Neighbors, Networks, and Institutional Change: Explaining the Diffusion of Turnpike Trusts in Eighteenth-Century England[1]

Dan Bogart

University of California, Irvine

dbogart@uci.edu

Abstract

Turnpike trusts improved roads and reduced transport costs in eighteenth-century England. They were created by acts of Parliament and were promoted by local groups. The first turnpike was established in 1663, but they were not widespread until 1770. This paper uses survival analysis to show that neighbor effects and network effects greatly influenced the diffusion of turnpikes. The results show that cities were more likely to adopt turnpikes if other turnpikes were adopted along their route to London, or near neighboring cities. The results also show that cities were less likely to adopt turnpikes if their competing cities adopted turnpikes.

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I. Introduction

In the early nineteenth century England had the largest toll road network in history. Users paid tolls on nearly 20 percent of all carriage roads, which is higher than the proportion of any road network before or since. English toll roads were managed by over 900 separate organizations called ‘turnpike trusts.’ Turnpike trusts were created by acts of Parliament that named a body of trustees and gave them authority to levy tolls, issue bonds, and purchase land for improvements. Trustees were often local landowners, merchants, and manufacturers who stood to benefit from improved communications or the introduction of tolls. They were also the main groups who promoted turnpike acts in Parliament.

The passage of turnpike acts marked a significant institutional change in the financing of road infrastructure. Previously roads were maintained by local units of government known as parishes. Due to fiscal and legal limitations most parishes spent little, and the quality of the road network suffered. Turnpike trusts by contrast made substantial road investments and contributed to significant reductions in freight charges and travel times. They also contributed to a growth in local property income, especially land rents [Bogart, 2005a, 2005b, 2006].

Turnpike trusts diffused slowly. The first turnpike was created in 1663, but the second was not created until 1695. Turnpike adoption accelerated in the 1720s and again in the 1750s and 1760s, but they continued to be adopted along some roads as late as the 1790s and 1810s. Several scholars have examined why turnpike trusts diffused slowly in some years and rapidly in others. The predominant explanation is that higher road traffic led to the adoption of turnpikes [Pawson, 1977]. An alternative explanation is that neighbor effects and network effects influenced turnpike adoption. William Albert [1972], for instance, argues that the adoption of turnpikes in one location encouraged their adoption in neighboring locations because cities were competing with one another, or because they learned about the benefits of turnpikes.

In this paper, I test whether network effects and neighbor effects influenced the diffusion of turnpike trusts. Specifically, I use survival analysis to identify factors which affected the timing of adoption along roads that intersected with major cities (i.e. cities with a population above 2500 in 1700). One of the main variables is the fraction of mileage managed by turnpikes between London and the closest segment to a major city. The other main variables are the fraction of major cities within 50 miles that have turnpikes and the fraction of major cities with the same economic specialization that have turnpikes. Several city characteristics are also analyzed, such as the number of wagon and coach services to London, distance to London, availability of water transport to London, and classifications for economic specialties.

There are two potential problems in identifying neighbor and network effects. First, there could be unobserved factors which are correlated with neighbor and network variables. Second, there could be simultaneity between a city's decision to adopt a turnpike and its neighbors' decision to adopt. I address unobserved heterogeneity by estimating a discrete-time hazard model that includes city random effects along with dummy variables for time periods, regions, routes to London, and economic specialties. The simultaneity problem is addressed by using lagged values for neighbor and network variables. The idea is that a city's current decision to adopt should not influence its neighbors' decision to adopt in previous periods.

My results show that major cities were much more likely to adopt turnpikes if other turnpikes managed a greater proportion of their route to London, or if turnpikes were adopted near major cities within 50 miles. They also show that the likelihood of adoption *decreased* if turnpikes were adopted near cities with the same economic specialization. Overall the results show that both neighbor effects and network effects had a major influence on the diffusion of turnpikes.

The findings add to the literature on legislation in eighteenth century England. Recent studies have shown that prior to the Industrial Revolution there was a dramatic growth in acts dealing with the provision of local transport infrastructure and public services [Hoppit, 1996; Bogart and Richardson, 2006]. Paul Langford [1991, p. 158] has suggested that neighbor effects were one of the key factors affecting the passage of infrastructure acts during this period. This paper is the first to test whether neighbor effects indeed influenced their diffusion.

My results also add to the broader literature on neighbor effects, which are sometimes referred to as contagion effects, social interactions, or spatial dependence. Neighbor effects have been shown to influence a wide range of social and economic phenomenon, such as crime, educational attainment, and technology adoption [Brock and Durlauf, 2001; Durlaf, 2004]. There are relatively few studies, however, which examine their effect on institutional changes, such as the adoption of legal or regulatory structures. An exception is the literature which focuses on the passage of 'Uniform Laws' among U.S. states during the early twentieth century. Donald Symthe [2005], for instance, argues that contagion effects were an important factor in the diffusion of Uniform Sales Acts, which sought to codify aspects of common law. Contagion effects have also been studied in the context of Uniform Small Loan Laws [Carruthers, Guinnane, and Lee, 2005] and Workers Compensation laws [Kantor and Fishback, 1998].

Neighbor effects play a potentially important role in accounting for the persistence of inefficient institutions [North, 1990]. The idea is that if private or public decision-makers believe that other decision-makers will not change their institutions, then the status quo becomes self-enforcing, and the efficiency gains from new institutions are lost. Turnpike trusts provide one example of this phenomenon. Local groups 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 rest of the paper is organized as follows. Section II provides an overview of turnpike trusts and the English economy during the eighteenth century. Section III discusses the data. Section IV describes the methodology. Section V shows the results. Section VI concludes.

II. Overview

In 1700 England was already undergoing the early stages of economic development. Agricultural output per worker was rising along with real wages [Allen, 2001; Clark, 2005]. 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 contributed to agglomeration economies, which raised the productivity of firms. As the eighteenth century progressed cities began to specialize in particular manufacturing products. For instance, Leeds specialized in woolen textiles, 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 higher demand for road investment, but the existing institutions were not well-suited to meet the increase in 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 or issue bonds.

Parishes were generally ineffective in providing road maintenance and investment. One problem was that parishes were small, and therefore, most of the benefits went to through-travelers [Pawson, 1977; Bogart, 2005a]. 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 increased through-traffic, which lowered prices in the London market or added to congestion.

The reluctance of parishes to finance road improvements led to higher transport costs and lower 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 began to address this problem by submitting petitions to Parliament. For example, in 1705 the inhabitants of Droitwich submitted a petition stating that the highway between Droitwich and Birmingham was "impassable, resulting in several carts and wagons being broken." They went on to state that "goods are spoiled, many horses are lost, and the inhabitants are incapable of repairing the [highway] by the Laws now in force, to the great prejudice of trade in this part of the country."[1]

A petition to improve a local highway, such as the Droitwich to Birmingham road, typically resulted in the passage of a turnpike act. In fact, nearly all turnpike acts began with petitions from local groups who had interest in the quality of their roads.

A turnpike act transferred authority from parishes to a body of trustees. Trustees were typically local landowners, merchants, and manufacturers. Trustees had the right to levy tolls, issue secured bonds, and purchase land. They did not have the right to profit from the tolls however. Instead they earned indirect benefits through higher land rents or profits from trade.

Turnpike trusts had a significant effect on road expenditure. Once they assumed control over the road, they generally increased expenditure by a factor of more than ten [Bogart, 2005a]. The ability to levy tolls was especially crucial because it helped resolve the through-traffic problem. Rights to issue secured bonds and purchase land were also important because parishes had difficulties borrowing and they lacked the power of eminent domain.

