of trustees. Trustees had the right to levy tolls, issue debt, and purchase land along a particular roadway. The ability to levy tolls was especially crucial because it helped resolve the through-traffic problem.[2] The result was that expenditures typically increased by a factor of more than 10 after turnpikes took over the road (Bogart, 2005).

Greater road expenditure affected the economy by contributing to lower transport costs. Between 1750 and 1820, freight charges fell by around 40%, while passenger travel times were reduced by 60%.[3] At the same time there was a significant increase in freight and passenger traffic, especially between London and major cities, like Birmingham, Leeds, Liverpool, Manchester, and Newcastle. The aggregate impact of turnpike trusts was substantial and

[2] Borrowing constraints were another reason why the parish system was unsuccessful in financing road investment. Legal restrictions on issuing debt forced parishes to rely on current tax revenues, and as a result, they had little incentive to undertake road investments that yielded benefits over the long run. Turnpikes resolved this problem because they could issue debt. See Bogart (2005) for more details.

[3] There is a large literature on the relationship between turnpike trusts and transport costs. See Jackman (1916), Albert (1972), Pawson (1977), Chartres and Turnbull (1983), Gerhold (1988, 1996), and Bogart (forthcoming).

amounted to a social savings of nearly 1% of national income by the early nineteenth century (Bogart, 2005, 2006).

Despite producing large benefits, turnpike trusts were adopted slowly. The first turnpike Act was passed in 1663 and applied to a 15 mile-stretch along the Great North Road connecting London with Newcastle. The next two turnpike trusts were created in 1695, and also applied to short road segments connecting London with major provincial cities. Diffusion accelerated during the 1720s and 1740s, as turnpikes were adopted along several routes leading into London and near provincial cities in the West and North. Turnpikes finally proliferated throughout the network during the 'turnpike boom' of the 1750s and 1760s. This period witnessed the adoption of over 300 trusts along 10,000 miles of road (Pawson, 1977). The two final waves of adoption occurred during the 1790s and 1820s, when most trusts were established on secondary roads near major cities.

Figure 1 shows the diffusion curve for turnpike trusts and the mileage managed by turnpike trusts. Both curves have the familiar S-shape, in which adoption starts slow, then accelerates rapidly, and then slows once again. The steep portion of the diffusion curve corresponds to the turnpike boom of the 1750s and 1760s. Closer inspection also reveals that the diffusion curve was steep during the 1720s and the 1790s.

There are a number of hypotheses about why certain decades, like the 1750s and 1760s, experienced more rapid turnpike adoption. Eric Pawson (1977) argues that macroeconomic variables were crucial, especially population, international trade, agricultural prices, and industrial production. Another hypothesis is that local factors, like demonstration effects, also influenced diffusion. William Albert argues that "trusts themselves were a major influence on expansion" (1972, p. 51). He based his claim on the observation that many new trusts were near or directly linked to existing turnpike roads.

It is difficult to determine, however, if demonstration effects or some other type of neighbor effect caused the clustering of adoption. It is possible that turnpikes were adopted along several neighboring roads because they shared some characteristic, like high demand for road improvements. In my analysis, I focus on the adoption of turnpikes near major cities and examine whether neighboring adoption had an effect after controlling for observable characteristics of cities. I also use instrumental variables to address the possibility that neighboring cities had similar unobservable characteristics. Before discussing the methodology in detail, it is necessary to introduce the data.

2. Data

I focus on the adoption of turnpike trusts near cities with a population above 2500 in 1700 (hereafter major cities). The list of 67 major cities includes Birmingham, Leeds, Norwich, and Manchester, which were the main manufacturing centers. It also includes Bristol, Liverpool, Hull, and Newcastle, which were the main ports, as well as cities like Derby, Salisbury, and Nottingham, which provided a mixture of manufacturing and services.[4]

London has a special place in the urban hierarchy because it was the 'central place' of the English economy. I do not include London among my list of major cities because it was so large relative to all other major cities. The size imbalance makes it unlikely that Londoners adopted turnpike trusts because one of its smaller neighboring cities did the same.

[4] See Corfield (1983) for a list of major cities in 1700, 1750, and 1800, along with estimates of their population.

I first examine turnpike adoption along road segments that connected London with major cities. The London road network is identified using the seventeenth century travel guide *Britannia* (see Bowen, 1970). I also use the database of turnpike Acts in Albert (1972) and Pawson (1977) to identify when turnpike trusts were established on each segment. Finally, I identify the year when a turnpike trust was established along any segment of the London network that begins or ends with a major city.

Second, I examine turnpike adoption along *any* road segment that begins or ends with a major city. I use the database from Albert and Pawson to identify the first year when turnpikes were established near major cities. It is worth emphasizing that turnpike adoption along any road segment includes turnpike adoption along the London road network. I distinguish between the two because some cities first had turnpikes along their non-London roads.

I also matched each city with information on the weighted fraction of neighboring cities that adopted turnpike trusts. For the London network, the set of neighboring cities is defined as all major cities that were on the same route to London. For example, Plymouth, Exeter, and Salisbury shared the same route to London. Plymouth had a turnpike on its portion of the London road beginning in 1757. Exeter had a turnpike on its portion in 1753, and Salisbury in 1755. For Plymouth, the fraction of neighboring cities that adopted turnpike trusts would be 0 for all years up to 1752, 0.5 in 1753 and 1754, and 1.0 in 1755 and beyond.

My analysis focuses on the weighted-fraction of neighboring cities with turnpikes because neighbor effects are likely to be stronger when cities are closer. Specifically, I use the inverse of distance as my weight, and then calculate the weighted fraction of neighboring cities with turnpikes in each year *t*.[5]

Neighbors are defined differently for the analysis of turnpike adoption along any road segment. Here the set includes all cities that lie within a 50-mile radius of each city. As before, I calculate the weighted-fraction of neighboring cities with turnpike trusts using the inverse of distance as the weight.

Lastly, I match cities with data on their characteristics. The city characteristics include distance to London, an indicator if they had water transport to London, an indicator if they had a population above 5000 in 1700, and the number of weekly coach and wagon services to London. Distance is provided in *Britannia*. Cities are defined as having water transport if they were located on the coast, or next to a navigable river which led to London (see Stevens). Population comes from Corfield (1983). The number of weekly coach and wagon services are drawn from a series of London travel directories published in 1705, 1715, 1740, 1749, 1760, 1770, 1779, 1790 and 1800.[6] Directories were designed for travelers and merchants who wanted to know when coach and wagon services were available to particular cities. They are generally regarded as the best source on the volume of transport services between London and major cities (Chartres and Turnbull, 1983; Gerhold, 1988; Bogart, 2005).

