

Canals and creative destruction in England's transport sector

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Abstract

Canals played a key role in the industrial revolution by expanding inland waterway transport. One open question concerns the effects of introducing inland waterway services on road freight services. We hypothesize canal barge services were a poor substitute for road services due to their slow speed, and that 'fly boats,' a faster service than barges, were a better substitute. We test these hypotheses using London trade directories, which detail road and waterway services between London and most towns and cities from 1779 to 1827. Our panel regressions show that introducing fly boat services reduced the number of road freight services for a London city pair. By contrast, barges had no effect on road freight services. An extension considers the effects of fly boats on hub-and-spoke road services and yields similar conclusions. The results provide new insights on creative destruction, new goods, and evaluations of transport improvements.

Key words: Canals, new goods, creative destruction, industrial revolution
JEL codes: N7, R4, L9

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1: Introduction

Several theories of growth and innovation emphasize the process of creative destruction. In these models, new innovations lead to cheaper or better goods and make older goods less valuable. The older goods get displaced and the products available in the market change.⁴ While sound in theory, it is not clear that major innovations lead to significant displacement in practice. Historically, some technologies continue to survive for long periods despite innovations that could have destroyed them.

In this paper, we study whether canals led to the displacement of road freight services in England's transport sector. Canals are the most famous infrastructure investment in England before railways. Canal mileage grew substantially from 1760 to 1830. Network expansion was followed by the introduction of inland barge services. Barges were important because they delivered freight services at much lower cost than wagons. But, barges were not the only service offered on canals. Express services called fly boats also became available. They operated at night and sometimes 'jumped the queue' in canal locks, which slowed regular barge services.

The effect of introducing barges and fly boats on existing road services depends on whether waterway and road transport were substitutes in cost and speed. One possibility is that road users especially valued low cost, and therefore barges should displace road freight services because they were a much cheaper alternative. Another view emphasizes the greater speed and reliability of road transport and sees barges and wagons as poor substitutes. Here the expectation is that introducing barges did not displace road freight services. Finally, it is possible that fly boats were a better substitute because they offered greater speed and lower cost than wagons.

⁴ Aghion and Howitt (1992) and Grossman and Helpman (1993) are the classic works.

The effects of barges and fly boats on road freight services are identified using new data from five London trade directories between 1779 and 1827. Directories list road freight services from London to numerous towns and cities. They are recorded by day of week and by inn of departure.⁵ The directories also identify whether waterway services are available between London and all towns. The waterway services include coastal vessels, barges, and fly boats.

We study the evolution of road freight services and the introduction of waterway services at a London-town pair level. Each town-pair is interpreted as a market, where we observe a proxy for quantity supplied and demanded, which is the number of listed road freight services. Our main analysis focuses on the 53 largest cities and towns. They include industrial centers like Manchester, Leeds, and Bristol, along with market towns like Cirencester, Colchester, and Lincoln. In all cases, cities and towns are at least 50 miles from London.

Our empirical framework is the standard ‘difference in differences’ model. In the baseline specification, the number of weekly road freight services for a London-town pair is regressed on indicator variables for the availability of vessel, barge, and fly boat services between the same London-town pair. The model includes city fixed-effects and time-dummies for each directory year. We also examine leads and lags to test whether road services changed before the introduction of waterways. Concerns about measurement error are addressed using additional data and samples.

The first major finding is that numbers of weekly road freight services for a London-town pair were not significantly reduced by the introduction of canal barge services in that London-town pair. However, the introduction of fly boat services significantly reduced the number of

⁵ London directories have been used by several scholars. Some examples include Chartres (1977), Gerhold (1986), (2014), and Bogart (2005b). Their advantages and disadvantages will be discussed below.

weekly road freight services in a London-town pair. The fly boat ‘displacement effect’ is sizeable and robust to alternative model specifications.

We argue that inland waterway services did not displace road freight services until they evolved and became a more effective substitute for road freight services. Canals were originally built to transport coal, grain, iron, and timber. Shipments of such commodities are very sensitive to transport costs, and trade in these goods was essentially absent by road away from rivers and the coast. Our evidence suggests that canal transport by barge largely created the market for inland transport of bulk, low value commodities. Fly boats, on the other hand, served a different customer. They transported lighter weight and higher value goods, which were hampered by the slow speed of regular barges. Fly-boats provided cheaper express services than road carriers, and therefore once fly boat services were introduced, road carriers were under-cut on price and quality.

As an extension, we also consider how road services between London and smaller towns near major cities were affected by barges and fly boats. Smaller towns could have services that connected through their closet major city, as in a hub-and-spoke network, or they could have direct services with London. When a barge or fly boat originating in London arrived in the nearest hub then the number of connecting road services in smaller towns could have declined because the hub-and-spoke system was disrupted.

Our estimates show that introducing London barges in the nearest hub had no effect on small town road services with London. However, introducing fly boats in the nearest hub reduced small town road freight services with London. All reductions occur in connecting road services through the hub. Direct services between London and the small town did not change

significantly. In short, fly boats were introduced to serve trade between larger urban centers, but they also affected smaller towns, which relied on hub-and-spoke networks.

Our analysis extends the historical transportation literature in new directions. There is a growing literature on pre-railway transport improvements, like roads, canals, and sail ships. Much of the focus is on productivity and quality improvements.⁶ We focus on a topic that is rarely studied, the extent of substitution between new and existing transport modes. The question of when and how canal services displaced road freight services is debated in the literature but there is no consensus.⁷ This paper is the first to employ econometric methods to address this issue. In doing so, it provides new evidence that fly boats—not barges—displaced road services.

Our results also have implications for the welfare impact of new goods during the industrial revolution. There is a view that growth accounting approaches have understated the increase in living standards during the industrial revolution.⁸ One key issue is whether the technologies of the industrial revolution produced new goods, that is products or services with few existing substitutes. There are studies on how the steam engine substituted for water power and on how high-pressure engines substituted for low-pressure engines.⁹ The literature is perhaps most developed in the case of transport through the analysis of social savings.¹⁰ In the case of canals, one would compare the observed freight rate and quantity shipped by barge with a counterfactual freight rate and quantity shipped by wagons. This approach works fine if the barge was a substitute for the wagon. But, as our estimates imply, the bulk, low value goods that went by barge between interior areas and London were not transported by road previously. The social savings method would not account for the creation of a market and thus it would understate the

⁶ See Gerhold (1996, 2016), Bogart (2005b), Solar and Hens (2015), Ronnback (2012).

⁷ See Turnbull (1980), Freeman (1980a, b), Bagwell and Lyth (2002), and Maw (2013).

⁸ See Berg (1992), Crafts (2004), and Mokyr (2009) for debates on the industrial revolution and growth accounting.

⁹ See Nuvolari and Verspagen (2009) and Wrigley (2010).

¹⁰ Leunig (2006) and Herranz Loncan (2006) are good recent examples of a social savings estimation in transport.

benefits of canals. The case of canals could be indicative of other new goods which came about during the industrial revolution.

This paper will be organized as follows: Section 2 provides background. Section 3 presents the data. Section 4 presents the empirical framework. Sections 5 and 6 discuss the results. Section 7 concludes.

2: Background

We begin by reviewing markets for freight transportation c.1760. The largest freight markets in terms of tonnage were in coastal transportation. The biggest of all was the northeastern coal trade between Newcastle and London (Armstrong 2009). River trade in corn, iron, and other agricultural product was also large, particularly along the great tidal rivers like the Thames, the Severn, and the Trent (Willan 1964). Another important market consisted of long distance transportation by land (Pawson 1977, Gerhold 1988). London was the focus of this market up to the late 18th century. Goods would be shipped from London to large cities, like Birmingham, Leeds, and Manchester. Often, goods would be forwarded from hubs to smaller towns along roads which we could interpret as ‘spokes.’ In this way, London trade reached an astonishingly large number of towns in the 18th century. Most London road trade was in high value, light weight goods because they could bear the high transport cost.