Greater road expenditure affected the economy by contributing to lower transport costs. Between 1750 and 1820, freight charges fell by around 40 percent, while passenger travel times were reduced by 60 percent.[2] At the same time there was a significant increase in long-distance freight and passenger traffic, especially between London and major cities, like Birmingham, Leeds, Liverpool, Manchester, and Newcastle. Turnpikes also generated local benefits, as land rents typically increased by more than 10 percent after they were established. The aggregate impact of turnpikes was also substantial and amounted to a social savings of nearly 1 percent of national income in 1815 [Bogart, 2005b, 2006].

Although they produced large benefits, turnpikes were not rapidly adopted. Figure I shows the diffusion curve for the number of trusts and the mileage under their control between 1695 and 1840. Both curves have the familiar S-shape, in which adoption starts slow, then accelerates, and then slows once again.[3] The peak of adoption occurred in the 1750s and 1760s when over 300 trusts were created along 10,000 miles of road [Pawson, 1977]. The 1720s, 1790s, and 1810s also stand out as periods where many turnpikes were created.

There are a number of hypotheses about why turnpikes were more rapidly adopted in some time periods. The leading hypothesis is that greater traffic led to the adoption of turnpikes. Eric Pawson [1977] argues, for instance, that the acceleration in economic growth starting in the late

1740s contributed to the spread of turnpikes in the 1750s and 1760s because it increased wheeled traffic along major highways [p. 123, 150].

Another hypothesis is that network effects influenced turnpike adoption. Network effects imply that the benefits of turnpikes increased as more turnpikes were established on connecting road segments. For example, consider three cities located consecutively along a road. The benefits of turnpikes between city 1 and city 2 may increase if there is a turnpike between city 2 and city 3 as well. If the change in benefits is large enough, then a turnpike between 1 and 2 may not be worthwhile unless one exists between 2 and 3.

A related hypothesis is that neighbor effects influenced turnpike adoption. William Albert [1972] gives several examples of how new turnpikes were established near existing turnpikes. He argues that the adoption of turnpikes in neighboring locations mattered because promoters "sought to mitigate any comparative disadvantage engendered by road improvement in other areas, while at the same time realizing economies similar to those achieved in other areas [p. 114]." Albert emphasizes how inter-city competition contributed to the adoption of turnpikes, but it could also deter turnpike adoption. The reason is that transport improvements can increase competition between firms in different locations. Therefore, the profits for less productive firms may fall, if its local road network is improved at the same time as its competitors in other cities.

Thus far the historical literature has documented the clustering of turnpike adoption in geographic areas, or along particular routes. However, it is not obvious that clustering was caused by neighbor or network effects. For example, it is possible that turnpikes were adopted along nearby roads because they shared similar traffic levels. This type of problem arises throughout the literature on neighbor effects. Manski [1993] argues that similar behavior within groups can be due to endogenous effects, in which the actions of the group cause an individual to take some action, or exogenous effects, in which individuals behave similarly because they share the same characteristics. It is possible to distinguish between endogenous and exogenous effects using panel data or non-linear models [Brock and Durlauf, 2001]. In my analysis, I focus on the adoption of turnpikes near major cities and examine whether changes in network or neighborhood adoption matter after controlling for city characteristics. Before discussing the methodology in detail, it is necessary to introduce the data.

III. Data

Local groups generally promoted turnpikes because they hoped to benefit through improved communications in their area. I measure these local decisions by focusing on the adoption of turnpike trusts near 66 major cities with populations above 2500 in 1700 [Corfield, 1983]. The list of 66 major cities includes manufacturing centers like Birmingham, Leeds, Norwich, and Manchester, along with resort or cultural centers like Bath, Oxford, and Cambridge. Also included are port cities like Bristol, Liverpool, and Newcastle, as well as market towns like Salisbury, Banbury, and Bury St. Edmonds.

I first examine turnpike adoption along any segment of the London road network that intersects with a major city. The London network was the main trade route between the capitol and provincial cities. I identified the routes between London and each major city using the seventeenth century travel guide *Britannia* [Bowen, 1970]. Then I use the database of turnpike acts in Albert [1972] and Pawson [1977] to identify the first year when turnpike trusts were established on each segment of the London road network, including segments that intersect with major cities.

Second, I examine turnpike adoption along *any* road segment that intersects with a major city. As before I use data from Albert and Pawson to identify the first year when turnpikes were established near major cities. Notice that turnpike adoption along any road segment includes adoption along London road segments. Therefore, if a city has a turnpike first along its portion of the London road network, then the year of adoption is identical under both definitions.

My data also includes information on the characteristics of cities, including distance to London, an indicator if they had water transport to London in 1700, and the number of weekly coach and wagon services to London. Distance is available in *Britannia* [Bowen, 1970]. Cities are defined as having water transport if they were located on the coast, or next to a navigable river which led to London [Stevens, 2005]. The number of weekly coach and wagon services are taken from London directories published in 1705, 1715, 1726, 1740, 1749, 1760, 1770, 1779, 1790 and 1800.[4] Directories contain a list of scheduled coach and wagon services between London and most cities. For example, the 1726 London directory reports two weekly wagon services to Portsmouth, one on Monday and one on Thursday. It also reports four weekly coach services from London to Portsmouth, two on Monday, one on Wednesday, and one on Friday.

Directories have been used by several scholars as a source on the growth in transport services between London and major cities [Chartres and Turnbull, 1983; Gerhold, 1988; Bogart, 2005b]. Their value has been questioned by some scholars because unscheduled services are not counted, and because they may contain errors. That being said, it appears that the growth in scheduled services is highly correlated with the growth in actual services. For instance, directories show that the number of wagon and coach services from London to major cities increased slowly before 1750, but rapidly thereafter. The growth of coach services was especially rapid, averaging 5.1 percent per year between 1749 and 1800 [Bogart, 2005b]. These findings are consistent with evidence that population, international trade, and industrial production all grew more rapidly after 1750.[5]

Weekly wagon and coach services are not available in all years because directories were published periodically, especially before 1740. I assume that wagon and coach services remained constant between years when directories are not observed. In others words, wagon and coach services start with their 1705 value and remain constant until 1715 when they are updated. A similar procedure is used for all years between 1715, 1726, 1740, 1749, 1760, 1770, 1779, 1790, and 1800. The assumption that scheduled services remained constant between directories is not unrealistic, especially before 1750 when they changed little for most cities.

I also match each major city with the adoption decisions of neighboring cities. Neighboring cities are defined in two ways. First, they include all major cities within a 50-mile radius, where distances are defined using latitude and longitude coordinates. Second, I define neighbors as all major cities that share an economic specialty. Penelope Corfield [1983] and Tim Lambert provide information on the economic characteristics of cities around 1700. I draw on their work and create 7 economic specialties: western port, southern port, eastern port, resort/cultural center, woolen cloth manufacturing, other manufacturing, and market town.

For both types of neighboring groups, I calculate the weighted-fraction of neighboring cities with turnpikes managing any road segment (or any London road segment) that interested with the city. The weights are equal to the inverse of the distance between cities. For example, Tiverton is 20 miles from Exeter and Taunton is 44 miles from Exeter. Tiverton had a turnpike on its portion of the London network in 1758 and Taunton in 1752. Therefore in the case of Exeter, the weighted fraction of neighboring cities within 50 miles that have turnpikes is 0 before 1752, 0.32 between 1752 and 1757, and 1 after 1758. The idea is that Exeter was influenced by the adoption of turnpikes near Tiverton and Taunton, but Tiverton's adoption mattered more because it was closer.

Each major city is also matched with the fraction of mileage managed by turnpikes between London and the closest segment to the city. Figure II shows the London network in 1700 along with major rivers. Most turnpike trusts controlled between 10 and 20 miles, and therefore, several turnpikes managed different segments along a route. For example, there were 4 segments between London and Oxford. The first was 15 miles and was managed by a turnpike starting in 1715. The second was 8 miles and had a turnpike starting in 1751. The third was 12 miles and had a turnpike in 1719. The fourth was 18.5 miles and had a turnpike in 1719.