3. Neighbor Effects and the Adoption of Turnpike Trusts

[5] For example, the distance between Plymouth and Exeter is 35 miles, and the distance between Plymouth and Salisbury is 103 miles. For Plymouth, the weighted fraction of neighboring cities with turnpike trusts is 0.746 in 1753 or (1/35)*1/[(1/35)+(1/103)].

[6] The travel directories include *the Traveller's and Chapman's Daily Instructor*, *The Merchants and Traders Necessary Companion*, *the New and Complete Guide to all Persons who have any Trade or Concern with London*, and *The Shopkeepers and Tradesman's Assistant*.

This section investigates whether neighbor effects influenced the adoption of turnpikes. I first focus on the adoption of turnpikes along segments of the London road network that began or ended with major cities. Second, I examine turnpike adoption along any road segment near major cities. The results show that neighbor effects were present in both contexts.

3.1 Neighbor Effects along the London road Network

The London road network was the main trade route between London and major cities. Figure 2 provides a series of maps that illustrate the adoption of turnpike trusts along the London road network in 1720, 1730, 1750, and 1770. The maps also show the location of all major cities. The darker lines represent road segments managed by turnpike trusts, and the white lines are segments that were still under the control of parishes. The grey lines are major waterways, which provided an alternative form of transport to London.

Panel A shows that turnpike trusts managed little of the road network in 1720. Most turnpikes were in the hinterland of London, or near cities like Bath, Reading, Gloucester, Oxford, Northampton, Portsmouth, and Colchester. Panel B shows that turnpikes spread deeper into the London network during the 1720s. In particular, there was an expansion to the west and northwest of London. Along some of these routes, turnpike trusts were established in a short time span. For example, turnpikes were adopted on 74% of the 110 miles between London and Bristol between 1726 and 1728.

Few turnpikes were created in the 1730s, but the rate of adoption accelerated in the 1740s. Panel C shows that by 1750 turnpike trusts controlled most of the mileage to cities like Manchester, Newcastle, Bristol, Hereford, Worcester, Shrewsbury, Chester, Canterbury, and Portsmouth. The pattern of development was geographically uneven, however, as trusts controlled little of the mileage to cities like Plymouth, Tiverton, Southampton, Lincoln, Norwich, King's Lynn, Yarmouth and Carlisle. As in the 1720s, some routes had turnpike trusts adopted in only a handful of years. For instance, they were adopted on 32% of the 275 miles between London and Newcastle between 1741 and 1747.

Panel D shows that turnpike trusts were adopted along most remaining segments between 1750 and 1770. For example, in the southwest, turnpikes were established on 112 miles of the London-Exeter-Plymouth road between 1753 and 1759.

The maps in figure 2 show that major cities had turnpike trusts adopted along their London roads at different times. What explains these differences? If first investigate this question using survival analysis. For my purposes, a city has 'survived' in year *t* if no turnpikes have been established along a London segment that begins or ends with the city. Table 1 presents estimates of the hazard ratio for various city characteristics at the beginning of the eighteenth century. The results are based on a Weibull distribution, but they were similar for other distributions as well. They show that if a city had a larger number of wagon or coach services in 1705 then its hazard ratio was larger than 1, and therefore its predicted survival time decreased. If a city had a water route to London then its hazard ratio was less than 1, and thus its predicted survival time increased. Surprisingly, the estimates suggest that greater population in 1700 and distance to London had little impact on the hazard ratio.

Survival analysis can determine whether observable city characteristics in 1700 influenced the time to turnpike adoption, but it cannot be used to study neighbor effects. Instead, I examine neighbor effects by exploiting the panel structure of my data. I consider the adoption of turnpike trusts as non-repeated events. In other words, I assume that in year one a city decides whether to adopt a turnpike trust along their London road. If they adopt, then they continue to have a turnpike trust for all future periods. If they do not adopt, then in year two they face the same choice. I encode these adoption decisions as a sequence of indicator variables. If a city has a turnpike trust in year t then the adoption variable equals 1 and otherwise it is 0.

It is useful to analyze the adoption decision in a latent variable framework. Let y_{it}^* be the benefits of adopting a turnpike trust near city *i* in year *t*, and let y_{it} be a variable that equals 1 if city *i* has a turnpike trust adopted in year *t*. I assume that a turnpike trust is adopted whenever the benefits are strictly positive. Thus $y_{it} = 1$ whenever $y_{it}^* > 0$.

I also assume that the benefits y_{it}^* are a linear function of city characteristics and the adoption decisions of neighboring cities. Specifically I consider the following equation:

$$y_{it}^* = \beta x_{it} + \delta a_{it} + c_i + e_{it} \qquad (1)$$

where x_{it} are the observable characteristics of city *i* in year *t*, a_{it} is the weighted-fraction of city *i*'s neighbors that have turnpike trusts in year *t*, c_i is an unobserved city effect, and e_{it} is the error term. x_{it} includes the distance to London, a dummy variable equal to 1 if the city had water transport to London in 1700, the year, and the number of weekly coach and wagon services between city *i* and London in year *t*.

Following Wooldridge (2002), it is necessary to make some assumptions about the distribution of y_{it} conditional on $(x_{it}, a_{it}, c_i, e_{it})$. I analyze several specifications. The first is a fixed effects linear probability model (hereafter, FEL). In this case, I assume that:

$$prob(y_{it} = 1 | x_{it}, a_{it}, c_i, e_{it}) = \beta x_{it} + \delta a_{it} + c_i + e_{it} \qquad (2)$$

where c_i is now a city fixed effect and e_{it} is independent of a_{it} and x_{it}. The main advantage of this specification is that it allows c_i and a_{it} to be correlated. In other words, the unobservable characteristics of a city can be related with the fraction of neighbors that have turnpikes in any given year. One disadvantage of the FEL model is that it imposes a linear structure on a binary outcome variable, like turnpike adoption. It also assumes that the error e_{it} is independent of a_{it}.

The second specification is based on the instrumental variables, fixed effects linear probability model (IVFEL hereafter).[7] Here I assume that e_{it} is not independent of a_{it} in equation (2). That is, I allow for some unobservable shock that raises the benefits of adopting turnpike trusts for several neighboring cities. The IVFEL model first predicts the weighted-fraction of neighboring cities with turnpikes in each year, and then uses the predicted value as an explanatory variable in equation (2). The first stage includes city dummies, the year, and the weighted-average of weekly coach and wagon services between neighboring cities and London.