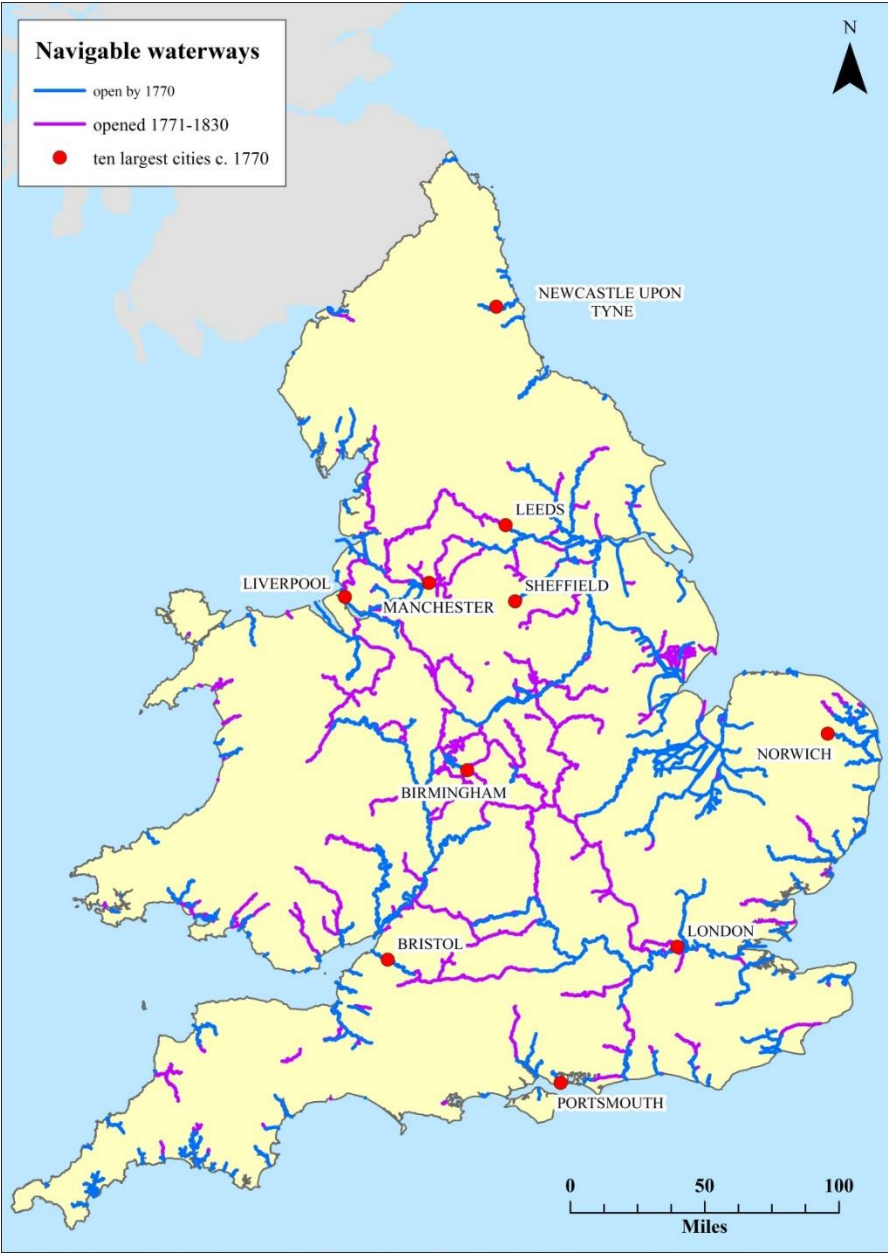
The introduction of canals marked an important shift in the British transport sector. Canals belong to the system of inland waterways which includes tidal rivers and river navigations (Satchell 2017). Canals were different because they include long stretches of artificial waterway, where river navigations involved ‘cuts’, which bypassed difficult sections of waterway. The canal age arguably began with the completion of the Bridgewater canal in 1761.

It linked Manchester with the town of Worsley. While many canals, including the Bridgewater, were constructed without the goal of a national network, canals did eventually span and connect England and Wales. The waterway network in 1770 and its expansion from 1770 to 1830 are shown in figure 1. The first north-south route, which connected the west Midlands with London was opened in 1790. The route started at the Thames to the west of London and extended northward through Birmingham towards Manchester. While this famous set of canals provided cross-country connections, the route was tortuously long. Getting to London required a journey of 177 miles including passage through 150 locks.

There was a flurry of canal building in the 1790s and early 1800s. Of most importance to this paper was the completion of the Grand Junction Canal in 1805. Its more direct connection with London shortened the distance from northwestern cities to the capital by 60 miles.

In England, most canals were proposed and financed by individuals, often in part for the benefit of their own business. The Duke of Bridgewater famously commissioned his canal for the purpose of transporting coal from his mines, while Josiah Wedgwood, a major promoter of the Trent-Mersey canal, was interested in dependable transportation for the inputs to his pottery business. Generally, the target market for canals was the shipment of bulky, low value goods.

Figure 1: The inland watery network and the expansion of canals from 1771 to 1830



Source: Satchell (2017).

Barges were the main type of watercraft on early canals. Barges were an adaptation of vessels, the traditional sailing-craft used to travel by coast and river. Canal barges often did not have sails. They were pulled by horses and even humans in some cases.

In the early 19th century there was an important service innovation on canals known as the fly boat. Fly boats were similar crafts to barges pulled by horses, but they were smaller and lighter. Faster speeds were obtained, in part, by switching out crews and teams of horses along the way, so that the journey could be made more or less ‘non-stop’. Fly boats were also granted right-of-way on the canals and had precedence at locks (Ville 2004, Hadfield 1981). The target market for fly boats was merchandise and light goods.

We should emphasize that none of the watercrafts studied in this paper were steam-powered. The first steamship services in London carried passengers to Margate in the mid-1820s. Steam power was not ubiquitous in water-transport until the mid-nineteenth century (Ville 2004).

2.1: Characteristics of Road and Water Transportation

This section discusses the characteristics of road and inland water freight services and, in the process, establishes the relative advantages of each mode. This discussion is organized around regulation, market structure, cost, speed, and reliability of different modes of transportation. We end with predictions for the empirical analysis.

2.2.1 Regulation and Market Structure

Road and waterway networks both required Acts of Parliament for expansion of their infrastructure. Canal Acts authorized the formation of a joint stock company and issuance of share capital. Turnpike Road Acts authorized the formation of a trust and the issuance of improvement bonds backed by tolls. In addition, Parliament regulated access to infrastructure. Parliament typically required separation of canal-ownership and operation of shipping services, though there were exceptions to this rule. It was also allowed for firms producing goods to ship on canals, but the largest shippers were specialists in providing transport services.

Road management and carrier services were also strictly separate. Many road carriers were small firms providing services between two or three destinations. Only a few firms operated large networks. Pickford is one of the most famous examples because it combined road and water transport. Pickford operated on the route between Manchester and London. By 1779, the first year of our analysis, they owned about 8 wagons and 72 horses; by 1803, they owned 50 wagons, 400 horses, and 28 barges; and by 1838 they owned 116 specialized canal-craft, like fly boats (Ville 2004, Turnbull 1980). Pickford was important to the innovations we study because they were among the early providers of fly boat services.

2.2.2 Cost

The cost of shipping goods is the criterion by which canals clearly dominated roads. Freeman (1980) argues the cost of canal conveyance by water was between 1/4 and 1/2 the cost of carriage by road. Similarly, Moyes (1978) reports that canals at least halved the cost of freight movement compared with road transport, and at most cut it by three quarters. The source of canals' efficiency is simple: it takes much less power. A horse can haul roughly 20 times the weight when pulling a barge versus pulling a cart (Bagwell & Lyth 2003, Table 1).

2.2.3 Speed

Most road-based modes of transportation held an advantage in speed. Canal travel was significantly slowed by the need to pass through locks. Thirty minutes were sometimes required to move a single boat through a lock. Actual delays could be even greater when there was congestion or multiple locks. Another factor was the tortuously winding routes of many rivers and canals. Elevation changes slowed wagons too, but there was no need to wait in locks. Also road routes were more direct.

2.2.4 Reliability

While both modes were subject to delays caused by extremes of weather, canals were affected even more so than roads. In the summer, drought was an issue. For instance, moving through a lock requires water from the higher plane be used to fill the lock in which the boat was sitting, so that the boat rises with the water level. Each such passage through a lock required upwards of 10,000 gallons of water. The loss of that much water is substantial and the possibility of water-shortage is not surprising. Methods for mitigating water shortages were derived, including the construction of reservoirs, the use of pumps to replenish water to the higher planes, and the design of more efficient locks. However, water-saving methods were insufficient to overcome severe drought (Freeman 1980).

Conversely, during winter, ice could make canals inoperable. Locks had many moving parts which easily became frozen, resulting in delays while the ice was removed or, in many cases, resulting in extended closure of the lock. Freeman (1980) shows that canals could be closed for weeks due to weather.

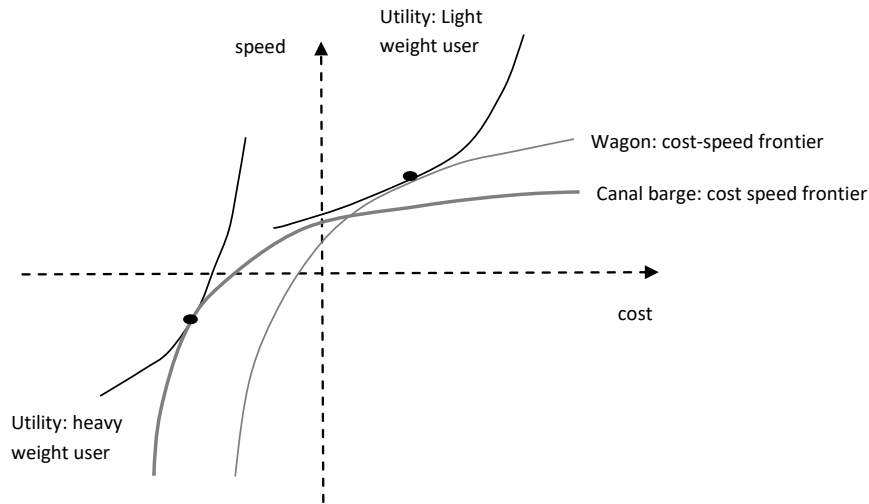
What can we say about the reliability of the road network? Turnpike road maintenance was generally good, especially along routes to London. The seasonality of road transport, a traditional problem, subsided by the late 18th century. The usual explanation is the incentives provided by the ability to toll arguably led to better roads. Also, turnpike trustees typically had a personal interest in the roads they oversaw (e.g, they were local landowners, merchants, and coal-masters).¹¹ The quality of roads improved further in the 1820s towards the end of our sample period (1779-1827). Turnpike trusts dramatically increased their borrowing and many roads were widened, resurfaced, or newly made.

