Canal carriers and creative destruction in English transport

Forthcoming in Explorations in Economic History

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August 2018

Abstract

Canals played a key role in the industrial revolution by creating the infrastructure for inland waterway transport. Public carriers responded to canals and the growing demand for transport by innovating in service speed, quality, and reliability. How did their innovations affect the transport market, especially road carriers? One hypothesis is that road and canal carriers complemented one another, offering services with different speeds and prices. Another sees them as competitors with canal carriers winning based on their lower operating costs. We test these hypotheses using London trade directories, which detail road and waterway services from London to most towns and cities from 1779 to 1827. Our main results show that introducing the standard canal barge service between London and a major city had no effect on the number of road carrier services supplied to that same city-pair. By contrast, introducing an express canal service, known as the fly boat, significantly reduced road carrier services supplied. Fly boats are found to have weaker competition effects if the ratio of waterway to road distance was greater and on short and long route distances. The results provide new insights on the importance of speed and service innovation during the industrial revolution.

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

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Data for this paper was created thanks to grants from the Leverhulme Trust (RPG-2013-093), Transport and Urbanization c.1670-1911 and NSF (SES-1260699), Modelling the Transport Revolution and the Industrial Revolution in England. We thank Jason Gravel for valuable research assistance. Special thanks also go to Alan Rosevear, Kara Dimitruk, and three anonymous reviewers for providing valuable comments. We also thank seminar participants at Caltech and UC Irvine for valuable feedback.

1. Introduction

Canals are one of the leading technological and infrastructural innovations in the English economy during the industrial revolution. Canals involved innovations in engineering, including the design of basins, locks, and incline planes, and innovations in finance, including the application of joint stock companies to infrastructure.[4] But this perspective ignores the services of public carriers. These firms offered regularly scheduled canal boat services and made innovations in speed, security, and reliability. The literature suggests some public carriers were seeking advantage over competitors, much like the process of 'creative destruction' described by Schumpeter.[5] For example, Turnbull (1972) describes the new express services offered by the famous carrier Pickfords, who operated in the competitive market for long distance transport.

How did the innovations by canal carriers affect the English transport market, including road carrier services? The answer to this question is not clear. In considering the broader impact of transport improvements Fogel (1979, p. 49) noted that it is "a misleading oversimplification to identify wagons, waterways and railroads with a sequence of temporal stages in which each was predominant…The transportation system that evolved during the nineteenth century embraced all three modes."[6] Some scholars studying British transport have argued along these lines that road and canal carriers operated in different complementary markets. Canal carriers offered low costs and served customers with heavy-weight, low-value goods. Road carriers offered higher speed, security, and reliability and served customers with light-weight, high-value goods. An alternative view argues that road carriers had higher costs and were displaced by canal carriers when they

[4] See Turnbull (1987) and Bagwell (2002) for discussion of canals as a key supply side change.
[5] Schumpeter (1975, pp. 82-85) described creative destruction as a "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one." See Aghion and Howitt (1992) and Grossman and Helpman (1993) for recent works.
[6] I thank an anonymous referee for recommending this passage from Fogel.

came into direct competition. In the literature, there are arguments favoring both views and thus the overall strength of complementarity or competition is ambiguous.[7]

In this paper, we use five London trade directories between 1779 and 1827 to shed new light on the impact of canal carriers on the transport market. London trade directories identify all carriers providing road and waterway services from London to other towns. Three types of waterway services were listed: (1) vessels, (2) barges, and (3) fly boats. Vessels refer to coastal sailing vessels and came in various types. Barges resembled vessels but were drawn by horses along a tow path. Fly boats were also drawn by horses, but they increased speed by operating relays and hauling on Sundays and at night. Fly boats also had more reliable crews. The three main types of road carrier services were: (1) wagons, (2) fly wagons, and (3) vans. Wagons usually carried 4 tons and were drawn by 4 to 6 horses. Fly wagons and vans were lighter and faster than wagons.

We document the trends in waterway services from London to 53 major English cities with a population greater than 2500 in 1750. Vessels were common for most of these cities by 1779 and remained so up to 1827. Barge services became more common after 1800 and fly boats became more common after 1810. Additional evidence shows that fly boats generally charged 50 to 100% higher freight rates than barges, but fly boat speeds were 75 to 100% higher than barges. Furthermore, fly boats tended to ship merchandise and barges tended to ship raw materials. Fly boats also reached comparable speeds to wagons and at lower freight rates.