The weighted-average of weekly coach and wagon services are the instrumental variables. I assume they are correlated with a_{it} but are independent of $e_{it} | x_{it}$. The idea is that neighboring cities experience a unique 'demand-shock' that leads to more transport services to London, and hence a greater likelihood of having a turnpike. Consider the example of Plymouth and Exeter discussed earlier. If Exeter experienced a productivity shock, then it will have more trade with London, and thus a greater value in adopting turnpikes. If Plymouth does not experience this productivity shock, then its value of adopting turnpikes will not change, unless Exeter adopts a turnpike.

[7] The third model is an application of the methodology originally proposed by Manski (1993), where the characteristics of neighbors are used to predict neighbor adoption. It has been applied in the network externalities literature by Gowriskankaran and Stavins (2004).

The IVFEL model is preferred over the FEL model if e_{it} is not independent of a_{it}. However, the IVFEL model is not entirely correct, because its linear structure implies that the predicted probability of adoption can be below 0 or above 1.

The third specification is based on the 'traditional' random effects probit model (hereafter REP).[8] As in the usual probit model, I assume that e_{it} is drawn from the standard normal distribution and is independent of a_{it} and x_{it}. This implies the following equation:

$$prob(y_{it} = 1 | x_{it}, a_{it}, c_i) = \Phi(\beta x_{it} + \delta a_{it} + c_i) \qquad (3)$$

In this case, it is not possible to directly estimate c_i, but if I assume that $c_t | x_{it}, a_{it} \sim N(0, \sigma_c^2)$ then I can find the maximum likelihood estimator of β and δ.[9] The REP model is preferred over the FEL and IVFEL models because it does not impose a linear structure. However, it assumes that c_i has a particular functional form and that c_i is uncorrelated with a_{it}.

The fourth specification is based on the Chamberlain's random effects probit model (hereafter CREP).[10] Here I assume that equation (3) holds and that $c_i = \Psi + \bar{x}_i \xi + \bar{a}_i \varsigma + d_i$, where $\bar{x}_i$ is the average number of weekly wagon and coach services over time, $\bar{a}_i$ is the average weighted-fraction of neighboring cities with turnpikes over time, and d_i is city-specific constant. In addition, the CREP model assumes that $c_t | x_{it}, a_{it} \sim N(\Psi + \bar{x}_i \xi + \bar{a}_i \varsigma, \sigma_d^2)$, where σ_d^2 is the variance of d_i. Estimation of the CREP model is identical to the REP model, but it includes $\bar{x}_i$ and $\bar{a}_i$ as additional explanatory variables.

[8] See Wooldridge (2004), p. 485 for a discussion of the traditional random effects probit model.
[9] This model also assumes that $y_{i1},..y_{iT}$ are independent conditional on x_{it}, $f(y_{-it})$, and c_i.
[10] See Wooldridge, pp. 487-88 for a discussion of the Chamberlain's random effects probit model.

The main advantage of the CREP model is that it allows for dependence between c_i and a_{it}. The CREP model also provides a test of the key assumption of the REP model. If we reject the hypothesis that the coefficients on $\bar{x}_i$ and $\bar{a}_i$ are equal to zero, then we can reject the assumption that $c_t|x_{it}, a_{it} \sim N(0, \sigma_c^2)$.

Table 2 presents the estimates based on 278 observations covering the years 1705, 1715, 1740, 1749, 1760, 1770, 1779, 1790 and 1800. Recall that I drop all observations beyond the first year in which a city has a turnpike trust, because I assume that adoption is irreversible. Column (1) presents estimates from the FEL model, column (2) shows the IVFEL model, column (3) the REP model, and column (4) the CREP model.

Across all specifications in Table 2 higher weekly wagon services to London raised the probability of turnpike adoption. This result suggests that observable city characteristics affected adoption. In particular, higher road traffic led to a higher demand for turnpike trusts.

The main finding in table 2 is that cities were more likely to adopt turnpike trusts along the London road network if their neighboring cities did the same. The estimates in the FEL and IVFEL models imply that if half of neighboring cities adopted turnpikes, then the probability that a city adopted increased by 35 or 33 percent respectively. The finding that the FEL and IVFEL estimators are similar suggests that any dependence between the error e_{it} and the weighted fraction of neighboring cities with turnpikes a_{it} has little effect on the estimates.

Figure 3 shows the distribution of predicted probabilities for each city-year observation under the FEL and IVFEL models. In the FEL model the predicted probability is less than zero for 116 of the 278 city-year observations. Most come from the years 1705 and 1715, in which only 3 out of 67 major cities had turnpike trusts. The IVEL model also predicts a negative probability of adoption for most observations in 1705 and 1715. These results suggest that the FEL and IVFEL estimates may be misleading, because they predict a negative probability of adoption for some observations. However, it should be emphasized that the predicted probabilities are not significantly below zero in most cases. In addition, the predicted probability in the FEL and IVFEL models at the sample means are very similar to the predicted probability of the REP and CREP models.

Column (3) shows the results from the REP model. The main finding is that a higher fraction of neighboring cities with turnpikes increased the probability of turnpike adoption. I evaluate the magnitude of this coefficient by calculating the probability when no neighbors adopt turnpike trusts, and other variables are evaluated at the sample mean. I also calculate the probability when half of neighboring cities adopted turnpike trusts, and other variables are evaluated at the mean. The results show there is a 2 percent probability that a city adopts when none of its neighbors adopt. By comparison, the probability increases to 21.3 percent when half of its neighbors adopt (a difference of 19.2 percent).

The estimated impact of neighboring adoption is lower in the REP model than in the linear probability models. Still the impact of neighboring adoption is large compared to the effects of other variables. For instance, the probability of adoption increases by only 1 percent if there is a one standard deviation increase in the number of wagon services, and all other variables are evaluated at their mean.

Column (4) shows the results for the CREP model. A higher fraction of neighboring cities with turnpikes continues to increase the probability of turnpike adoption. The coefficients on the average fraction of neighbors with turnpikes and the average number of weekly wagon services to London are also of interest. The coefficients on both variables are economically and statistically different from zero. Thus we can reject the assumption of the REP model that $c_t | x_{it}, a_{it} \sim N(0, \sigma_c^2)$. In other words, the random effect c_i is not independent of city characteristics and the fraction of neighboring cities that adopted turnpike trusts.

I evaluate the magnitude of the coefficients in the CREP model by comparing the probability of adoption when no neighbors adopt and when half of neighbors adopt. The results show that the probability of adoption increases by 21.5 percent when half of neighboring cities adopt turnpikes and other variables are at the sample mean. Thus the coefficients in the CREP model are of a similar magnitude as the REP model.