When calculating the fraction of mileage, I omit the last segment connecting to the major city to avoid any direct correlation with its adoption decision. In the Oxford example, the fraction of mileage managed by turnpikes between London and the closest segment to Oxford is 0 before 1715, 0.43 between 1715 and 1718, 0.77 between 1719 and 1750, and 1 after 1751.

IV. Methodology

Survival analysis is the appropriate tool to study the adoption of turnpikes, because once they were created along a road, a turnpike usually retained control for a century or more. Survival analysis is based on a survival function and a hazard function. In my case, the survival function $S(t)$ describes the probability that a major city does not have a turnpike along any intersecting road segment (or any intersecting London road segment) in year t. The hazard function $\lambda(t)$ describes the probability that a major city will adopt a turnpike in year t given that it has not adopted before year t.

An important distinction in survival analysis is whether time is continuous or discrete. I observe whether turnpike trusts were adopted in each year because they were created during annual legislative sessions. Therefore, time is measured as a discrete variable, beginning with 1695, the first year a turnpike was established near Gloucester, and ending in 1795 when a turnpike was established near South Shields in northern England.

The most common discrete-time hazard functions are the logistic and the complementary log-log.[6] The logit assumes that the natural log of the odds ratio takes the form

(1) $$\log\left(\frac{\lambda(t \mid w_{it})}{1-\lambda(t \mid w_{it})}\right) = \alpha_t + \beta w_{it}$$

where α_t is the log of the odds ratio for the baseline hazard $\lambda_O(t)$, w_{it} is a vector of characteristics for city *i* in year t, and β is a vector of parameters. The baseline hazard is the probability that a city will adopt a turnpike in year t given that w_{it} is zero and that it has not adopted before year t.

The complementary log-log (hereafter cloglog) assumes that the hazard takes the form

(2) $$\lambda(t \mid w_{it}) = 1 - [1 - \lambda_O(t)]^{\exp(\beta w_{it})}$$

where all variables are the same as above. A clog-log transformation of (2) yields the equation

(3) $$\log(-\log(1-\lambda(t \mid w_{it}))) = \alpha_t + \beta w_{it}$$

where α_t is the clog-log transformation of the baseline hazard $\lambda_O(t)$. The logit and cloglog generally yield similar estimates in practice. Below I report results from both models to evaluate the robustness of the findings.

Following Brock and Durlauf's [2001] formulation of social interactions, I assume that βw_{it} takes the form

(4) $$\beta w_{it} = cx_{it} + dy_i + ez_i + Jm_{it-1} + Kq_{it-1} + u_i$$

where x_{it} is a vector of characteristics for city *i* in year t, including distance to London, the number of weekly coach and wagon services to London, and an indicator for whether the city had water transport to London. y_i is a set of dummy variables for each region or each type of economic specialty. z_i is a set of dummies for each route to London. m_{it-1} is the weighted fraction of cities within 50 miles that have turnpikes on intersecting road segments in year $t-1$, or the weighted fraction of cities with the same economic specialty that have turnpikes on intersecting road segments in year $t-1$. q_{it-1} is the fraction of mileage managed by turnpikes between London and the closest segment to city *i* in year $t-1$. Finally, u_i is a city random effect, normally distributed with mean 0 and variance σ_u^2.

J and *K* are the main parameters of interest. *J* measures the strength of neighbor effects in influencing turnpike adoption, while *K* measures the strength of network effects. *K* is hypothesized to be greater than zero, while *J* could be positive or negative depending on which neighbor effect is being tested.

There are three potential problems in identifying *J* and *K*. First, there could be unobservable factors that influence the adoption of turnpike trusts. The city random effect u_i partly mitigates this problem, but it requires that unobservable factors are not correlated with other variables, like m_{it-1} and q_{it-1}. Ideally I would include a city fixed effect, but this approach is infeasible in my case.

The dummy variables for region, economic specialties, and London routes are similar to a city fixed effect because they capture unobservable factors that are common to all cities in a region, specialty, or along a route. For instance, table I describes the major cities along 21 routes to London. When dummy variables are included for each of these routes, the estimate for *K* shows the effect of increasing turnpike mileage between London and city *i* after controlling for unobservable factors associated with location on a particular route. This approach exploits the fact that the fraction of mileage managed by turnpikes varies across cities along a route.

Second, there could be simultaneity between city *i's* decision to adopt a turnpike and its neighbors' decision to adopt a turnpike. To address this problem, I estimate the model with one-year lagged values for the neighbor and network variables (i.e. m_{it-1} and q_{it-1} rather than m_{it} and q_{it}). Lagged values mitigate the simultaneity problem because city *i's* decision to adopt a turnpike in year t should not influence its neighbors' decision to adopt in $t-1$. Including lagged values does come at cost however. If city *i* adopts in year *t* because it expects that its neighboring cities will adopt in year *t* then lagged values will not capture this interaction.

Third, there may be a reverse causation between wagon and coach services to London and turnpike adoption. Although this is a legitimate concern, the evidence suggests that turnpikes reduced transport costs several years after they were adopted [Gerhold, 1996, Bogart, 2005b]. Thus reverse causation is unlikely to be a problem when estimating the effect of wagon and coach services in year *t* on turnpike adoption in year *t*.

There are several ways to estimate the logit and cloglog hazard functions. The most common is to create a sequence of indicator variables for each time period up to and including the year a city adopts a turnpike.[7] The city indicator variables are then matched with m_{it-1}, q_{it-1}, x_{it}, z_i, y_i, as well as dummy variables for time periods. The hazard is then estimated using maximum likelihood procedures for logit or cloglog models on the city-year data set. I modify this method slightly by including city random effects in the estimation.

V. Results

The results are discussed in two sections. The first focuses on the adoption of turnpikes along London road segments that intersect with major cities. The second looks at turnpike adoption along any road segment that intersects with major cities. Figure III shows the two survival curves to illustrate the differences. They are similar in shape because 55 of the 66 cities had turnpikes first along their London road segments. The survival curves also show that all major cities had turnpikes by 1796, which means there is no censoring in the sample.

V.A. London Road Segments

I begin with a series of maps showing the adoption of turnpike trusts along the London road network in 1720, 1730, 1750, and 1770. The black lines in Figure IV represent road segments managed by turnpike trusts and the white lines are segments that were still under the control of parishes. Panel A shows that turnpikes managed little of the London road network in 1720. Most were in the hinterland of London, or near major 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 outward expansion to the west and northwest of London. Along some routes several turnpike trusts were established in a short time-span. For example, trusts were adopted on 74 percent 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 less of the mileage to cities like Plymouth, Tiverton, Southampton, Lincoln, Norwich, King's Lynn, Yarmouth and Carlisle. As in the 1720s, turnpikes were adopted quickly along some routes. For instance, they were adopted on 32 percent 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. Once again turnpikes often spread quickly. In the southwest, they were established on 112 miles of the London-Exeter-Plymouth road between 1753 and 1759.

The maps suggest that neighbor effects and network effects may have influenced the adoption of turnpikes along the London road network. To study these hypotheses more closely, I now turn to estimates of the hazard function. Table II shows estimates for the logit and cloglog models after including the lagged weighted-fraction of cities within 50 miles that have turnpikes with the lagged fraction of mileage managed by turnpikes between London and the closest segment. Also included are dummy variables for the North and Midlands (the South is omitted), dummies for each route to London (route 1 is omitted), and dummies for each decade (1695 to 1710 is omitted). I did not include dummies for every year because this would require the estimation of 100 additional parameters.

The results reveal a number of findings. First, none of the city characteristics has a significant effect on the hazard. Greater scheduled wagon and coach services and the availability of water transport to London raise the hazard, but neither is significant. Distance to London also has no effect, perhaps because it is included with the regional dummies. Ports and Resort cities have a higher hazard than market towns, while manufacturing cities have a lower hazard, but none of these variables is significant.