With respect to road carriers, we follow an established literature counting weekly services between London and cities.[8] Our figures confirm that road carrier services continued to grow in

[7] See Turnbull (1972, 1987), Freeman (1980a, b), and Maw (2009, 2013). More references are below.
[8] See Chartres (1977), Freeman (1977), Gerhold (1986, 2014), Turnbull (1977), and Bogart (2005b).

the aggregate, even as canals spread through England. Moreover, speedy fly wagon and van services account for an increasing share of road carrier services after 1800.

The directory data are especially useful for testing the competition and complementarity hypotheses. We create a variable for the number of weekly road carrier services from London to each major city and indicators for availability of vessel, barge, and fly boat services over several years. In the main specification, we estimate how road services for a London-city pair changed once each waterway service was introduced in that same city-pair. The model includes destination city and year fixed-effects following the generalized difference-in-differences model. The analysis is guided by the following theoretical framework. Each town-pair represents a transport market, which is being supplied by road carriers or vessels or both prior to canals. If cost efficiency was the most important consideration for existing road-users, then the introduction of barges in a market should reduce the number of road carrier services supplied because barges were lower cost. But if speed and reliability were more important for existing road-users, and if road carriers were better on these dimensions, then introducing barges should *not* affect the number of road carrier services supplied. In this case, barges created a complementary new service. By the same logic, the introduction of fly boats could reduce the number of road carrier services supplied if speed and reliability were most important for existing road users and if fly boats offered comparable speed to wagons, but at a lower cost.

The regressions using London directories show that the introduction of barges did not significantly reduce road carrier services in a market. But the regressions also show that the introduction of fly boat services significantly reduced the number of road carrier services. These findings suggest that barges and road carrier services were complementary, but fly boats were strong competitors to road carriers in the transport market connecting London with major cities.

These conclusions are supported by checks on the model specification. One check introduces leads of barge and fly boat variables to test for 'pre-treatment' effects. Another uses passenger coach services as a placebo. We also test for heterogeneity in the competition effect. Fly boats are found to have a weaker competition effect if the ratio of waterway to road distance was greater and if the route was short or long distance. These results are notable because there is a debate on whether competition depended on distance and other route characteristics.[9]

In summary, we think of initial canal development as an effort to provide services to traders in heavy goods, which were prohibitively expensive by road. Traders in light goods were served by roads and operated in different, complementary markets. Once canal infrastructure was in place, entrepreneurial canal carriers developed express services, like fly boats, which became substitutes for traditional road services.

Our analysis extends the historical transportation literature in new directions. There is a growing literature on pre-railway transport improvements. Much of the focus is on productivity gains associated with new technology and infrastructure improvements.[10] Studies of service providers are relatively rare in the literature.[11] We contribute by documenting quality improvements made by public carriers and through analysis of competition and complementarity.

Our findings link this case to the literature on creative destruction. Many of the canonical examples come from transport. For example, Schumpeter observed that "competition between the Pennsylvania and New York Central Railroads…might be sporadic and even trifling, but the competition to railroads provided by new transportation media such as trucks, automobiles, and

[9] Turnbull (1987) has made the strongest claims concerning distance. This debate will be discussed more below.
[10] For examples on infrastructure see Bogart (2005b) and on technology Solar and Hens (2015), Ronnback (2012).
[11] Gerhold (1988, 1996, 2014) are exceptions.

airplanes really mattered."[12] We add a new case to the creative destruction literature by showing that fly boats—not barges—displaced road services.

Finally, our findings suggest that canal barge services provided a new transportation service for heavy goods. In the conclusion, we discuss future directions for studying the social savings of canals and new technologies during the industrial revolution.[13]

2. Background on transport modes

At the beginning of the canal era c.1760, coastal transport was the largest mode by tonnage. The biggest market was the northeastern coal trade (Armstrong, 2009). River trade in corn, iron, and agricultural products was also large, particularly along the Thames, Severn, and Trent (Willan, 1964). Long-distance land transport was another important market (Pawson, 1977; Gerhold, 1988). Goods were shipped from London to large cities and back. London shipped mainly imported goods like sugar and calicoes, but also received a diversity of goods from the manufacturing regions. Often, goods would be forwarded from major cities to smaller towns along roads, which we interpret as 'spokes' in a hub and spoke network.