3.2 Neighbor Effects and along Any Road Near a Major City

Major cities traded with smaller cities in their hinterland, as well as other major cities that were on a different route to London (see Chartres and Turnbull, 1983). Therefore, focusing solely on the London road network will not capture all relevant neighbor effects. In this section, I provide a broader measure of neighbor effects by focusing on the adoption of turnpike trusts along any road leading into a major city. Figure 4 shows the survival curve for all major cities, where survival means there were no turnpikes along any road segment that begins or ends with the city in year *t*. For comparison, the figure also shows the survival curve for major cities along the London road network. The curves are similar because most cities had turnpikes adopted first along their London road network. There were cases, however, where cities adopted turnpike trusts on other roads first. For example, Ipswich had its first turnpike trust in 1711, but it did not have a turnpike trust along its London segment until 1785.

I estimate the impact of neighbor effects in the same manner as before, except now neighboring cities are defined as all cities that lie within a 50-mile radius of a major city. The idea is that the adoption of a turnpike within 50 miles could create a neighbor effect, even if it was not on the same route to London. I continue to use city dummies, the year, and weekly wagon and coach services to London as controls. I also continue to use the weighted-average of weekly wagon and coach services among neighboring cities as my instruments. Ideally, I would like to have weekly transport services to all cities, but this data is not presently available.

Table 3 presents the estimates for all four specifications using 257 observations covering the years 1705, 1715, 1740, 1749, 1760, 1770, 1779, 1790 and 1800. The FEL estimates imply that if half of neighboring cities adopted turnpikes, then the probability of adoption increased by 33 percent. The IVFEL estimates suggest that if half of neighboring cities adopted, then the probability of adoption increased by over 50 percent. The IV estimates suggest that neighboring adoption played a larger role if we include all major cities within 50 miles. In fact, they imply that neighboring adoption explains a substantial portion of the variation in the data.

Figure 5 shows the predicted probabilities of turnpike adoption for city-year observations under the FEL and IVFEL models. Once again we see that the linear models predict that some cities have a negative probability of turnpike adoption. The predictions are negative for 91 of 258 observations in the FEL model, and for 137 observations in the IVFEL model. As before, most of these observations come from the years 1705 and 1715.

Columns (3) and (4) show the estimates from the REP and CREP models. They also show that the weighted-fraction of neighboring cities with turnpikes is positive and significant. In the CREP model, the coefficients on the average fraction of neighboring cities with turnpikes, the average number of weekly wagon services, and the average number of coach services are also significant. This implies that we can reject the independence assumption of the REP model. Lastly, I evaluate the magnitude of neighboring adoption by subtracting the probability when no neighbors adopt turnpike trusts from the probability when half of the neighboring cities adopt (all other variables are evaluated at their sample mean). Under the CREP model, the calculations show that a city was 22.0 percent more likely to adopt a turnpike trust when half of its neighbors adopted turnpike trusts.

Overall, the impact of neighboring adoption appears to be similar regardless of whether I define neighbors as all major cities that shared a common route to London, or all cities within a 50-mile radius. The finding that the coefficient on neighboring adoption does not decline after using instrumental variables suggests that we can interpret these results as being causal. The estimates from the Chamberlain random effects probit model are probably the most informative because it does not impose a linear structure, and it does not assume independence between neighboring adoption and the city-specific constant c_i. It shows that a city was around 21 percent more likely to adopt a turnpike, when half of their neighbors did the same.

4. Interpreting Neighbor Effects

My results show that neighbor effects influenced the adoption of turnpike trusts. It is not obvious, however, why neighbor effects mattered. One explanation is that local groups learned about the benefits of turnpike trusts by observing a demonstration of the effects in neighboring locations. Learning was necessary if groups were uncertain about whether the tolls would provide enough revenues to finance road improvements. Similarly, investors may have been uncertain about the risks associated with turnpike bonds. These uncertainties could be overcome if groups were able to observe the effects of turnpikes in their area. Local demonstrations were likely to have been most informative, because regional economies were similar and most investors were local.

Network externalities are another explanation for why neighboring adoption mattered. Network externalities would be present if the benefits increased when turnpike trusts were adopted in neighboring locations. The benefits would increase if the value of improving one road segment increased as connecting road segments were improved. This would be a likely scenario if road-users traveled over connecting segments when going to their destination. Neighboring adoption could also affect the benefits of turnpikes if cities were in competition with one another. Suppose, for example, that two cities were competing to become the commercial center of their region. If one city adopts a turnpike and gains a comparative advantage, then the other city may want to adopt as well to offset this advantage.[11]

At the moment, I cannot distinguish between different types of neighbor effects, but I do have evidence that network externalities were important in some cases. Network externalities imply that the value of improving a road segment increased as connecting segments were improved. As are result, we might expect that turnpikes will be adopted along a particular segment of the London road network, after turnpikes were adopted along segments that were closer to London.

The maps in figure 2 suggest that along some routes turnpikes did indeed spread outwards from London. For instance, along the London-Durham-Newcastle road segments further away from London got turnpikes shortly after segments closer to London. Starting in 1741, a turnpike trust was established along the Doncaster to Boroughbridge segment. In 1745, a second turnpike was established along the Boroughbridge to Durham segment. In 1747, a third turnpike was adopted along the Durham to Newcastle segment, as well as a fourth along the segment from Durham to Sunderland.

[11] Network externalities would also be present if the costs of creating turnpike trusts went down when more were adopted along neighboring roads. The costs could fall if the adoption of turnpike trusts in neighboring areas raised

The London-Salisbury-Exeter road provides an example where some turnpikes were adopted away from London first. There were four segments between Salisbury and Exeter. The first was Salisbury to Shaftesbury, which had a turnpike in 1762. The second was Shaftesbury to Crewkerne which had two separate turnpikes in 1753. The third was the Crewkerne to Axminster, which had two turnpikes in 1758 and 1759. The fourth was the segment between Axminster and Exeter, which had a turnpike in 1753. Here the second and fourth segments were the first to have turnpikes, followed by the third and the first. In this case, demonstration effects or some other type of network externality must have played a role.

A final example from the West of Yorkshire illustrates how different types of neighbor effects influenced the adoption of turnpike trusts. In 1735, the West Riding had one turnpike trust managing 13 miles between Halifax and Elland. In 1741, 6 turnpike trusts were established along 239 miles linking cities like Doncaster and Wakefield, Wakefield and Pontefract, Leeds and Elland, Doncaster and Boroughbridge, Doncaster and Saltersbrook, as well as Leeds and Selby. The Halifax and Elland turnpike may have encouraged the other turnpikes by providing a demonstration of the benefits between 1735 and 1741. Later, network effects were more important because several turnpikes linked with Doncaster, which was a central point in the local transport network.[12]

Inter-city competition is likely to have been a factor in the adoption of turnpike trusts near Leeds and Wakefield. These two cities were the main marketing centers for woolen textiles in the West Riding. They had an advantage in the region because they were located on the Aire and Calder rivers, which flowed to the eastern sea coast (Wilson, 1971). In 1741, Leeds improved its

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toll revenues by increased local road traffic.