2.2.5 Predictions

¹¹ See Albert (1972), Pawson (1977), and Bogart (2005a, 2005b) for details on turnpike trusts and road quality.

After considering costs, speed, and reliability, it is not obvious that the introduction of inland waterway services displaced road freight services. It is important to consider the users of transport services and how the characteristics of barge and road services would appeal to different types. Think of users as having a utility for transport speed and reliability and a disutility for transport cost. A 'light-weight' user has a stronger preference for higher speed and reliability and less of a preference for lower cost. A 'heavy-weight' user has a stronger preference for lower cost and less of a preference for higher speed and reliability. If road and barge technologies were sufficiently different in speed, reliability and cost, then it is possible that the introduction of barges would not affect road services. Consider figure 2 which plots indifference curves for heavy and light users in speed and cost space. The wagon's cost-speed frontier delivers greater speed and is chosen by the light weight user. The barge's cost-speed frontier delivers lower cost and is chosen by the heavy user. In this scenario, the barges and road services operate in different market segments.

Figure 2: The co-existence of barge and road services

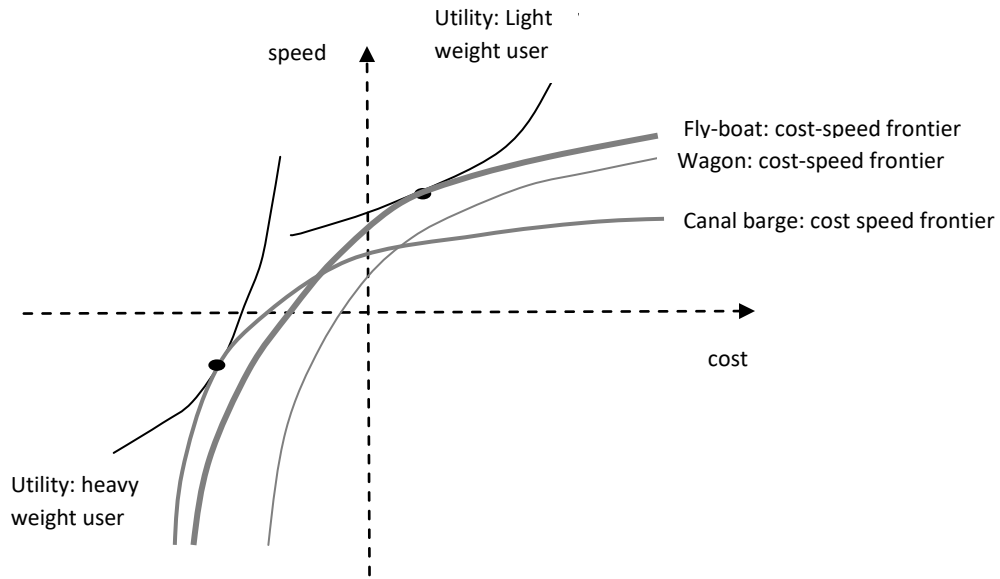


In terms of timing, we can think of the wagon as the only technology available in interior areas before canals. Light users went by road and heavy users probably did not ship any goods in the interior areas away from rivers. However, once canals were built and barge services were offered, then we would expect heavy users to enter the market. Light users would not change unless there was some positive spillover from the expansion of heavy users.

Our predictions are different if barges or fly boats were more like road services in their characteristics. For example, suppose fly boats went faster than wagons and they were also cheaper. If so, then fly boats should poach some of the light weight users that previously went by road. This scenario is depicted in figure 3. The fly-boat's cost-speed frontier delivers higher speed and at a lower cost than a wagon. The light-user achieves a higher utility by shifting to fly boats, whereas previously they would obtain their highest utility using wagons. The main

prediction of this model is that the introduction of fly boats will displace road services. If barges were also like fly boats, then they could also displace road services.

Figure 3: The displacement of road services by fly boats



3: Data

The primary data sources for this paper are a series of directories titled *The Shopkeeper's and Tradesman's Assistant* and its later title, *Kent's Original Tradesman's Assistant*. We have five such directories for the years 1779, 1790, 1800, 1816, and 1827.¹² In this section, we discuss the directories in detail and explain how their information is used in this paper.

3.1 Listed services

Directories provide several pieces of information about every professional road transportation service from London to thousands of cities and towns. They include the vehicle

¹² These directories all published by the same firm. They are available online through Gale, Eighteenth century collections online monographs and The Making of the Modern World. Details are given in the references. Also, note the five years for which we have directories span the majority of the canal age (roughly dated 1761-1834).

type, departure times, and pick-up locations of each service. Figure 4 is a directory entry for Bristol in the year 1800. The first lines read: “Post C. golden cross, charing-cross, daily, M. 4, A. 6;” This meant there was a ‘post-coach’ which departed at 4 in the morning and one which departed at 6 in the afternoon from the inns, Golden Cross and Charing-Cross. There is some ambiguity on whether daily included Sunday services. We conservatively assume daily meant 6 services a week. In the example above, this line implies 12 post-coach services per week (i.e. two per day for 6 days) from London to Bristol.

Figure 4: Directory Entry for Bristol, 1800

Bristol [Somerset. 115] Post C. golden cross, charing-cross, daily, M. 4, A. 6; swan with two necks, lad-lane, daily, A. 4; faracen's head, snow-hill, daily, M. 4, A. 3; bolt in tun, fleet-street, daily, M. $\frac{3}{4}$ past 3, A. 5; angel, behind St. clement's, daily, M. 4; bell savage, ludgate-hill, and black bear, piccadilly, daily, A. 5; old and new white horse cellars, ditto, daily, M. 4, A. 6, white bear, ditto, daily, M. 4, A. 3; faracen's head, friday-street, daily, A. 5; george and blue bear, holborn, daily, A. $\frac{3}{4}$ past 2; gloucester coffee-house, piccadilly, daily, A. $\frac{1}{2}$ past 4; Flying Wa. white bear, bassinghall-street, *w. s.* A. 4; white swan, holborn-bridge, *w. s.* A. 6; Wa. ditto, *t. w. s.* king's arms, ditto, *ib.* M. 3; white bear, piccadilly, daily, *sun.* excepted, N. 12; blossom's inn, lawrence-lane, and gerrard's hall, basing-lane, daily, A. 3; castle and falcon, aldergate, *f.* M. 10; Barges, kennet's wharf, thames-street; Vef. clouder's and symond's wharfs, southwark; brook's wharf, queenhithe; hambro' wharf, upper thames-st.

Source: The shopkeeper's and tradesman's assistant, 1800.

About halfway through the Bristol entry one sees “Flying Wa. White Bear, Bassinghall street, w, s, A. 4”. This meant there was a fly wagon (or express) service which departed at 4 in the afternoon, but only on Wednesday and Saturday. So this line implies 2 weekly freight services. The final type of road service in this entry was a wagon (signified by Wa. in Figure 4).

In total, the entry tells us that in 1800 there were 90 weekly ‘Post-Coach’ services, 4 weekly ‘Flying-Wagon’ services, and 18 weekly ‘Wagon’ services between London and Bristol.

In general, our directories list over two dozen types of road freight services. The main categories include wagon, cart, fly wagon, van, fly van, fly caravan, and post wagon. Carts usually have two wheels and wagons have four wheels. Vans or caravans are larger than wagons and can combine some freight with passenger services. In our baseline analysis we do not distinguish between different types of road vehicles. The outcome variable is the total number of weekly road freight services between a town and London. In the Bristol example above, we count 22 weekly road freight services (4 fly wagon and 18 regularly wagon).¹³

The directories also identify the availability of waterway services. Towards the bottom of the Bristol entry shown in Figure 4, one can see there was one wharf in London from which a barge departed for Bristol and three wharfs from which a vessel departed. Generally, the directories contain listings for three categories of water-based service: vessel, barge, and fly boat. There are a few categories of watercraft in which fly boats are paired with wagons or vans.¹⁴ The ‘hybrid’ categories with the greatest number of observations are: fly boat & wagon and fly boat, van, & wagon. We exclude hybrid services from the count of road freight services but they are included in whether a city had a fly boat service.¹⁵

¹³ In a robustness check, we study only wagon services and drop fly wagons. The results are similar.

¹⁴ In hybrid listings, we will sometimes see the name ‘boat’ instead of ‘fly-boat’, as in the category ‘Fly-Van, Boat & Wagon’. ‘Boat’ and ‘Fly-Boat’ are interpreted to refer to the same type of craft; with ‘fly’ referring, as it does elsewhere, to an expedited service. However, it seems that this expedited service is the norm. The simple term ‘boat’ is rarely used in the directory; this term is only employed in those hybrid listings that include a non-expedited, road-based service. In all other cases, the directory employs the term ‘fly-boat’. In light of this fact, we use the term ‘fly-boat’ rather than ‘boat’ to refer to this particular type of watercraft and, furthermore, we do not distinguish between the two services.

¹⁵ Two issues remain. (i) There is exactly one occurrence of something called a “packet boat” in one year: 1779. This is simply a small boat used for regularly-scheduled mail, passenger, and cargo services. We have tried various ways of categorizing this service (e.g. as a fly-boat or as a barge or as a separate service), and it doesn’t significantly affect the results. For this paper, we simply ignore the one “packet boat” observation. (ii) There are some water-based services (We have identified two: Steamboat and Yacht) which appear in the directories but not for any of the 66 major cities we sample; thus, we do not analyze these services.