Canals belonged to the system of inland waterways, which included tidal rivers and river navigations. Canals were different because they included long stretches of artificial waterway, where river navigations involved 'cuts,' which bypassed difficult sections of waterway. The Bridgewater is thought to be the first canal. The aim of its financier, the Duke of Bridgewater, was to connect Manchester with his coal mines at Worsley. The Bridgewater was a financial success and many more canal companies were proposed in parliamentary bills from the 1770s to the mid-1820s. The approval process was difficult, however, as many canals were opposed by

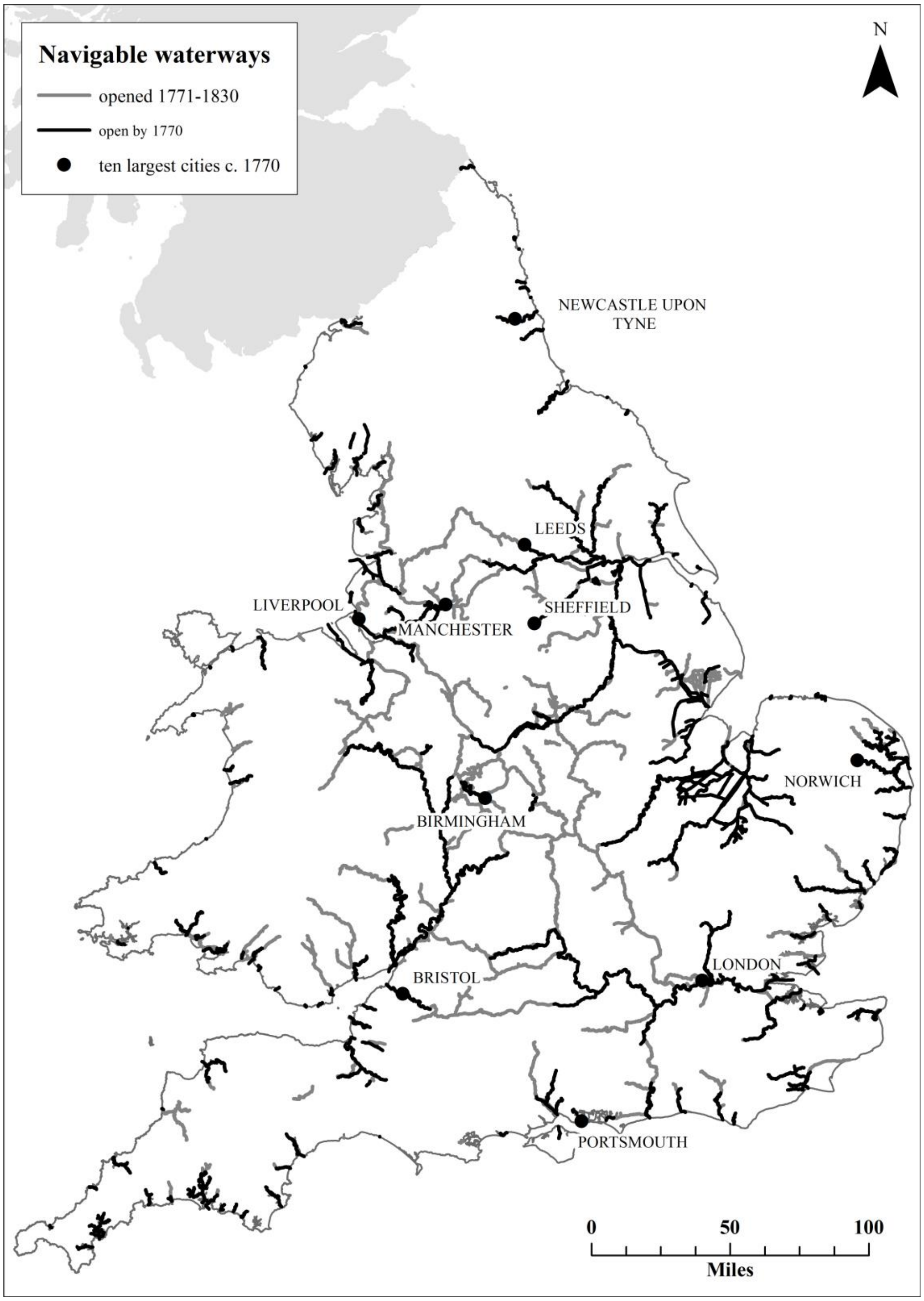
[12] This passage was quoted in Stigler (2003, p. 101).
[13] See Fogel (1964), Fishlow (1965), and Hawke (1970) for classic works on social savings and Leunig (2005) and Herranz-Loncán (2006) for recent studies. See Berg and Hudson (1992), Crafts (2004), Mokyr (2009), Leunig and Voth (2011) for debates on the industrial revolution and welfare impacts of technologies.

landed interests and existing canal companies. Financing was also a challenge because large-scale infrastructure finance was new. Most promoters and investors participated because of their local trade interests (Ward 1974).