The finding that scheduled wagon and coach services had little effect is surprising because one would expect that more transport services to London would make it more likely that a city would have a turnpike along its London road. One explanation is that the coefficients are downwardly biased because of measurement error. Another possibility is that higher traffic did not lead to a greater hazard in the current period. Instead, cities may have adopted in the anticipation that traffic would increase in the future. For the most part these expectations were met, because wagon and coach services between London and major cities grew dramatically between 1750 and 1800.

The results in table II also show that the hazard is significantly higher for cities in the North and Midlands compared to the South. One explanation is that cities in the North and Midlands were industrializing more rapidly. The coefficients on the route dummies are not reported to save space. They were significant in a number of cases, which again suggests that location was an important factor in the diffusion of turnpikes.

The decade dummies are generally positive and significant. The hazard tends to be higher during years in the 1740s, 1750s, and 1760s compared to the early eighteenth century. This is consistent with the view that unobservable time effects played an important role.

In both specifications the hazard is unaffected by the lagged weighted-fraction of major cities within 50 miles that have turnpikes. Thus there is no evidence that a city was more likely to adopt a turnpike along its London road if more of its neighboring cities did the same. It is worth noting that the weighted fraction of major cities within 50 miles that have turnpikes in year t is positively and significantly related to the hazard in year t, but concerns about simultaneity make it difficult to interpret such a result.

The results show that the hazard is much larger if there was a higher lagged fraction of mileage managed by turnpikes between London and the closest segment to city *i*. Across both specifications the coefficient is larger in magnitude than the coefficients for any of the indicator variables, including the region and decade dummies. The odds ratio implies that a city was 58.9 times more likely to adopt when turnpikes managed all the mileage between London and the closest segment in the previous year or earlier.

Figure V uses the logit estimates from table II to compute the hazard function and survival probabilities under two hypothetical situations. In each case all variables are evaluated at their mean except for the network variable. If none of the mileage to London was ever managed by turnpikes, then the estimated hazard is generally below 0.05, and the survival probability remains above 50 percent until the 1790s. If all of the mileage to London is managed by turnpikes from the beginning, then the estimated hazard varies between 0.025 and 0.5, and the survival probability falls below 50 percent by 1710 and is close to zero by the 1750s.

These findings suggest that the benefits from adopting turnpikes along a London road segment were low unless other turnpikes managed most of the segments closer to London. There are a number of examples where turnpikes did indeed spread outwards from London. For instance, in 1741 a turnpike was established along the Doncaster to Boroughbridge segment of the Great North Road in Yorkshire. 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, and a fourth turnpike was established along the segment from Newcastle to Buckton. Finally, in 1753 a fifth turnpike was adopted on the last segment between Buckton and Berwick.

Another example is the Lincoln-London road. In 1730, all of the segments between London and the village of Yaxley were under the control of turnpikes, but none of the segments between Yaxley and Lincoln had turnpikes. In 1754, the situation changed when a six-mile stretch of road from Yaxely to Peterborough came under the control of a turnpike trust. Two years later, the final 52 miles of the Lincoln-London highway came under the control of turnpikes.

The examples and the econometric results suggest that the adoption of turnpikes along one road segment created a network externality for segments further up the route. They also suggest that turnpike adoption along outlying segments could be significantly delayed if segments closer to London did not have turnpikes. This may explain why adoption was slow on the outer segments of the London-Plymouth, London-Halifax, and London-Yarmouth routes.

V.B All Road Segments

In this section, I analyze turnpike adoption along any road that intersects with major cities. Cities traded with many locations that were not on their route to London, and therefore, it is important to test whether neighbor effects or network effects influenced turnpike adoption in a more general setting. As before, the main variables of interest are the lagged fraction of mileage managed by turnpikes between London and the closest road segment and the lagged weighted fraction of cities within 50 miles that have turnpikes along any intersecting road segment.

I also include the lagged weighted fraction of major cities with the same economic specialty that have turnpikes. Cities are separated into seven specialties: western port, southern port, eastern port, resort/cultural center, woolen cloth manufacturing, other manufacturing, and market town. I distinguish western ports because they were primarily involved in the American and West Indian trade, whereas southern and eastern ports had stronger trade links with Africa, Asia, and Europe. Woolen textiles are distinguished from other manufacturing because it was the largest industry in the early eighteenth century, and it was the primary specialty of many cities including Leeds and Norwich. Table III provides a list of all cities in each specialty.

Table IV reports results for the logit and cloglog discrete-time hazard functions after including all the network and neighbor variables with dummies for each decade, each economic specialty, each region, and each route to London. The period 1695 to 1710 is omitted as are market towns, route 1, and the southern region. The results show that some of the dummies for economic specialties have a significant effect on the hazard. Resorts and woolen cloth manufacturing centers have a higher hazard than market towns, perhaps because they were more reliant on road transport services. Other manufacturing towns, such as those involved in the metalworking industries, have a lower hazard. This finding could be due to greater reliance on water transport for low value or high bulk goods. Interestingly, western, southern, and eastern ports have a hazard that was similar to market towns.

The regional variables are again significant with northern and midland cities having a higher hazard than southern cities. The same holds for the time variables as all cities had a higher hazard in the 1740s, 1750s, 1760s, and afterwards. The results also show that London variables, like the number of wagon and coach services, distance, and water transport to London continue to have no significant effect on the hazard.

As before the estimates show that the lagged fraction of mileage managed by turnpikes between London and the closest segment has a large and positive effect on the hazard. The odds ratio is 104.8 when other turnpikes managed their entire route to London in the previous year or earlier. The results also show that cities were more likely to adopt when more of their neighboring cities had turnpikes. The odds ratio is 4.33 when all cities within 50 miles have turnpikes in the previous year or earlier. Surprisingly, the estimates show that cities were *less* likely to adopt when more cities with the same economic specialty had turnpikes. Here the odds ratio implies that a city would be 16 times less likely to adopt if all cities with the same specialty had turnpikes in the previous year or earlier.

Figure VI shows the estimated hazard function and survival probabilities for the logit model in four hypothetical cases.[8] The first case assumes that no cities within 50 miles have turnpikes, no cities with the same specialty have turnpikes, and none of the mileage to London is managed by turnpikes. The resulting hazard is less than 0.1 and the survival probability falls below 50 percent around 1760. The second case assumes that all mileage between London and the closest segment is managed by turnpikes immediately, but no cities within 50 miles ever have turnpikes and no cities with the same specialty ever have turnpikes. The hazard is between 0.05 and 0.9 and the survival probability falls below 50 percent starting in the early 1700s. The third case assumes that only cities within 50 miles have turnpikes right away. Here the hazard is between 0 and 0.4 and the survival probability falls below 50 percent around 1750. The fourth case assumes that only cities with the same economic specialty have turnpikes. Now the hazard stays close to zero and the survival probability remains above 80 percent. Overall, it appears that both network effects and neighbor effects had a large impact on turnpike adoption.

The results suggest that more turnpikes near neighbor cities encouraged adoption, unless the neighboring city shared the same economic specialty, in which case it discouraged turnpike adoption. Neighboring adoption could be encouraging if they led to the type of network effects that were found along the London routes. For example, in 1769 Yarmouth adopted its first turnpike along the road to its neighboring city of Norwich. In that same year, a turnpike was established along the road between Norwich and Bury St. Edmond. In this particular case, the value of improving the road between Yarmouth and Norwich likely increased once the connecting road between Norwich and Bury St. Edmond was improved.

Network effects also appear to have influenced turnpike adoption near several cities in Yorkshire. In 1741, three turnpikes were established linking Doncaster with Wakefield, Boroughbridge, and Saltersbrook. Doncaster was the local hub of the transport network, and therefore turnpikes between Doncaster and any of these cities would have become more valuable if all connecting segments had turnpikes.