[12] The adoption spurt in the West Riding was partly due to the expansion of its main industry, woolen textile manufacturing. Between 1730 and 1735, the average annual growth rate for woolen textile production in the West

transport links to the east by promoting the Leeds to Selby turnpike trust. Wakefield did the same in 1741 by promoting the Wakefield to Pontefract turnpike trust. The latter improved Wakefield's transport links to the eastern coast and was parallel to the Leeds-Selby turnpike. The behavior of Leeds and Wakefield suggests that each city adopted in response to the adoption of the other. One possibility is that Wakefield tried to offset the advantages that might have gone to Leeds, if Leeds was the only city with a turnpike trust to the eastern seaboard.

5. Conclusion

In 1700, there were a handful of turnpike trusts managing roadways in England and Wales. By the 1830s there were nearly 1000 turnpike trusts managing 20,000 miles. Why did it take so long for this institutional innovation to diffuse? In this paper, I show that neighbor effects are one reason why turnpike trusts were adopted slowly. My results show that turnpikes were more likely to be adopted in one location, when they were also adopted in neighboring locations. One reason is that the local benefits from turnpikes increased as turnpikes were adopted in neighboring locations. Another reason is that local groups learned about the benefits of turnpikes by observing their effects in neighboring locations. The combination of network externalities and demonstration effects meant that local groups did not want to promote turnpike trusts unless their neighbors did as well. As a result, there was a pattern in which turnpike trusts were absent until several neighboring cities adopted simultaneously. Afterwards, more cities followed and within a short time period most major roads had turnpike trusts.

It is worth emphasizing that my results do not dismiss the importance of economic growth as a contributing factor to turnpike adoption. For instance, I find that cities with more wagon

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Riding was zero. It increased to 5.75% between 1735 and 1740, and was 4.04% between 1740 and 1745 (Mitchell, and coach services to London had a higher probability of turnpike adoption. Thus as the economy developed and traffic increased, more turnpike trusts would have been adopted. Therefore, the results support the view that a combination of neighbor effects and economic growth influenced the diffusion process.

More generally, my findings provide an illustration of how neighbor effects influence institutional changes like new legislation. There are often uncertainties about how new legislation will influence the economy. In such cases, lobbyists and politicians may learn about the benefits of legislation by observing its effects in neighboring jurisdictions. It is also possible that the benefits increase when neighboring jurisdictions pass similar legislation. These factors can lead to a coordination problem, in which political actors will enact new legislation only if they believe others will as well. The result is that the status quo becomes self-enforcing, and the efficiency gains associated with the new institution are lost.

Appendix: Data Sources for the London road network

Table 4 lists the 22 London routes, along with the major cities on each route. Each route can be identified in Figure 2. There are two types of routes. The first is a major highway that linked London to several major cities. For instance, route 9 connected London with Colchester, Ipswich, and Yarmouth. Another example of the first type is route 12, or the Great North Road, which linked London with Newcastle, Berwick, Durham, Sunderland, and South Shields. The second type was a branch highway that linked with a major highway. For instance, route 14 was a branch highway that connected Whitby, Scarborough, and York to the Great North road. It was classified as being separate from the Great North Road because of its length and the distance

1971).

to other branches. Another example of a branch highway is route 18, which linked Whitehaven, Carlisle, Kendal, Lancaster, Liverpool, and Macclesfield with route 22, which was the major highway between Chester and London.

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Tables

Table 1: Survival Analysis of Turnpike Adoption along the London Network

Variable	Hazard Ratio (standard error)
Dummy variable if city had a population above 2500 in 1700	0.7235123 (0.2076907)
Distance from London	1.001602 (0.0020118)
The Number of weekly wagon services from London in 1705	1.132877 (.0898938)
The Number of weekly coach services from London in 1705	1.252795 (.0774167)*
Dummy variable if city had water transport to London in 1700	0.5771038 (0.1609982)*
N	67
Log Likelihood	201.21602
LR Chi-square(5)	13.71

Notes and Sources:

Table 2: Neighbor Effects and the Probability of Turnpike Adoption along Segments of the London Road Network that begin or end with Major Cities

Variable	(1) (FEL) Coefficient (Stand. Error)	(2) (IVFEL) Coefficient (Stand. Error)	(3) (REP) Coefficient (Stand. Error)	(3) (CREP) Coefficient (Stand. Error)
Weighted Fraction of Neighboring Cities with Turnpikes in year t	0.7044611 (.0749101)*	0.6608485 (0.2332922)*	2.470019 (.4193493)*	4.785473 (.6682086)*
Number of Weekly Wagon Services to London in year t	0.0249234 (.0135791)*	0.0260167 (.014675)*	0.1117474 (0.0606515)*	0.2002393 (.102433)*
Number of Weekly Coach Services to London in year t	0.0028504 (.0079278)	0.0025586 (.0080706)	0.0135369 (0.0335281)	0.0046049 (.0527363)
Distance to London (in miles)	—	—	-0.0004516 (0.0022569)	-0.0027213 (.0023286)
Dummy for Water Transport to London	—	—	-0.267707 (0.3336732)	0.1748478 (0.3534642)
year	0.0027512 (0.0013989)*	0.0032767 (.0030073)*	0.0201723 (0.0084624)*	0.0064528 (.0089)
Average Fraction of Neighboring Cities with Turnpikes	___	___	___	-7.222599 (1.126131)*
Average Number of weekly wagon services to London	___	___	___	-0.2593347 (.1357622)*
Average Number of weekly coach services to London	___	___	___	0.0971331 (.0974452)
Intercept	-4.834978 (2.393208)*	-5.733313 (5.142337)	-37.04803 (14.52525)*	-11.83326 (15.37453)
N	278	278	278	278
R square	0.5969	0.5962		
Wald Chi Square			62.51	67.79

Sources: see text.

Notes: The Dependent Variable equals 1 if they city had a turnpike trust adopted along its portion of the London road network in year t. *Indicates statistical significance at the 90% level.