Despite their local focus, canal companies collectively formed a national network. The waterway network in 1770, and its expansion from 1770 to 1830, are shown in figure 1.[14] The two north-south routes to London are of most importance to this paper. The first via the Oxford Canal was opened in 1790. It was tortuously long and had more than 150 locks. It was also controlled by seven different canal companies.[15] In 1805, a second north-south route to London opened with the completion of the Grand Junction Canal. Its more direct connection with London shortened the distance by 60 miles for cities like Manchester. The other long-distance routes of importance to London were the connections with Bristol and Gloucester in the southwest.

[14] See Satchell (2017) for details on mapping the navigable waterways of England and Wales.
[15] The canal is described in a House of Lords Report, Sunday Trading on Canals (p. 44, 85).

Figure 1: The inland watery network of England and Wales from 1771 to 1830



Source: Satchell (2017).

2.1 Canal carriers

There is a large literature explaining the development and financing of canals.[16] This article focuses on the carrier services by canal. Some of the early canal companies provided their own carrier services. The users of the Bridgewater canal, for example, mainly used Bridgewater boats. But after the first generation of canals it was more common for independent carriers to use their own boats in exchange for paying tolls.[17] In this respect, roads and canals were similar in England. Road and waterway networks both required Acts of Parliament for investment. Parliament did not allow the trustees who managed turnpike roads to provide wagon services.[18]

By 1800, there were two main types of independent canal carriers, public and private. Private carriers might work for a firm who shipped their own commodities, or they might be 'owner-boatmen' acting on contract with a trader. Owner-boatmen were paid by the voyage and sometimes travelled with their family, who acted as the crew.[19] Public carriers had several key features. They accepted the goods of any trader, meaning they did not ship their own goods. Public carriers were generally organized as partnerships (Hanson, 1975). They owned their boats and horses and contracted with shipmasters, who hired an all-male crew.[20] The public boats ranged in size. For Birmingham to London, boats were 10 tons at the low end and 22 tons at the high end.[21] Some shipped a great distance, like Liverpool to London. There were intermediate stops along the way in manufacturing or market towns.[22] As with private carriers, there was a

[16] See Ward (1974), Hadfield (1981), Arnold and McCartney (2010) and Broughey and Hadfield (2012).
[17] Boughey and Hadfield (2012, ch. 3 pp. 11-12). Also see Report on Sunday trading (p. 6). Note that some canal companies offered inducements for carriers to use their waterway. See Turnbull (1972, p. 146).
[18] For more details on turnpike roads see Albert (1972), Pawson (1977), and Bogart (2005a).
[19] The Report on Sunday trading (p. 9, 17) describes boatmen and families in 1840. Hanson (1975, p. 21) analyzes owner-boatmen and finds they were 4% of all registered boats in 1795.
[20] Report on Sunday trading (p. 54).
[21] Report on Sunday trading (p. 47). Vessels on the tidal river trades were larger. Flats on the Mersey and Irwell navigation were 40 to 70 tons (p. 72).
[22] Turnbull (1972, p. 32) describes how Pickfords routed through Leek because it was a silk manufacturing town.

primary haul with higher earnings and a back haul with lower earnings. For example, one carrier shipped coal, slate, and salt from Stafford to Oxford and returned with grain.[23]

Our study focuses on public carriers for three reasons. First, there is more information on public carriers in sources like directories. Second, the available evidence suggests that public carriers had more boats or they account for most of the revenues associated with canals. Hanson (1975, p. 21) estimates that 61% of all boats registered in 1795 belonged to owners with 6 or more boats, which would probably qualify them as public carriers. Maw (2009, pp. 217-218) has identified the share of toll revenues paid on credit by public and private carriers on the Rochdale canal. In 1815 public carriers accounted for £8251 and private carriers £763.