Neighboring adoption could also encourage a city to adopt because it helped local groups learn about the benefits of turnpikes. Learning was necessary if promoters were uncertain whether the tolls would provide enough revenues to finance road improvements. Similarly, investors may have been uncertain about the risks associated with turnpike bonds. It is difficult to identify cases where learning occurred, although there are examples where it could have played a role. Wolverhampton and Dudley, for instance, both adopted turnpikes one year after they were established near neighboring cities like Coventry, Worcester, and Warwick. None of their roads directly linked with Coventry, Worcester, and Warwick and each of these cities had a different specialty. Instead Wolverhampton and Dudley may have been more likely to adopt because they learned about the benefits of turnpikes through their neighbors.

Why were cities less likely to adopt turnpikes when other cities with the same economic specialty had turnpikes? As discussed earlier it could be that local turnpikes increased competition once roads were also improved in other cities with similar products or services. If so, then cities with less productive firms may want to delay their adoption of turnpikes. This argument may have some applicability to the woolen textile industry. Many of the woolen textiles cities in the east and south, such as Norwich, Tiverton, and Taunton were slow in adopting turnpikes, whereas woolen cities in the north adopted more quickly. The eastern and southern woolen textile cities had higher labor costs, and thus delaying the adoption of turnpikes may have been beneficial because poor roads provided protection from northern producers.

VI. Conclusion

In 1700 nearly all roads in England were free. By the 1830s England had the largest toll road network in history with nearly 1000 turnpike trusts managing 20,000 miles. Over this same period, turnpikes improved the quality of the road network and contributed to lower transport costs and greater trade. Why did it take so long for turnpikes to diffuse?

A survival analysis of turnpike adoption along London roads shows that the hazard rate increased when turnpikes managed a greater fraction of the mileage between London and a major city. The results also show that having more wagon and coach services to London did not significantly increase the hazard. These results cast doubt on the argument that higher traffic was the primary factor influencing the timing of turnpike adoption. Instead they suggest that network effects were the most important factor.

Network effects imply that local groups had less incentive to adopt turnpikes on their roads if turnpikes were absent on connecting roads. Network effects contributed to a diffusion pattern in which turnpikes were absent along a route until a few locations adopted. Afterwards, more locations followed and within a short time-period turnpikes were adopted along an entire route.

The results also show that neighbor effects influenced the diffusion of turnpikes. A survival analysis of turnpike adoption along any road segment shows that the hazard increased when more cities within 50 miles adopted turnpikes, while the hazard decreased when more cities with the same economic specialty adopted. These findings suggest that neighboring adoption had different effects. Neighboring adoption could encourage a city to adopt if it led to improvements along connecting roads or provided a local demonstration of the benefits. However, neighboring adoption could also discourage a city to adopt if it led to increased competition from outside firms.

The findings add to the recent literature which shows that England experienced a dramatic increase in legislation affecting the provision of local transport infrastructure and public services. Most of these acts had a diffusion pattern similar to turnpikes, in which they were passed in neighboring cities within a short time-span. The results suggest that network effects and neighbor effects may have influenced acts for constructing canals, bridges, ports, water distribution systems, railways, and a host of other local improvements which were crucial for the Industrial Revolution.

The findings also suggest that neighbor effects help to explain the persistence of inefficient institutions. The take-away point is that beneficial institutions may not emerge because of coordination problems arising from interdependences in decision making. Recall that the first turnpike was created in 1663, but it was not until the 1770s that they were widespread. As a consequence many roads were unimproved until after the mid-eighteenth century.

References

Albert, William, *The Turnpike Road System in England 1663-1840* (Cambridge, England: Cambridge University Press, 1972).

Allen, Robert, "Economic Structure and Agricultural Productivity in Europe, 1300-1800," *European Review of Economic History,* IV (2000), 1-27.

Bogart, Dan, "Did Turnpike Trusts Increase Transportation Investment in Eighteenth century England?" *Journal of Economic History*, LXV (2005a), 439-468.

Bogart, Dan, "Turnpike Trusts and the Transport Revolution in Eighteenth Century England," *Explorations in Economic History*, XLII (2005b), 479-508.

Bogart, Dan, "Turnpike Trusts and Property Income: New Evidence on the Effects of Transport Improvements and Legislation in Eighteenth Century England," mimeo, 2006.

Bogart, Dan and Gary Richardson, "Law and Economic Development in England: New Evidence from Acts of Parliament, 1600-1815, mimeo, 2006.

Bowen , Emanuel, *Britannia Depicta* (Newcastle, England: Frank Graham, 1971).

Brock, William A. and Steven N. Durlauf, "Economics of Interaction-Based Models," in Heckman, James and Ed Leamer eds., *Handbook of Econometric*s Vol. 5, (Amersterdam, NL: North Holland, 2001).

Carruthers, Bruce, Timothy Guinnane, and Yoonseok Lee, "The Passage of Uniform Small Loan Law," mimeo, 2005.

Chartres, John and Gerard Turnbull, "Road Transport," in *Transport in the Industrial Revolution*, Aldcroft, Derek and Michael Freeman eds., (Manchester, England: Manchester University Press, 1983).

Clark, Gregory, "The Condition of the Working Class in England." *Journal of Political Economy*

CXIII (2005), 1307-1340.

Corfield, Penelope, *The Impact of English Towns, 1700-1800* (Oxford, England: Oxford University. Press, 1982).

Crafts, N. F. R. and C.K. Harley, "Output Growth and the British Industrial Revolution," *Economic History Review*, XLV new series (1992), 703-730.

Durlauf, Steven, "Neighborhood Effects," in *Handbook of Regional and Urban Economics 4*, Henderson, J. V. and J. F. Thisse eds., (New York, NY: Elsevier, 2004).

Fishback, Price and Shawn E. Kantor, "The Adoption of Workers' Compensation in the United States, 1900-1930," *Journal of Law and Economics*, XLI (1998), 305-341.

Gerhold, Dorian, "The Growth of the London Carrying Trade, 1681-1838," *Economic History Review* XLI new series (1988), 392-410.

Gerhold, Dorian, "Productivity Change in Road Transport before and after Turnpiking, 1690 1840," *Economic History Review* XLIX (1996), 491-515.

Geroski, P.A., "Models of Technology Diffusion," *Research Policy* XXIX (2000), 603-625.

Great Britain. House of Commons, "Report of the Commissioners for Inquiry into the State of Roads in England and Wales," *Parliamentary Papers*, XXVII (1840).

Hoppit, Julian, "Patterns of Parliamentary Legislation, 1660-1800," Historical Journal XXXIX (1996), 109-131.

Jackman, W. T., *The Development of Transportation in Modern England* (Cambridge, England: Cambridge University Press, 1916).

Langford, Paul, *Public Life and the Propertied Englishman: 1689-1798* (Oxford, England: Oxford University Press, 1991).

Lambert, Tim. "Local and National Histories: Histories of British and Irish Towns."

www.localhistories.org/, 2006

Manski, Charles, "Identification of Endogenous Social Effects: The Reflection Problem, *The Review of Economic Studies* LX (1993), 531-542.

Mitchell. Brian, *Second Abstract of British Historical Statistics* (Cambridge, England: Cambridge University Press, 1971).

North, Douglass, *Institutions, Institutional Change, and Economic Performance* (Cambridge, England: Cambridge University Press, 1990.

Pawson, Eric, *Transport and Economy: The Turnpike Roads of Eighteenth Century Britain* (New York, NY: Academic Press, 1977).

Smythe, Donald, "Transaction Costs, Contagion Effects, and the Diffusion of the Uniform Sales Act, 1906-1947," mimeo, 2005.

Stevens, Michael, "Waterways of England Wales: Their History in Maps", www.mike-stevens.co.uk/maps, 2005.

[1] This passage was taken from Journals of the House of Commons, March 29, 1717.