Table 3: Neighbor Effects and the Probability of Turnpike Adoption along any Road Segment beginning or Ending with a Major City

Variable	(1) (FEL) Coefficient (Stand. Error)	(2) (IVFEL) Coefficient (Stand. Error)	(3) (REP) Coefficient (Stand. Error)	(3) (CREP) Coefficient (Stand. Error)
Weighted Fraction of Neighboring Cities with Turnpikes in year t	0.6726711 (.0882719)*	1.170841 (.3057321)*	2.365177 (.48149413)*	4.998026 (.7827257)*
Number of Weekly Wagon Services to London in year t	0.0343931 (.0148138)*	0.015307 (.0195004)	0.1072204 (0.0641439)*	0.1665249 (.1179384)
Number of Weekly Coach Services to London in year t	-0.0131648 (.0163307)	-0.0141729 (.017663)	0.0747355 (.0513913)	-0.0516344 (.0845793)
Distance to London (in miles)	__	__	-0.001412 (.0022869)	-0.0025884 (.0023953)
Dummy for Water Transport to London	__	__	-0.0734474 (.3428256)	-0.4044423 (.3491793)
year	0.0037736 (.0016487 9)*	-0.0029759 (.0043201)	0.0280988 (.0109674)*	0.0228565 (.0116262)*
Average Fraction of Neighboring Cities with Turnpikes	___	___	___	-8.918788 (1.439353)*
Average Number of weekly wagon services to London	___	___	___	-0.2690885 (.1519415)*
Average Number of weekly coach services to London	___	___	___	0.1930705 (.0969108)*
Intercept	-6.549954 (2.824132)*	5.016695 (7.402779)	-50.70026 (18.86318)*	-39.35614 (19.95816)*
N	257	257	257	257
R square	0.6144	0.5494		
Wald Chi Square			51.61	57.62

Sources: see text.

Notes: The dependent variable equals 1 if a turnpike trust was adopted along any road segment that began or ended with the city in year t. *Indicates statistical significance at the 90% level.

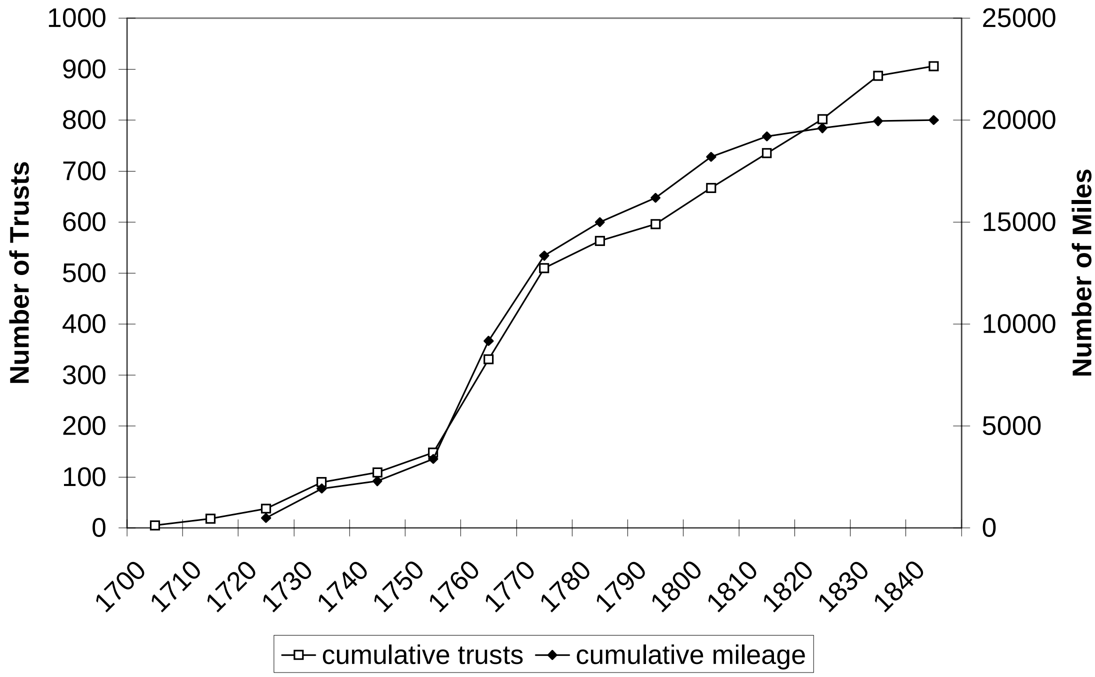
Table 4: The London Road Network

Route Number	City 1	City 2	City 3	City 4	City 5	City 6
1	Halifax	Sheffield	Nottingham	Bedford		
2	Plymouth	Exeter	Salisbury			
3	Tiverton	Taunton	Frome			
4	Bristol	Bath	Reading			
5	Southampton	Winchester				
6	Portsmouth	Chichester				
7	Canterbury	Rochester				
8	Maidstone					
9	Yarmouth	Ipswich	Colchester			
10	Norwich	Bury				
11	King's Lynn	Ely	Cambridge			
12	Berwick	Newcastle	South Shields	Sunderland	Durham	
13	Bradford	Leeds				
14	Whitby	Scarborough	York			
15	Manchester	Derby	Northampton	Leicester		
16	Hereford	Gloucester	Circenster			
17	Beverley	Hull	Lincoln	Boston		
18	Whitehaven	Liverpool	Macclesfield	Lancaster	Carlisle	Kendal
19	Shrewsbury	Birmingham	Wolverhampton	Coventry	Dudley	
20	Worcester	Oxford				
21	Kidderminster	Warwick	Banbury			
22	Chester	Lichfield	Coventry			

Notes and Sources: The network was constructed using data from Albert (1972), Pawson (1977), and the Great Britain, 1840).

Figures

Figure 1: The Diffusion of Turnpike Trusts, 1695-1840



Sources: Data on Acts and mileage comes from Albert (1972) and Pawson (1977).