London directories contain listings for hundreds of towns and cities. The 1816 directory has over 1000 listings for example. We do not study the entire population and instead focus on services between London and the major commercial and industrial cities and between London and important market towns. Many of these large cities and towns also acted as hubs, which allows us to study services to smaller towns linked through the hub-and-spoke network. The sample cities and towns are discussed in the next sub-section.

3.2 Sample cities and towns

The list of cities and towns is selected based on several criteria. First, we use population. Corfield (1983) identifies 66 English cities and towns with a population greater than 2500 in 1750. The 2500 population threshold sorts important market towns from less important ones. We further restrict our sample based on information in the directories which identify a correlation with other cities' services. Sometimes, the entry for city B will consist of a single line "see city A." In other cases, the directory entry for city B may list some services but then say "see city A for others." We chose to drop 13 of the 66 major towns and cities that contain at least one entry stating see another city for services. It appears they became subsidiary to another large city, which is perhaps endogenous to barges and canals. We address this issue directly for our sample of subsidiary cities to be discussed momentarily.

The 53 major cities and towns are shown as larger pink and open circles in figure 5. Our sample cities and towns come from a wide geographic area. A full listing of the major cities is given in appendix table 1 along with the number of road services in 1827.

Figure 5: Major cities and subsidiary cities in our sample



Source: created by authors using sources stated in text.

There is one more restriction that we make as a robustness check for our sample of major cities. Bates (1969) directory of stage coach services identifies the major routes to London in 1836. Some routes connect several major cities. For example, Bath and Bristol lie on the same route. We identify 25 major cities at the end points of each Bates' route and analyze them as a

sub-sample. They are revealing because they cannot be an intermediate to another major city ‘upstream’ on a Bates route.

In an extended analysis we examine road transport services to what we call subsidiary towns, near the 53 major cities and towns. They are likely to be reliant on the hub-and-spoke network, and therefore of special interest. The ideal subsidiary has enough economic activity to justify road services to London and is the same or a farther distance from London than its nearby hub. We use a list of market towns as our candidate subsidiaries. There are 39 towns identified as meeting the criteria for a subsidiary to each major city. They are shown in figure 1 in smaller purple circles. While some decisions had to be made, the approach was to avoid matching errors if no market town was an obvious subsidiary. Yarmouth, for example, is on the coast and there is no nearby market town to make a match.

The method for counting freight services is different for subsidiary cities. We measure direct and connecting services, meaning they operated through the nearest hub, which we assume is the major city or market town. The distinction is based on matching subsidiary and major city services on departure inn, departure day, and departure time in London. An example is provided in figure 6 for the subsidiary city, Sleaford, and its nearby major city, Boston. All six of Sleaford’s wagon services are listed under Boston as well and we assume they connect through Boston.

Figure 6: Directory entries for Sleaford and Boston in 1800

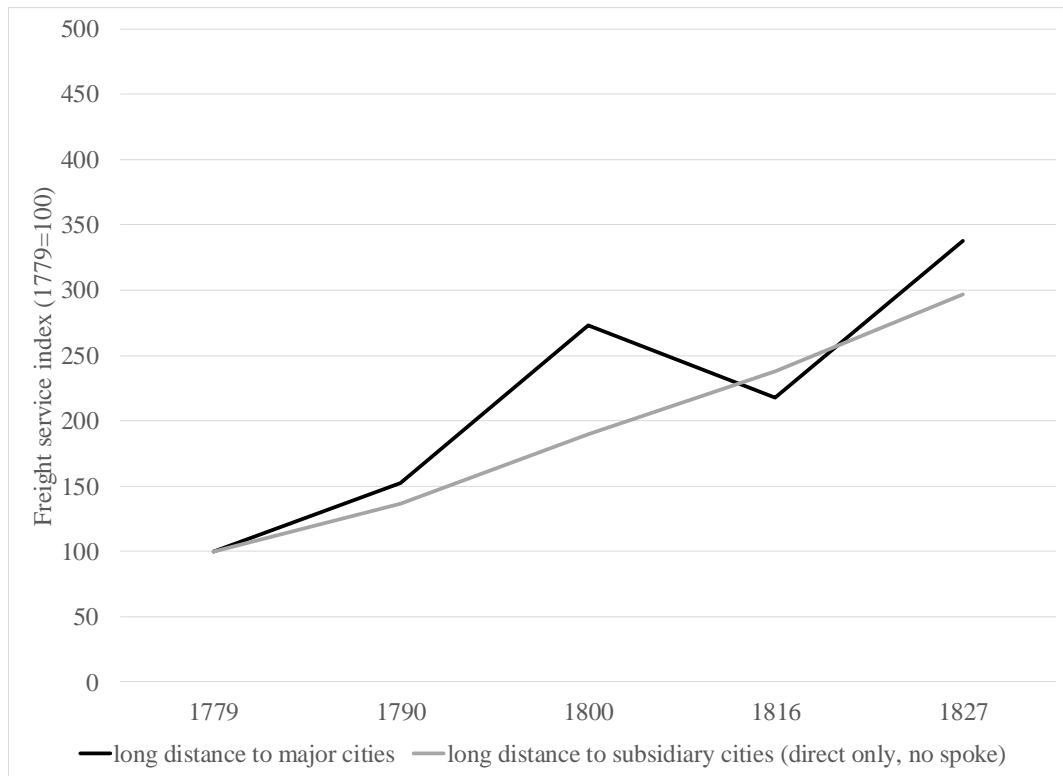
Sleaford [Lincoln. 117] C. spread eagle, gracechurch-street, and golden cross, charing-cross, daily, *s. excepted*, A. 4; Wa. blossom’s inn, lawrence-lane, *t. f.* A. 2; horseshoe, goswell-street, *w. f.* M. 9; Post Wa. bull and mouth, near aldergate, daily, A. 4

.Boston [Lincoln. 114] C. faracen's head, fnow-hill, *m. w. f.*
 A. 4; Wa. horseshoe, goswell-street, *w. f.* M. 10; bluf-
 som's inn, lawrence-lane, *t. f.* A. 2; vine, bishopsgate
 within, *w. f.* N. 12; Post Wa bull and mouth, near al-
 dergate, daily, A. 4; Vef. gun and shot and stanton's
 wharfs, fouthwark

Source: The shopkeeper's and tradesman's assistant, 1800.

Figure 7 plots indices for total numbers of weekly road freight services between London and major cities and direct services between London and subsidiary towns. There was an overall growth in services for both, mainly reflecting the economic expansion at this time.¹⁶ But growth was uneven for London to major cities. In 1816, road freight services fell between major cities and London. Direct services to subsidiaries did not change.

Figure 7: Trends in road freight and passenger services from London

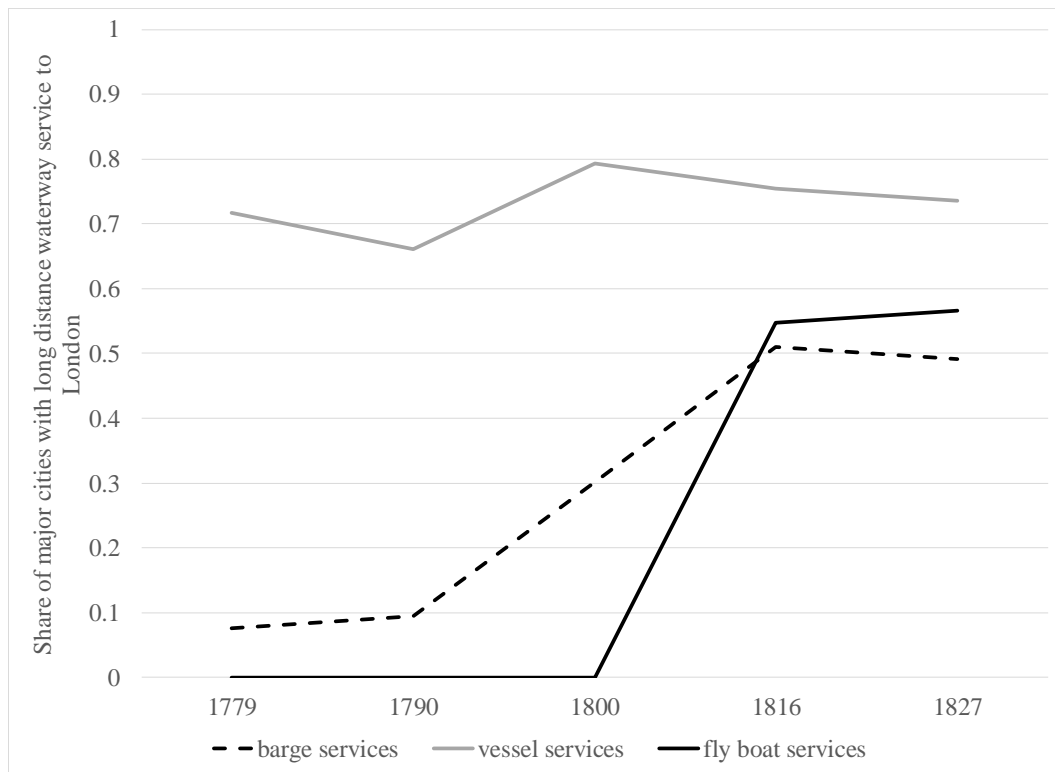


¹⁶ Services to major cities grew at an annual average rate of 2.57% between 1779 and 1827. Broadberry et. al. (2015) report that industrial production grew at 2.39% over the same period.