[2] For the literature on turnpikes and transport costs see Jackman [1916], Albert [1972], Pawson [1977], Chartres and Turnbull [1983], Gerhold [1988, 1996], and Bogart [2005b].

[3] See Geroski [2000] for an overview of research on the S-curve and diffusion.

[4] The London directories include the Traveller's and Chapman's Daily Instructor [1705], The Merchants and Traders Necessary Companion [1715], Chapmans's and Traveller's Best Companion [1726], New and Complete Guide to all Persons who have any Trade or Concern with London [1740, 1749, 1760, 1770], and The Shopkeepers and Tradesman's Assistant [1779, 1790, 1800].

[5] There is a large literature on macroeconomic indicators in eighteenth century Britain. See Crafts and Harley [1992] for more details.

[6] See Singer and Willett [2003] for an overview of discrete time hazard models.

[7] Specifically, if a city i adopts a turnpike trust in year one then the indicator equals 1, and the city is dropped from the sample for all years $t=2,\ldots,T$. If city i does not adopt a turnpike in year one, then the variable is 0 and the city is kept in the sample. If city i adopts in year two, then the variable is 1 in year two and it is dropped from the sample. A similar algorithm is applied to all years $t=3,\ldots T$ or until all cities have adopted.

[8] As before all variables are evaluated at their mean except for the neighbor and network variables.

Table I: Major Cities on the 21 routes to London

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	Yarmouth	Ipswich	Colchester			
9	Norwich	Bury				
10	King's Lynn	Ely	Cambridge			
11	Berwick	Newcastle	South Shields	Sunderland	Durham	
12	Bradford	Leeds				
13	Whitby	Scarborough	York			
14	Manchester	Derby	Northampton	Leicester		
15	Hereford	Gloucester	Circenster			
16	Beverley	Hull	Lincoln	Boston		
17	Whitehaven	Liverpool	Macclesfield	Lancaster	Carlisle	Kendal
18	Shrewsbury	Birmingham	Wolverhampton	Coventry	Dudley	
19	Worcester	Oxford				
20	Kidderminster	Warwick	Banbury			
21	Chester	Lichfield	Coventry			

Sources: The network was constructed using data from Albert [1972], Pawson [1977], Bowen [1970], and the Great Britain, House of Commons [1840].

Table II: Turnpike Adoption along any London Road Segment that intersects with a Major City

Variable	Logit Coeff	Cloglog Coeff
Lagged Weighted Fraction of Cities	0.015	0.002
within 50 miles that have turnpikes	(0.556)	(0.533)
Lagged Fraction of Mileage with Turnpikes	4.04	3.898
between London and Closest Segment to City i	(1.145)*	(1.089)*
Number of Weekly Wagon Services to London	0.162	0.154
	(0.106)	(0.102)
Number of Weekly Coach Services to London	0.024	0.021
	(0.065)	(0.063)
Dummy for Water Transport to London	0.257	0.214
	(0.539)	(0.525)
Distance to London (in miles)	0	0
	(0.007)	(0.007)
Dummy for Port	0.498	0.483
	(0.56)	(0.541)
Dummy for Resort or Cultural Center	1.23	1.193
	(0.786)	(0.769)
Dummy for Manufacturing Center	-0.822	-0.876
	(0.637)	(0.623)
Dummy for North	2.057	2.077
	(1.154)*	(1.127)*
Dummy for Midlands	1.917	1.932
	(0.813)*	(0.784)*
Dummy for 1711 to 1720	-1.017	-0.959
	(0.913)	(0.891)
Dummy for 1721 to 1730	1.155	1.156
	(0.744)	(0.726)
Dummy for 1731 to 1740	-0.77	-0.685
	(1.125)	(1.092)
Dummy for 1741 to 1750	1.519	1.58
	(0.972)	(0.943)*
Dummy for 1751 to 1760	2.796	2.826
	(1.08)*	(1.05)*
Dummy for 1761 to 1770	2.289	2.354
	(1.284)*	(1.241)*
Dummy for 1771 to 1780	2.133	2.227
	(1.49)*	(1.442)*
Dummy for 1781 to 1796	2.869	2.942
	(1.505)*	(1.453)*
constant	-10.102	-10.062
	(1.881)*	(1.84)*
City Random Effects	Y	Y
Route Dummies	Y	Y
N	3289	3289
Log Likelihood	-240.2339	-239.9102

Note: Standard errors in parentheses. * Indicates statistical Signficance at the 90% level and above.

Table III: Economic Specialties of Cities

Market	Woolen Cloth Manufacture	Other Manufacture	Resort or Cultural	Western Port	Southern Port	Eastern Port
carlisle	halifax	macclesfield	cambridge	whitehaven	southampton	ipswich
winchester	frome	sheffield	ely	lancaster	chichester	yarmouth
bury	taunton	nottingham	durham	chester	plymouth	boston
shrewsbury	kendal	birmingham	bath	liverpool	portsmouth	scarborough
bedford	bradford	derby	lichfield	bristol	exeter	whitby
reading	tiverton	northampton	warwick			sunderland
cirencester	colchester	south shields	cantebury			rochester
gloucester	worcester	wolverhampton	oxford			king's lynn
hereford	leeds	dudley				hull
lincoln	norwich	manchester				newcastle
berwick		leicester				york
banbury		coventry				
kidderminster						
beverley						
salisbury						
carlisle						

Sources: Corfield [1983], Lambert [2006], and author’s interpretation.

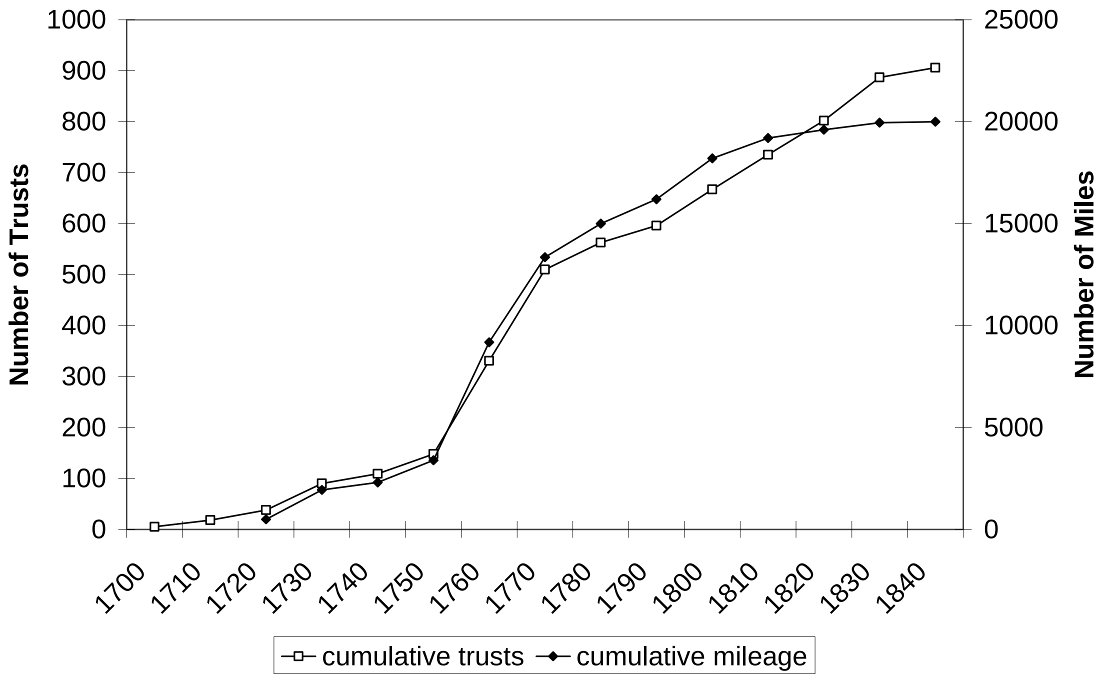
Table IV: Turnpike Adoption any Road Segment that Intersects with the Major City