Figure 2: Maps of the London Turnpike Network:

Panel A 1720

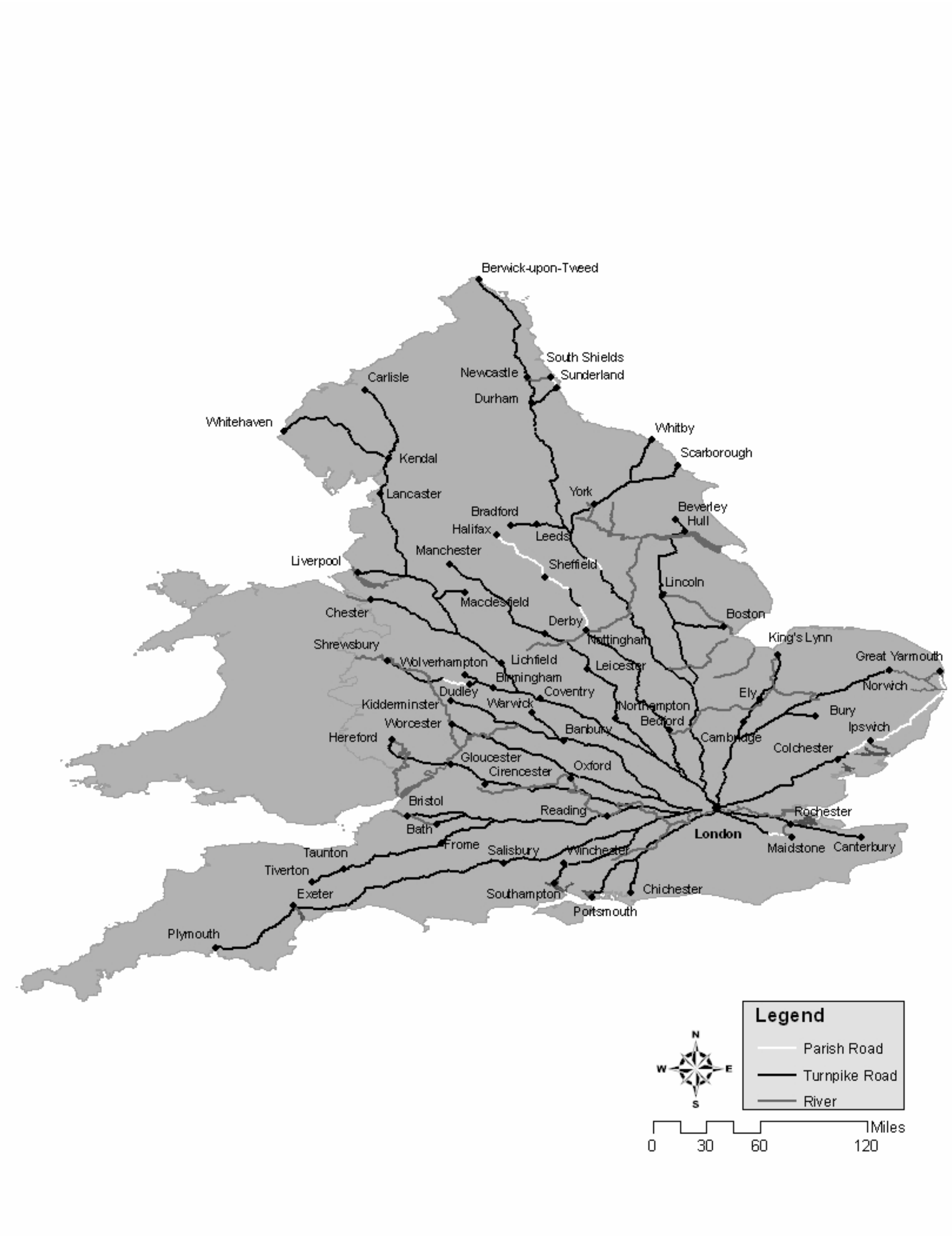
Panel B 1730


Berwick-upon-Tweed
South Shields
Newcastle
Sunderland
Carlisle
Durham
Whitehaven
Whitby
Kendal
Scarborough
Lancaster
York
Bradford
Beverley
Halifax
Hull
Leeds
Manchester
Liverpool
Sheffield
Lincoln
Chester
Macclesfield
Boston
Derby
Nottingham
King's Lynn
Shrewsbury
Lichfield
Great Yarmouth
Wolverhampton
Leicester
Birmingham
Norwich
Dudley
Coventry
Ely
Kidderminster
Warwick
Northampton
Bury
Worcester
Bedford
Ipswich
Banbury
Hereford
Cambridge
Colchester
Gloucester
Oxford
Cirencester
Bristol
Reading
Rochester
Bath
London
Maidstone
Canterbury
Frome
Taunton
Salisbury
Winchester
Tiverton
Exeter
Southampton
Chichester
Portsmouth
Plymouth
Legend
Parish Road
Turnpike Road
River
N
W
E
S
Miles
0
30
60
120

Panel C 1750


Berwick-upon-Tweed
South Shields
Newcastle
Sunderland
Carlisle
Durham
Whitehaven
Whitby
Kendal
Scarborough
York
Lancaster
Bradford
Beverley
Halifax
Hull
Leeds
Manchester
Liverpool
Sheffield
Lincoln
Macclesfield
Chester
Boston
Derby
Nottingham
King's Lynn
Shrewsbury
Lichfield
Great Yarmouth
Wolverhampton
Leicester
Birmingham
Norwich
Dudley
Coventry
Ely
Kidderminster
Warwick
Northampton
Bury
Worcester
Bedford
Ipswich
Banbury
Hereford
Cambridge
Colchester
Gloucester
Oxford
Cirencester
Bristol
Reading
Rochester
Bath
London
Maidstone
Canterbury
Frome
Salisbury
Winchester
Taunton
Tiverton
Southampton
Chichester
Exeter
Portsmouth
Plymouth
Legend
Parish Road
Turnpike Road
River
N
W
E
S
Miles
0
30
60
120