Source: see text.

Figure 8 shows the diffusion of different types of watercraft between London and major cities. The vertical axis is the proportion of 53 major cities for which the directories list the availability of each type of waterway service. Vessels were common throughout and show no time trend. Canal barges become more common from 1790 to 1816. Fly boat services are absent until 1816, but diffuse rapidly after. As a preview of our results, notice road services between London and major cities decline in 1816 when fly boats widely diffuse in the London market.

Figure 8: Share of major cities with different types of waterway services to London



Source: see text.

4. Empirical framework

The effect of introducing inland waterway services on road freight services is identified using a generalized difference in differences model. The specification is the following:

$$r_{it} = \alpha_i + \delta_t + \beta \cdot w_{it} + e_{it} \quad (1)$$

where i and t are city and time indices, respectively, r is the number of weekly road freight services, α is a city-fixed effect, δ is the coefficient on a time dummy for the date of directory publication, and w is an indicator for water-based services. City-level fixed effects control for unobserved city-specific factors influencing road-service levels. Time dummies for each of the directory years control for unobserved time effects. Summary statistics for the different samples are shown in appendix tables 3 and 4.

The number of weekly road freight services, r , is a count variable with some zeros. Thus, a Poisson or negative binomial model is appropriate in estimating (1). We ran several Poisson models and there is evidence for over-dispersion in all. This suggests the negative binomial model is more suitable. However, standard statistical packages, like Stata, cannot calculate clustered standard errors for the negative binomial model. We report bootstrap standard errors. In our models, the bootstrap standard errors are generally larger than conventional standard errors so we are more conservative in reporting statistical significance.

Our main variables of interest concern water transport services w_{it} . Most models include indicators for having vessel services, another for having barge services, and another for having fly boat services. We will mainly focus on the indicator variables for barges and fly boats, while controlling for changes in vessel services.¹⁷

¹⁷ We argue that an indicator variable for water transport services is desirable even if there was richer water-service data. We are not actually interested in the correlation between levels of road-services and canal-services; rather, we are interested in understanding how the introduction of canals impacted the quantity of road services in a market.

It is easier to interpret the coefficients in the negative binomial model in terms of incident rate ratios (IRRs). An IRR below 1, say 0.8, indicates that if a city gets waterway services its number of road services would decrease by 20% relative to the case where it had no waterway service. The relative change is partly identified by the change in road services for cities that did not get waterway services.

There are several identification issues that deserve discussion. The first issue relates to measurement error in the quality of waterway services. For example, some waterway services required travel by road to use them. We create an indicator variable if the city center was more than 2 km from the inland waterway. We then interact the distance indicator with barge and fly boat to test whether such distance matters.¹⁸ A different quality dimension relates to distance. Some inland waterway services to London had a circuitous route and would take more time. Here we create a variable for waterway distance to London and test whether a barge or fly boat service with distance above the median has a different effect.

Second, our model does not have a variable for the freight rate of road transport in a London-city pair. Freight rates will certainly differ across city pairs, but much of this variation is related to distance and geography which are captured by the city fixed effects. There is variation in road freight rates across time, but much of this will be common across city pairs and is captured by the time fixed effects. Finally, there could be some city-pair and time-specific variation in road freight rates, but we think most of this was due to differential canal competition which is our focus. In the mid-18th century, there was variation in freight rates across city pairs due to differential road improvement, but this was largely before our period.¹⁹

¹⁸ GIS data on waterway and road networks provide information to construct the distance by road between each major city and the nearest waterway with a connection to London. See Satchell (2017) for a full description of the inland waterways GIS.

¹⁹ See Bogart (2005b) for an analysis of road freight rates in the 18th century.

There are other potential concerns relating to omitted variable bias. For example, growing levels of economic activity in a city likely meant a higher probability of canals being built and shipping firms offering inland waterway services between London and that city. Growing economic activity in a city could also increase the demand for road services between the city and London, and thus would be correlated with the error term e_{it} . There is also a possibility the introduction of a fly boat was endogenous to the composition of a city's trade with London. If a city started to ship more light weight and high value goods over time, then fly-boats might be more likely to enter to serve this market. This shift in demand composition would also affect road services and hence be correlated with the error term e_{it} .

Unobserved increases in demand and composition are not necessarily a problem in our case because they bias against finding a displacement effect. If canal services were introduced in cities with a growing economy, we would expect a positive correlation between canals and road freight services all else equal. Likewise, if fly boats were introduced in cities with a growing preference for lighter and high value goods we would also expect a positive correlation between fly boats and road freight services all else equal because roads traditionally served the lighter user. Therefore, if we find that introducing canal services was associated with lower road freight services then this would represent stronger evidence that canals displaced road services.²⁰

Omitted variable bias concerns are further addressed by testing for a changing trend in road services before canal services. Specifically, we run regressions similar to (1) except for the addition of variables for leads and lags of when services were introduced. This regression is:

$$r_{it} = \alpha_i + \delta_t + \sum_{j=-1}^1 \beta_j \cdot w_{it+j} + e_{it} \quad (2)$$

²⁰ We also worry that in some locations canals may have been a prerequisite to the provision of cheap road materials (Moyes), in which case canal infrastructure contributed to a lower cost of road carriage, thereby positively biasing the regression coefficient on the indicators for canal services. We think this again works against our hypothesis.

where w_{it-1} is an indicator for the city getting a waterway service one period earlier and w_{it+1} is an indicator for a city getting a waterway service in the upcoming period. The latter variable is most important because it identifies whether the parallel trends assumption is violated. If we find a coefficient on w_{it+1} significantly different from zero, then the difference in difference model likely suffers from an endogeneity problem. In particular, if road services increased significantly before the introduction of barges or fly-boats that would suggest a shift in level and composition of demand, which could mean a bias.

5: Estimation Results for services between London and major cities

Table 1 presents the results of the baseline model for road freight services between London and major cities. In columns (1) and (2) we see that the coefficient for barges or vessels is less than one, but it is not precisely estimated. This implies that the incident rate ratio (IRR) for barges and vessels is not statistically different from one. However, the IRR for fly boats is 0.51 and is more precisely estimated (see column 2). The IRR estimate implies that when a fly boat was introduced the number of weekly road freight services declined by 43 to 48%. The same result is found using the sample of major cities that lie at the end of a Bates route and have no correlation in services across cities (see column 3). Broadly, these regressions suggest that canal services displaced some road freight services between London and major cities, but the effect is dependent on the type of service available.

Table 1: Inland waterways and road freight services: London to major cities

VARIABLES	All Major cities (1) IRR (std. error)	All Major cities (2) IRR (std. error)	Major cities at end of Bates route (3) IRR (std. error)
Vessel indicator	0.932 (0.173)	0.875 (0.127)	0.811 (0.299)
Barge indicator	0.832 (0.114)	0.844 (0.137)	0.942 (0.195)
Fly boat indicator		0.515 (0.075)***	0.574 (0.110)***
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	265	265	125
Prob > chi2	0.000	0.000	0.000
Number of cities	53	53	25

Notes: The dependent variable is the number of weekly freight services between a major city and London. IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1.

Table 2 reports estimates of the IRR for leads and lags in the introduction of barges and fly boats. The IRR one period before fly boats were introduced is greater than one but it is not precisely estimated. This indicates there is *no significant* pre-trend, and therefore that road freight services were not changing before fly boats were introduced.²¹ Importantly, we also find the fly boat IRRs are significantly less than one in the period when fly-boats were introduced and in the period that followed. This supports the key findings in table 1 that fly boat services displaced road freight services between London and major cities.

Our earlier conclusions concerning barges and road freight services are also unchanged by the lead and lag analysis. In table 2, the IRR for barges is not significantly different from one

²¹ In unreported regressions we find that the share of fly wagon services in all road services significantly rise before fly boats. Therefore, we think there is compositional shift in demand. But it is not affecting regularly wagon services.

in the lead and lag variables. Thus there is no evidence for this slower service having a displacement effect on road services between London and major cities.

Table 2: Pre and post effects of inland waterways on road freight services: London to major cities

VARIABLES	IRR (std. error)
One period before barge starts	1.076 (0.132)
Period barge starts	1.007 (0.191)
At least one period after barge starts	0.901 (0.160)
One period before fly boat starts	1.179 (0.348)
Period fly boat starts	0.652 (0.093)***
One period after fly boat starts	0.414 (0.073)***
Vessel indicator	Yes
City FE	Yes
Year FE	Yes
Observations	265
Prob > chi2	0.000
Number of cities	53

Notes: The dependent variable is the number of weekly freight services between a major city and London. IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1

In table 3, we address service quality differences by incorporating modified fly boat variables accounting for distance between the city and inland waterways and distance to London. The dependent variable remains the number of weekly road freight services. The estimated IRRs for fly boats remain below one and are significant in all cases. The effect of fly boats was stronger when the road distance between a city and its nearest waterway was less than 2km. This result makes sense because having to travel by road to use fly boats would have make them a

worse substitute for wagons. Being above or below median distance to London has little impact on fly boat IRR as seen in column (2).