Variable	Logit Coeff	Cloglog Coeff
Lagged Weighted Fraction of Cities	1.472	1.32
within 50 miles that have turnpikes	(0.613)*	(0.566)*
Lagged Fraction of Mileage with Turnpikes	4.653	4.401
between London and Closest Segment to City i	(1.27)*	(1.191)*
Lagged Weighted Fraction of Cities with	-2.693	-2.409
the same specialization that have turnpikes	(1.051)*	(0.996)*
Number of Weekly Wagon Services to London	0.076	0.068
	(0.143)	(0.136)
Number of Weekly Coach Services to London	-0.113	-0.114
	(0.088)	(0.084)
Dummy for Water Transport to London	0.917	0.888
	(0.605)	(0.584)
Distance to London (in miles)	-0.017	-0.016
	(0.008)	(0.008)
Dummy for Resort or Cultural Center	2.705	2.571
	(0.873)*	(0.836)*
Dummy for Woolen Cloth Manufacturing	1.551	1.225
	(0.928)*	(0.838)
Dummy for Other Manufacturing	-2.147	-2.07
	(0.785)*	(0.73)*
Dummy for Western Port	0.523	0.504
	(0.94)	(0.909)
Dummy for Southern Port	1.234	1.139
	(1.189)	(1.127)
Dummy for Eastern Port	0.195	0.212
	(0.853)	(0.822)
Dummy for North	4.151	4.016
	(1.204)*	(1.152)*
Dummy for Midlands	1.563	1.481
	(0.78)*	(0.739)*
Dummy for 1711 to 1720	-0.282	-0.242
	(0.81)	(0.795)
Dummy for 1721 to 1730	1.535	1.529
	(0.699)	(0.684)*
Dummy for 1731 to 1740	0.826	0.813
	(0.972)	(0.945)
Dummy for 1741 to 1750	2.815	2.753
	(0.961)*	(0.933)*
Dummy for 1751 to 1760	4.795	4.582
	(1.136)*	(1.093)*
Dummy for 1761 to 1770	5.314	5.094
	(1.357)*	(1.288)*
Dummy for 1771 to 1796	4.303	4.125
	(1.812)*	(1.744)*
Constant	-7.325	-7.246

	(1.666)*	(1.541)*
City Random Effects	Y	Y
Route Dummies	Y	Y
N	3047	3047
Log Likelihood	-223.885	-223.7475

Note: Standard errors in parentheses. * Indicates statistical significance at 90% level and above

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

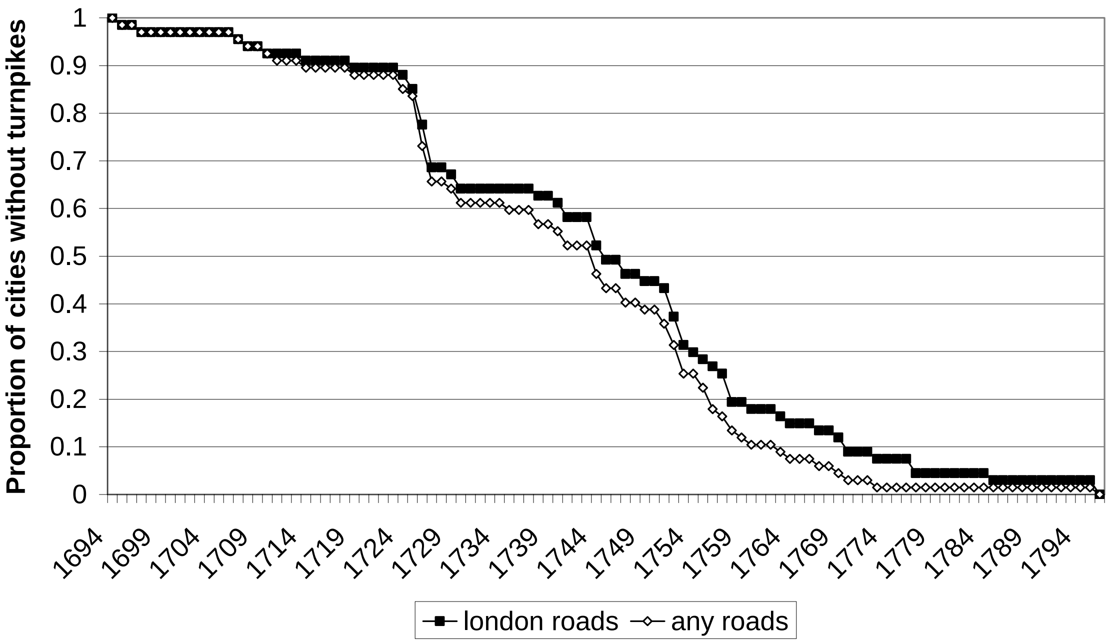


Sources: Data on acts and mileage comes from Albert [1972] and Pawson [1977].

Figure II: The London Road Network c1700.

Notes and sources: see text.

Figure III: Survival Curve for City Turnpike Adoption along London road segments and any road segments



Notes and sources: see text.

Figure IV: Maps of the London Turnpike Network:

Panel A 1720

Notes and Sources: see text

Panel B 1730

Notes and Sources: see text

Panel C 1750

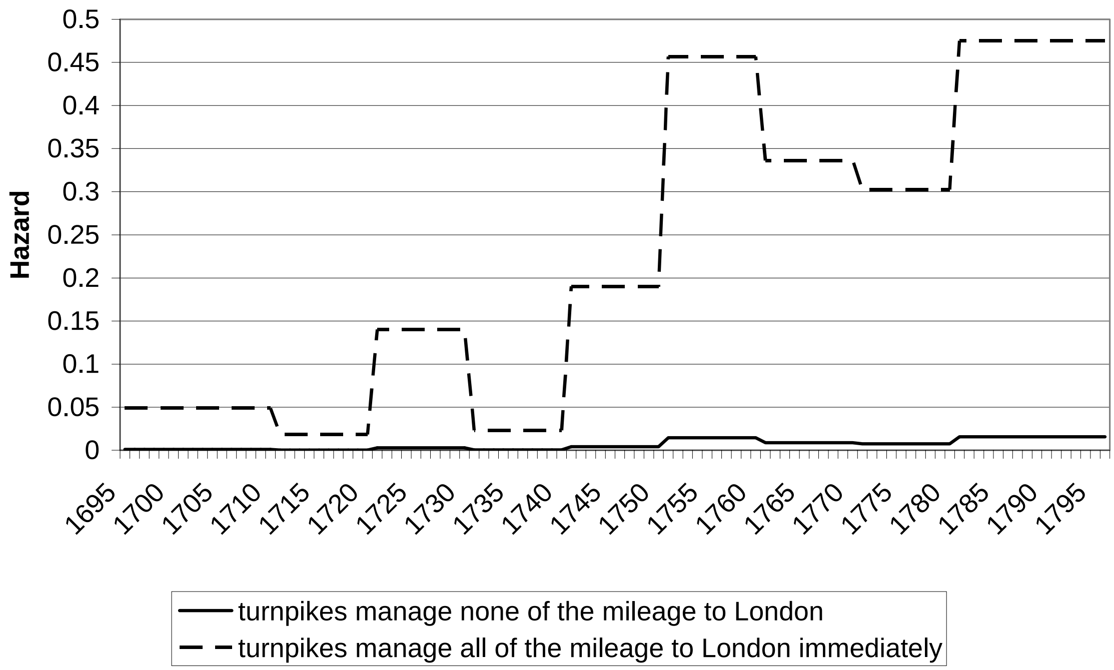
Notes and Sources: see text

Panel D 1770

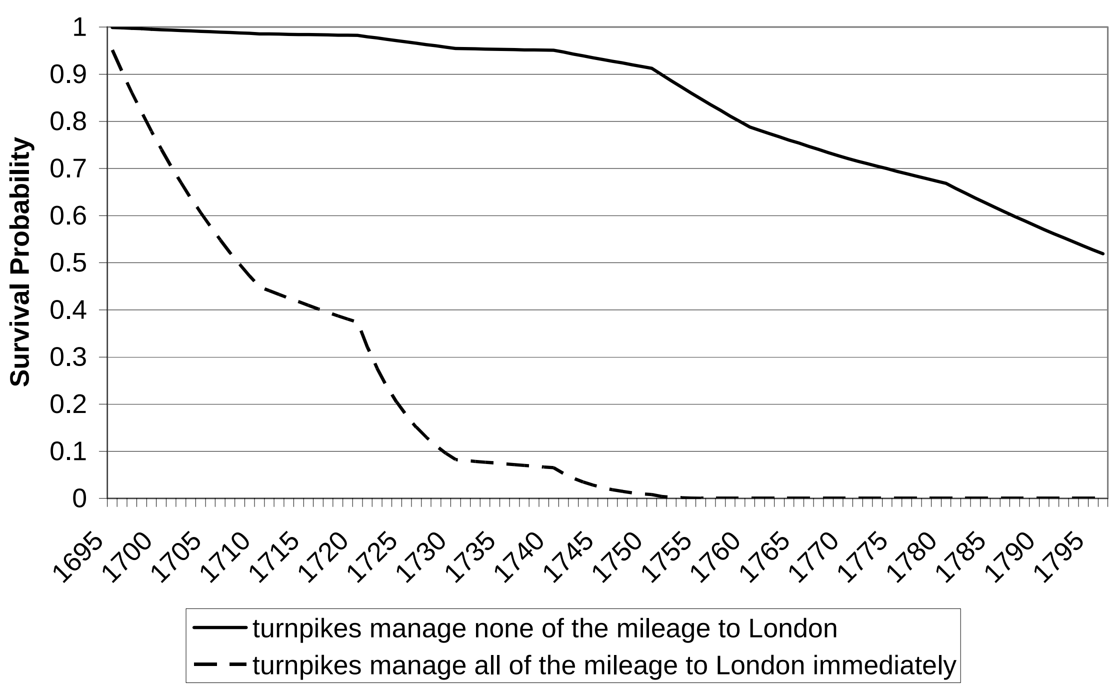
Notes and Sources: see text

Figure V: Estimated Hazard Function for Turnpike Adoption along any London Road Segment that intersects with a Major City

Panel A: Estimated Hazard Function



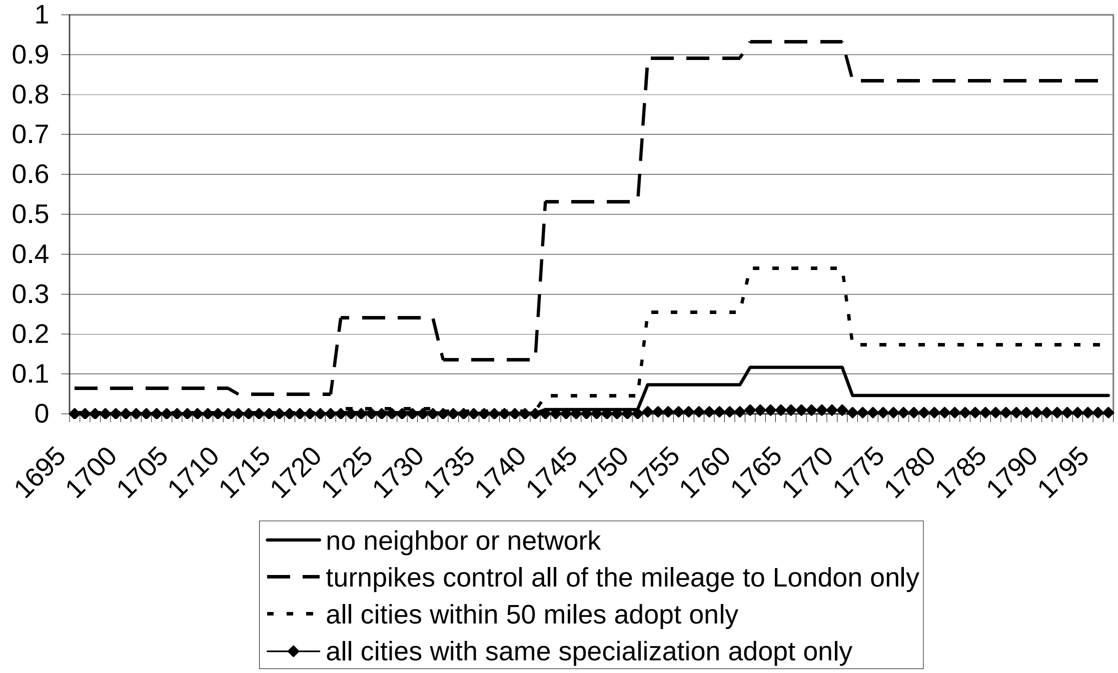
Panel B: Estimated Survival Probability



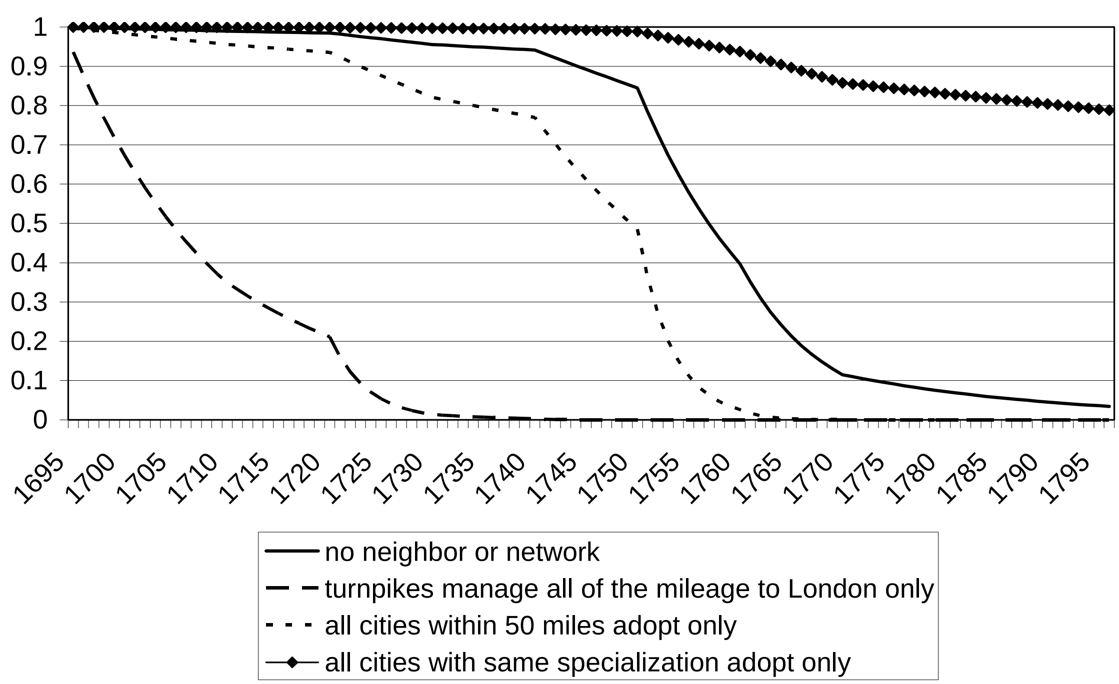
Notes and Sources: see text.

Figure VI: Estimated Hazard Function for Turnpike Adoption along any Road Segment that intersects with a Major City

Panel A: Estimated Hazard Rate



Panel B: Estimated Survival Probability



Notes and Sources: see text.