Panel D 1770



Berwick-upon-Tweed
South Shields
Newcastle
Sunderland
Carlisle
Durham
Whitehaven
Whitby
Kendal
Scarborough
Lancaster
York
Bradford
Beverley
Halifax
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Derby
Nottingham
King's Lynn
Shrewsbury
Lichfield
Great Yarmouth
Wolverhampton
Leicester
Birmingham
Norwich
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Kidderminster
Warwick
Northampton
Bury
Bedford
Worcester
Ipswich
Banbury
Cambridge
Hereford
Colchester
Gloucester
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Cirencester
Bristol
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Rochester
Bath
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Maidstone
Canterbury
Frome
Taunton
Salisbury
Winchester
Tiverton
Exeter
Southampton
Chichester
Portsmouth
Plymouth
Legend
Parish Road
Turnpike Road
River
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Miles
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60
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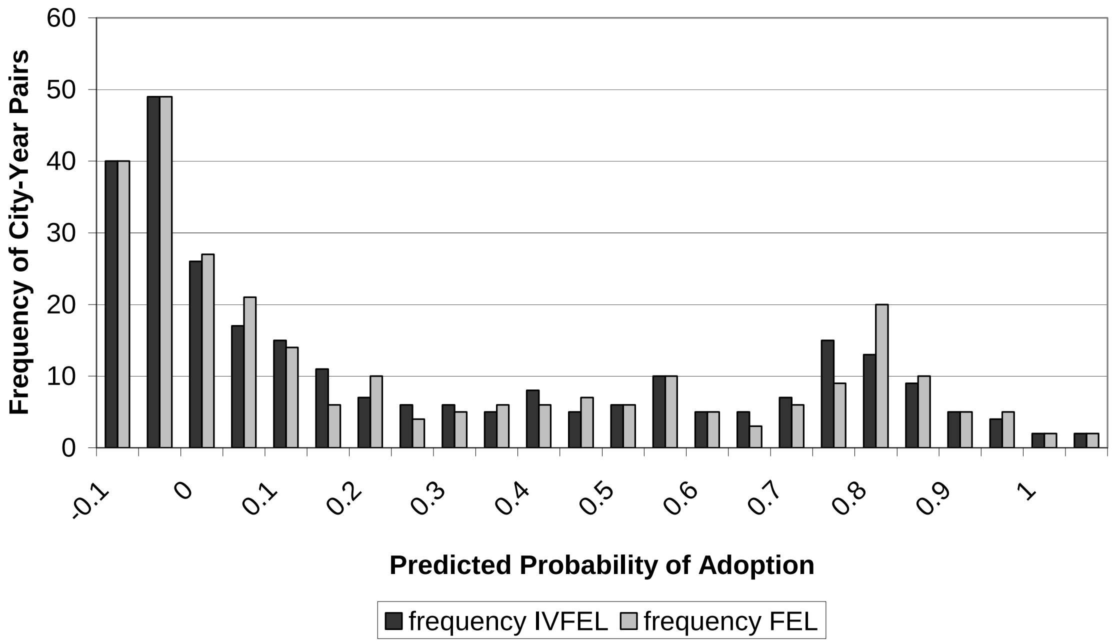
Figure 3: The Distribubution of Predicted Probabilities for each city-year observation (London Road Segments)



Notes and sources: The predicted probabilities are based on the estimates in columns (1) and (2) of table 2.

Figure 4: Survival Curve for City Turnpike Adoption along London Road Segments and all Road Segments

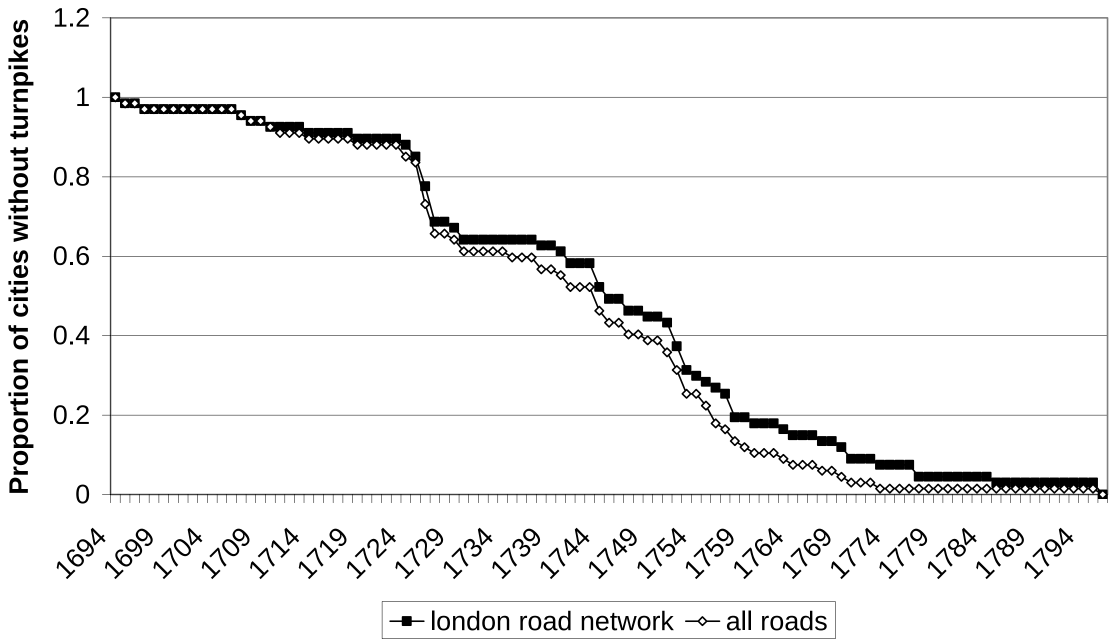
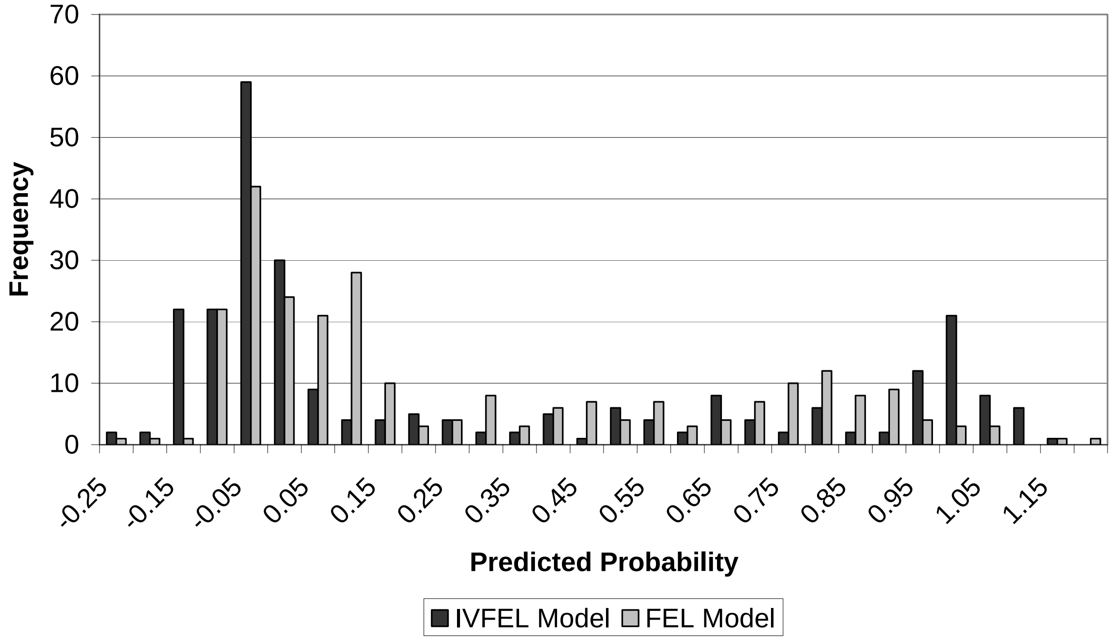


Figure 5: The Distribution of Predicted Probabilities for each City-year Observation (All Road Segments)



Notes and sources: The predicted probabilities are based on the estimates in columns (1) and (2) of table 3.