Table 3: Effects of waterway services on road freight services between London and major cities depending on distance to waterway or to London

VARIABLES	(1) IRR (std. error)	(2) IRR (std. error)
Fly boat if road distance to waterway is less than 2km	0.455 (0.076)***	
Fly boat if road distance to waterway is greater is greater than 2km	0.682 (0.129)***	
Fly boat if waterway distance to London below median		0.538 (0.107)***
Fly boat if waterway distance to London greater median		0.491 (0.081)***
Barge and vessel indicators	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
Observations	265	265
Prob > chi2	0.000	0.000
Number of cities	53	53

Notes: The dependent variable is weekly freight services. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1.

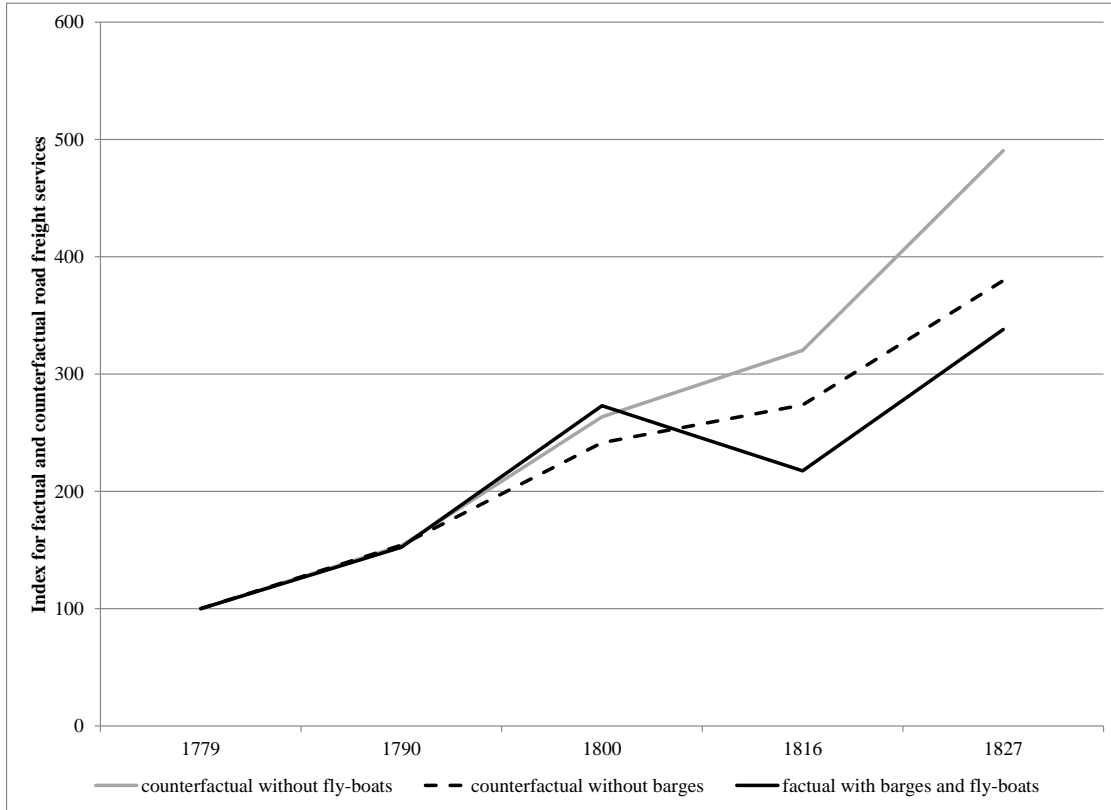
The effect of fly boats on passenger services provides a placebo analysis. There is little evidence in the literature that passenger services by coach were affected by the introduction of barges or fly boats. Therefore, we should not expect passenger services between London and a major city to be displaced by barges and fly boats. Counts of road passenger services are described in the appendix and the results of a similar model are also reported there. In brief, there is no evidence that the introduction of fly boats and barges affected passenger services between London and major cities. This finding further supports our conclusions.

The effects of barges and fly-boats are also illustrated using a counterfactual. Assume there were no barges or no fly-boat services between major cities and London. In this case, we

use our model to predict the number of weekly road freight services over time. The aggregate counterfactual estimate of London road services (the sum of services across all major cities and towns) is shown in figure 9. The factual index of road freight services between London and major cities increases from an index value of 100 in 1779 to 337 by 1827. This is equivalent to a 227% increase in services. In the counterfactual without barges the index rises to 380 by 1827. Barges do have an effect on the overall trends but it was not large. By contrast, in the counterfactual without fly boats the road service index rises to 490 by 1827. In other words, there would have been 153 percentage points (490-337) more growth in road freight services without fly boats.

The preceding conclusion suggests one should be careful in interpreting the effect of fly-boats on transport markets. In their absence, there would have been a greater use of road freight services. Users would not have realized the cost savings from fly boats but the market for lighter weight and high value goods would not have disappeared.

Figure 9: Actual and counterfactual road freight services without barges and fly-boats

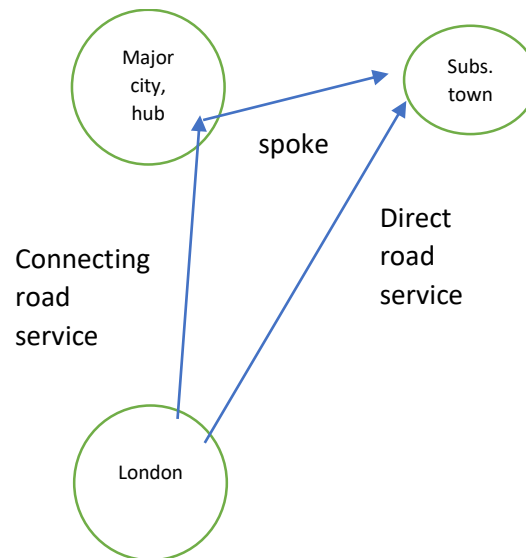


Source: see text.

6: Displacement of services between London and subsidiary towns

In this section, we study whether a subsidiary town's road freight services were affected by fly boats. Subsidiary towns were near major cities. Many had road services which connected through the hub and spoke system. Figure 10 illustrates connecting services to the subsidiary through its nearby major city or hub. In this scenario, wagons would travel from London to the major city, unload and then travel to the subsidiary town along the spoke. There were also some direct road freight services to subsidiary towns. They did not use the hub and spoke system.

Figure 10: Illustration of road services to subsidiary towns direct and through connections



How might fly boat services affect road services to subsidiaries? If the fly boat service was introduced between London and the subsidiary town, then we should expect its road freight services to decline. The rationale is the same for why fly boats affected services between London and major cities. The outcomes could be similar if fly boat services were introduced to the major city but not the subsidiary town. One hypothesis is that the connecting service to the subsidiary was displaced. This could occur if the road carrier's main business was with the major city and once demand to the major city was reduced by the fly boat, then the connecting service to the subsidiary was no longer viable. Another hypothesis is that the subsidiary town's direct service to London increased when fly boats were introduced between the major city and London. The argument is that direct services were a substitute for the lost connecting services.

We test these hypotheses using the same difference and difference framework. The outcomes of interest are the number of direct or connecting road freight services between

London and a subsidiary town. Recall that connecting are identified as services to the major city and the subsidiary city that departed from the same inn, day, *and* hour in London.²² The inland waterway services are the main explanatory variable. They are the waterway services to the major city near the subsidiary town.

The results are reported in table 4. Connecting road services to the subsidiary decline significantly when fly-boat services were introduced in the major city (see column 1). The IRR is 0.10 implying a 90% decline relative to the case when there were no fly-boat services to the nearest major city. By contrast, direct services to the subsidiary do not decline significantly when fly boat services were introduced in the nearest major city (see column 2).

Table 4: Inland waterways and road freight transport services: London to subsidiary towns

VARIABLES	(1) Connecting services to subsidiary towns IRR (std. error)	(2) Direct services to subsidiary towns IRR (std. error)	(3) Connecting services to subsidiary towns IRR (std. error)	(4) Direct services to subsidiary towns IRR (std. error)
Barge indicator (to nearest major city)	1.127 (0.483)	0.980 (0.374)		
Fly boat indicator (to nearest major city)	0.102 (0.069)***	0.728 (0.297)		
Barge indicator (connect to subsidiary through major city)			1.048 (0.465)	1.502 (0.392)
Fly-boat indicator (connect to subsidiary through major city)			0.056 (0.032)***	0.536 (0.138)**
Barge indicator (major city only, no connect to subsidiary)			1.302 (0.460)	0.777 (0.192)
Fly boat indicator (major city only, no connect to subsidiary)			0.299 (0.180)**	1.634 (0.561)
Vessel indicators	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	166	195	166	195

²² Some connecting observations had to be dropped because the directory records “see city A.” In this case it is not clear if all major city’s services offered a connection to the subsidiary. But it is clear, that no direct service is offered to the subsidiary.

Prob > chi2	0.000	0.000	0.000	0.000
Number of cities	38	39	38	39

Notes: IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1.

We also examine a model distinguishing fly boat services that connected to the subsidiary through the major city and those that only went to the major city and did not connect to the subsidiary. Connecting inland waterway services are identified as waterway services to the major city and the subsidiary city that departed from the same wharf and day in London. Our results show that connecting road freight services to a subsidiary town decreased if the fly boat connected to the subsidiary (see IRR=0.056 in column 3). That is not surprising given earlier results. Interestingly, connecting road freight services to the subsidiary decreased even if fly-boats did not connect to the subsidiary. The effects are shown in column (3) in table 4 under the variable Fly boat indicator (major city only, no connect to subsidiary). The IRR=0.299 shows that the impact of fly boats on the subsidiary’s connecting services were large.

The impacts on subsidiary towns’ direct road services depended on whether the inland waterway service had a connection to the subsidiary. We find that direct road services to the subsidiary were significantly reduced if fly-boats connected to the subsidiary through the major city. See Fly boat indicator (connect to major city through subsidiary) in column 4. The effects on direct road services to the subsidiary were different if the fly boat did not connect to the subsidiary. See Fly boat indicator (major city only, no connect to subsidiary) in column 4. The estimate for the IRR is greater than one but is not precise. Thus, there is weak evidence that direct services to the subsidiary become a substitute for the lost connecting services to the subsidiary.

In summary, the broader implication is that fly boats had further displacement effects through the hub-and-spoke structure. When a fly boat service was introduced to a major city, it

not only reduced road freight services to the major city, it also reduced connecting services to nearby towns operating through spokes.

7: Conclusion

In this paper, we show that inland waterway services associated with canals displaced road freight services, but only after the appearance of fly boats. We think of initial canal development as an effort to provide services which were prohibitively expensive by road, so that canals and roads served segregated markets. Once some canal infrastructure was in place entrepreneurs developed new express services; which were substitutes for traditional road services and ultimately displaced them.

Our conclusions extend to road freight services between London and what we call subsidiary towns. They often had connecting services to London through nearby major cities. When fly boats were introduced to major cities they also displaced the connecting services to subsidiary towns. The displacement effects of fly boats extended through the hub and spoke network.

One might wonder about the generality of these findings. Did fly boats displace road freight services in other types of transport markets? In one extension, we look at road freight services between London and smaller towns within 50 miles of the capital. We still find that road freight services decreased after fly boats were introduced but the effects are smaller and are statistically indistinguishable from no effect. We conjecture there were fixed costs associated with using fly boats which did not apply to wagons. Wagons could travel point to point, while fly boats required some loading and unloading. We think that when travelling a short distance, like less than 50 miles, road freight services were able to compete with fly boats.

More generally, this paper offers insights on the effects of transport improvements. This paper suggests that the standard social savings estimates can understate the total benefits because they ignore the possibility that the newer mode led to the creation of a trade that the older mode could not serve. Our research suggests that future analysis ought to give more consideration to those benefits of transport which are often ignored in social savings calculations.

Directory sources

The shopkeeper's and tradesman's assistant: being a new and correct alphabetical list of all the stage-coaches, carriers, coasting vessels, &c. containing An Account of the several Inns in London where the Coaches and Carriers put up and go out from; the Days of the Week, and Hours of those Days, when they set out; Also the Counties in which those Places lie, and their Distances in Miles from the Standard in Cornhill, London. With An Account of the Coasting Vessels, Barges and Boats, with the several Wharfs, Keys and Stairs where they usually lie to take in Goods and Passengers. Also the Rates paid to Carmen for the Carriage of Goods, together with their Orders and Ordinances, as settled by the Lord Mayor, &c. at a General Quarter Sessions of the Peace, holden for the City of London, at the Guildhall. The Whole being well digested, is designed as a proper Assistant for Shopkeepers, Tradesmen and others, who have Occasion to write, or send Goods into the Country. London, 1779. Eighteenth Century Collections Online. Gale. UC Irvine. 26 Oct. 2017.

The shopkeeper's and tradesman's assistant: being a new and correct alphabetical list of all the stage-coaches, carriers, coasting vessels, &c. containing An Account of the several Inns in London where the Coaches and Carriers put up and go out from; the Days of the Week, and Hours of those Days, when they set out; Also the Counties in which those Places lie, and their Distances in Miles from London. To which is Prefixed, A correct List of all the Mail Coaches; with An Account of the Coasting Vessels, Barges and Boats, with the several Wharfs, Keys and Stairs where they usually lie to take in Goods and Passengers. Likewise a Collection of the most common Shilling and Eighteen Penny Fares for Hackney Coaches, and the Rates of Watermen. Also the Rates paid to Carmen for the Carriage of Goods, together with their Orders and Ordinances, as settled by the Lord Mayor, &c. at a General Quarter Sessions of the Peace, holden for the City of London, at the Guildhall. The Whole being well digested, is designed as a proper Assistant for Shopkeepers, Tradesmen and others, who have Occasion to write or send Goods into the Country. London, 1790. Eighteenth Century Collections Online. Gale. UC Irvine. 26 Oct. 2017.

The shopkeeper's and tradesman's assistant: being a new and correct alphabetical list of all the stage coaches, carriers, coasting vessels, &c. Containing An Account of the Inns in London where the Coaches and Carriers put up and go out from; the Days of the Week, and Hours of those Days, when they set out; the Counties in which the Places lie, and their Distance in Miles

from London; with the Wharss, Keys and Stairs, where the Vessels, Barges and Boats usually lie to take in Goods and Passengers, with the Charges of General Post Letters, Inland and Foreign. Likewise The Rates of Portage, to be taken by Inn Keepers and others, within the Cities of London and Westminster, the Borough of Southwark, and Places adjacent; A Collection of the most common Shilling and Eighteen Penny Fares for Hackney Coaches, and the Rates of Watermen. Also the Rates paid to Carmen for the Cartage of Goods, together with their Orders and Ordinances, as settled by the Lord Mayor, &c. at a General Quarter Sessions of the Peace, holden for the City of London, at the Guildball. To which is prefixed A correct list of all the mail coaches. The Charges of Landing, Loading, Housing and Weighing Merchandize; with The Names of all the Carriers, the Inns they put up at, and the principal Places they go to. The Whole being well digested, is designed as a proper Assistant for Shopkeepers, Tradesmen and others, who have Occasion to write, or send Goods into the Country. London, 1800. Eighteenth Century Collections Online. Gale. UC Irvine. 26 Oct. 2017.

Kent's original London directory: 1816. Being an alphabetical list of more than 17,000 merchants & traders of London. 84th ed. London, [1816]. The Making Of The Modern World. Web. 26 Oct. 2017.

Kent's directory, 1827. [s.l.], [1827]. The Making Of The Modern World. Web. 26 Oct. 2017.

Bibliography

Aghion, Philippe, and Peter Howitt. "A model of growth through creative destruction." *Econometrica* 60.2 (1992): 323-351.

Armstrong, John. "Management Response in British Coastal Shipping Companies to Railway Competition." *NORTHERN MARINER* 7 (1997): 17-28.

Arnold, A. J., and S. McCartney. "'Veritable gold mines before the arrival of railway competition': but did dividends signal rates of return in the English canal industry?." *The Economic History Review* 64, no. 1 (2010): 214-236.

Bagwell, Philip, and Peter J. Lyth. *Transport in Britain: from canal lock to gridlock*. Continuum, 2002.

Bates, A. *Directory of Stage Coach Services 1836*. Newton Abbot: David & Charles, 1969.

Berg, Maxine, and Pat Hudson. "Rehabilitating the industrial revolution." *The Economic History Review* 45.1 (1992): 24-50.

Bogart, Dan. "Did turnpike trusts increase transportation investment in eighteenth-century England?" *Journal of Economic History* 65, no. 2 (2005): 439.

Bogart, Dan. "Turnpike trusts and the transportation revolution in 18th century England." *Explorations in Economic History* 42, no. 4 (2005): 479-508.

- Crafts, Nicholas. "Productivity growth in the industrial revolution: A new growth accounting perspective." *The Journal of Economic History* 64.2 (2004): 521-535.
- Freeman, Michael J. "The carrier system of South Hampshire, 1775-1851." *Journal of Transport History* 4 (1977): 61-85.
- Freeman, M. J. "Road transport in the English Industrial Revolution: An interim reassessment." *Journal of Historical Geography* 6, no. 1 (1980): 17-28.
- Freeman, M. "Transporting methods in the British cotton industry during the industrial revolution." *Journal of Transport History* (1980): 67
- Gerhold, Dorian. "The growth of the London carrying trade, 1681-1838." *The Economic History Review* 41, no. 3 (1988): 392-410.
- Gerhold, Dorian. "Productivity change in road transport before and after turnpiking, 1690-1840." *The Economic History Review* 49, no. 3 (1996): 491-515.
- Gerhold, Dorian. "The development of stage coaching and the impact of turnpike roads, 1653–1840." *The Economic History Review* 67.3 (2014): 818-845.
- Griffin, C. P., "Transport Change and the Development of the Leicester Coalfield in the Canal Age: A Reinterpretation." *Journal of Transport History* 4 (1978): 227-238.
- Grossman, Gene M., and Elhanan Helpman. *Innovation and growth in the global economy*. MIT press, 1993.
- Hadfield, Charles. *The canal age*. David & Charles Publishers, 1981.
- Hazell, Martin. *Sailing barges*. Vol. 13. Shire. (2008).
- Herranz-Loncán, Alfonso. "Railroad impact in backward economies: Spain, 1850–1913." *The Journal of Economic History* 66.4 (2006): 853-881.
- Hopkinson, G. G. "Road Development in South Yorkshire and North Derbyshire, 1700-1850." *Transactions of the Hunter Archaeological Society* 10, no. part 5 (1979).
- Leunig, Timothy. "Time is money: a re-assessment of the passenger social savings from Victorian British railways." *The Journal of Economic History* 66.3 (2006): 635-673.
- Maw, Pete. *Transport and the industrial city: Manchester and the canal age, 1750–1850*. Manchester University Press, 2013.
- Mokyr, Joel. *The Enlightened Economy: An Economic History of Britain 1700-1850*. Yale University Press, 2009.

- Moyes, A. "Transport 1730-1900." *An Historical Geography of England and Wales* (1978): 401-29.
- Nuvolari, Alessandro, and Bart Verspagen. "Technical choice, innovation, and British steam engineering, 1800–50." *The economic history review* 62.3 (2009): 685-710.
- Pawson, E. *Transport and Economy: The Turnpike Roads of Eighteenth Century Britain*. New York. (1977)
- Phillips, A. D. M., and B. J. Turton. "Staffordshire Turnpike Trusts and Traffic in the Early Nineteenth Century." *The Journal for Transport History* (1987): 126-146.
- Rönnbäck, Klas. "The speed of ships and shipping productivity in the age of sail." *European Review of Economic History* 16.4 (2012): 469-489.
- Satchel, A.E.M. "Navigable waterways and the economy of England and Wales 1600-1835," in *The Online Historical Atlas of Transport, Urbanization and Economic Development in England and Wales c.1680-1911*, eds. L. Shaw-Taylor, D. Bogart and A.E.M. Satchell, 2017.
- Solar, Peter M., and Luc Hens. "Ship speeds during the Industrial Revolution: East India Company ships, 1770–1828." *European Review of Economic History* 20.1 (2015): 66-78.
- Turnbull, Gerard. "Canals, Coal and Regional Growth during the Industrial Revolution." *Economic History Review* (1987): 537-560.
- Turnbull, G. L. *Provincial road carrying in England in the eighteenth century* (1975).
- Turnbull, Gerard L. *Traffic and Transport: An Economic History of the Pickfords* (1980).
- Ville, Simon. "Transport." *The Cambridge economic history of modern Britain*. Vol. 1. Cambridge University Press, 2004.
- Ward, John Robert. *The finance of canal building in eighteenth-century England*. Oxford University Press, 1974.
- Willan, Thomas Stuart. *River navigation in England, 1600-1750*. Psychology Press, 1964.
- Wrigley, E. A. *Energy and the English Industrial Revolution*. Cambridge University Press, 2010.

Appendix

The main text focused on categories of freight services. We also measure passenger services. The main categories are ‘Post-Coach,’ ‘Coach,’ ‘Diligence,’ and ‘Machine’. Coaches were generally larger and slower vehicles. They could have 6 inside and outsider passengers. Post-coaches operated by relay as note above, and they were light sprung vehicles to carry 4 inside and generally no outsiders. ‘Machines’ typically were smaller and required less horsepower, while ‘diligences’ were probably larger than the standard ‘coach.’²³ While the variety is interesting, we focus on total passenger services.

We should also point out there is another type of road service called the mail coach. They carried mail, small packages, and passengers. They operated under contract with the post office. This paper omits analysis of mail coaches because decisions on its routes and frequency were different due to their public enterprise nature.

The following table lists the 53 major cities in the sample.

Appendix Table 1: List of 53 major cities in sample with summary information on 1827 services

City	End of Bates route to London	Subsidiary city	Indicator for barge in 1827	Indicator for vessel in 1827	Indicator for fly-boat in 1827	Number of wagon services in 1827	Number of coach services in 1827
Rochester	N	Maidstone	0	1	0	18	330
Canterbury	Y	Ashford	0	1	0	27	290
Oxford	N	Bicester	1	0	0	37	244
Birmingham	N	Bromsgrove	1	0	1	11	198
Bristol	Y		1	1	1	53	168
Bath	N		1	1	0	45	162
Liverpool	Y	Wigan	1	1	1	16	144
Colchester	N	Sudbury	0	1	0	18	132
Shrewsbury	Y	Wem	1	1	1	10	126
Reading	N	Reading	1	0	0	37	124
Ipswich	N	Basingstoke	0	1	0	15	117

²³ There is confusion over design of an English Diligence in the literature. Gerhold in *Bristol Stage Coaches*, pp 71-73, says English Diligences of this period were a larger version of a postchaise with 3 passengers seated across inside and driven from seat with 2 horses. (ie smaller and lighter than a standard coach) French Diligences developed into large vehicles carrying lots of luggage and passengers.

Coventry	N	Hinckley	1	0	1	21	114
Manchester	Y	Oldham	1	1	1	19	114
Portsmouth	Y	Fareham	0	1	0	36	114
Cambridge	N	Newmarket	0	0	0	30	108
Northampton	N	Daventry	0	0	1	8	102
Exeter	Y	Tiverton	1	1	0	33	99
Leicester	N	Melton M.	1	0	1	20	97
Salisbury	N	Amesbury	1	1	0	34	96
Norwich	N		0	1	0	45	90
Warwick	N	Stratford	1	0	1	19	90
Plymouth	N	Liskeard	0	1	0	56	81
Nottingham	N	Newark	0	1	1	3	72
Gloucester	N	Stroud	1	1	1	21	66
Chester	Y	Mold	0	1	1	8	60
Sheffield	N	Rotherham	0	1	1	9	60
Southampton	Y	Romsey	1	1	0	24	58
Bury St. Ed.	N		0	1	0	33	57
Carlisle	Y	Cockermouth	0	1	1	6	54
Hull	Y	Beverley	0	1	1	22	54
Kendal	Y		0	1	1	6	54
Macclesfield	N	Buxton	1	1	1	24	54
Taunton	Y	Bridgwater	1	1	0	31	51
Derby	N	Ashbourne	1	1	1	6	48
Hereford	Y	Bromyard	1	1	1	9	48
Lichfield	N		1	0	1	6	48
Newcastle	Y	Sunderland	1	0	1	6	48
Worcester	Y	Droitwich	0	1	1	10	48
York	N	Knaresbor.	0	1	1	15	48
Durham	N		0	1	1	6	42
Halifax	Y		1	1	1	9	42
King's Lynn	Y	Swaffham	0	1	0	32	39
Yarmouth	Y		0	1	0	18	36
Leeds	Y	Bradford	0	1	1	15	36
Berwick	N		0	1	0	6	32
Chichester	N	Arundell	1	1	0	15	30
Ely	N		0	1	0	6	30
Boston	Y	Sleaford	0	1	0	21	28
Bedford	N	Sandy	0	0	1	9	24
Lincoln	N	Horncastle	0	1	1	6	24
Banbury	N	Shipston	1	0	1	6	21
Frome	N	Bruton	1	0	0	29	17
Cirencester	N	Tetbury	1	0	1	16	15

Sources: see text.

Summary statistics are shown in appendix tables 3 and 4.

Appendix table 3: Summary statistics: London services to major cities

	Mean	Std. Dev.	Min	Max
Number of wagon services	12.61	10.68	0	59
Number of coach services	40.85	45.84	0	330
indicator for barge services	0.294	0.457	0	1
indicator for vessel services	0.732	0.444	0	1
indicator for any fly boat service	0.223	0.417	0	1
indicator for fly boat where distance to waterway is less than 2 km	0.14	0.347	0	1
indicator for fly boat where distance to waterway is greater than 2 km	0.083	0.276	0	1
indicator for flyboat where distance to London is below median	0.117	0.322	0	1
indicator for flyboat where distance to London is greater than median	0.106	0.308	0	1
year	1802.4	17.337	1779	1827
N				264

Sources: see text

Appendix Table 4: Summary statistics: London services to subsidiary cities

	Mean	Std. Dev.	Min	Max
Number of direct wagon services	3.85	4.48	0	26
Number of connecting wagon services	3.05	4.26	0	21
indicator for barge service to major city	0.31	0.46	0	1
indicator for any fly boat service to major city	0.23	0.42	0	1
indicator for barge service, connect to major city	0.13	0.34	0	1
indicator for any fly boat service, connect to major city	0.15	0.35	0	1
indicator for barge service, no connect to major city	0.18	0.38	0	1
indicator for any fly boat service, no connect to major city	0.08	0.27	0	1
N				210

Sources: see text

The following tables show the results focusing on passenger services as the outcome.

Appendix Table 5: Inland waterways and road passengers transport services: London to major cities

	All Major cities	All Major cities	Major cities at end of Bates route
VARIABLES	(1)	(2)	(3)
	IRR	IRR	IRR
weekly passenger services			

	(std. error)	(std. error)	(std. error)
Vessel indicator	1.083 (0.348)	1.083 (0.181)	1.179 (0.348)
Barge indicator	0.915 (0.086)	0.915 (0.074)	0.905 (0.122)
Fly boat indicator		1.074 (0.105)	1.006 (0.175)
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	265	265	125
Prob > chi2	0.000	0.000	0.000
Number of cities	53	53	25

Notes: IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1.

Appendix table 7: Pre and post effects of inland waterways on passengers services: London to major cities

VARIABLES	IRR (std. error)
One period before barge starts	1.042 (0.121)
Period barge starts	0.951 (0.122)
At least one period after barge starts	0.847 (0.094)
One period before fly boat starts	0.939 (0.128)
Period fly boat starts	0.912 (0.133)
One period after fly boat starts	1.250 (0.174)
Vessel indicator	Yes
City FE	Yes
Year FE	Yes
Observations	265
Prob > chi2	0.000
Number of cities	53

Notes: IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1