Third, we focus on public carriers because they were the main innovators in service quality. Pickford & Co. or Pickfords is the most well-known innovative carrier. According to Turnbull (1972, p. 63), Pickfords entered as a road carrier between Manchester and London in the 1770s. Its first innovation was to introduce a 'fly wagon' service in 1776. It cut the travel time from 9.5 to 5 days (p. 43). Next in 1788, the firm introduced a mixed wagon and barge service between Manchester and London (p. 50, 84). The speed of this service was increased in 1797 (p. 89). In 1805, Pickfords provided its first all-canal 'fly boat' service to London. Travel times by fly boat reached 7 days in 1806 and then 5 days by 1820 (p. 125). Pickfords expanded their fly boat services to several northern towns in the 1810s and 20s. The firm grew by providing speed and reliability (p. 126).[24]

2.2 Fly boats

[23] Report on Sunday trading (p. 78).

[24] Throughout Pickfords faced competition, but usually from one firm offering similar express services (Turnbull 1972, p. 180). Competition usually ended with a merger or exit of one firm. In fact, Pickfords faced financial distress in 1816 (Hanson 1975, p. 28, Turnbull p. 130, 145).

Fly boats are central to our analysis. They were essentially a different way of organizing freight transport by canal. Hanson (1975, p. 48) describes their essential features as follows:

> The fly boat started at fixed times, usually carried 15 tons or less, and proceeded with all speed, night and day, to its destination (averaging about 3 m.p.h.), being drawn by relays of horses and worked by four men, two of them resting.

Hanson also distinguishes fly boats from so-called 'slow-boats.' On the latter, "there was less travelling at night, there was not the brisk turn around at both ends, or the same frantic haste all day and night (p. 52)." These descriptions are supported by the House of Lords Report, *Sunday Trading on Canals* (henceforth the Report), which detailed features of the canal trade around 1840. Several witnesses in the Report stated that fly boats carried 10 to 12 tons, had a crew of 3 plus the captain, and that two crew rested while the others steered the boat and ensured the security of the cargo.[25] Concerning relays of horses, a witness stated that fly boats used shorter stages and fed the horses with nose baskets to replace grazing.[26] Several further reported that fly boats were more likely to travel on Sundays and at night than slow boats.[27] In some cases, fly boats paid slow boats to pass at locks.[28] One witness stated that turnaround times for fly boats could be as little as 6 to 10 hours versus one day for slow boats.[29] Security and reliability were also thought to be better. One witness argued that fly boat crews were "a superior Class; they are

[25] See Report on Sunday trading (p. 111) for tonnage. For crew size and activity see (p. 7, 50-51, 118). In addition, (Turnbull 1972, p. 192) reports that Pickfords boats were generally 25 tons, but the economical minimum was 15.
[26] See Report on Sunday trading (p. 21, 47) for more details on stages and use of horse by fly boats.
[27] See Report on Sunday trading (p. 5, 7, 21, 47, 49, 99) for fly boat travel at night and Sundays.
[28] Hanson (1975, p. 51) notes that fly boats sometimes paid slow boats to pass.
[29] See Report on Sunday trading (p. 50, 59, 79) for loading.

Men that may be trusted; better Men, who have better Ideas (p. 49)."[30] This marks a contrast with slow boats, where pilferage by the crew was a noted problem.[31]

Cargoes also differed. Slow boats carried coal, stone, and grain, whereas fly boats carried goods. Hanson (1975, p. 48) describes fly boat cargoes to and from London in 1832.

> Those from Birmingham were usually loaded with about 15 tons of finished metal and glass goods. As they neared Braunston their numbers were swollen by [fly] boats bringing metaled goods from other midland towns, cotton goods from Manchester, Cheshire cheeses, earthenware and pottery goods from Staffordshire, woolens and cutlery from Yorkshire, and lace from Derbyshire and Nottingham…On their return these fly boats would be loaded with about 8 tons of colonial goods.

The Report gives additional details on cargo. One witness states there were "[fly boats] leaving Northamptonshire on Saturday carrying meat and butter to arrive early on Monday in London (p. 98)." Similar valuable or perishable goods are noted on fly boats.[32]

How far was cargo shipped by fly boat? The sources suggest they concentrated on the trade between large cities.[33] Birmingham and Manchester to London are the most often mentioned. The two towns were 150 and 318 miles respectively from London by water in the early 1800s. Most of the slow boat traffic in coal, stone, and grain travelled less: 26 miles by Hawke's (1970) estimate.

[30] Another witness in the Report on Sunday Trading explained why valuable goods would go by fly boat. They state, "if Persons have Property of consequence they would wish to put it into the Hands of Men of Property, so that if there is any Loss they can get, if not the whole, at least 10s. in the Pound, but if they are put into the Hands of a Man not worth a Bawbee, they can get nothing. (p. 118).

[31] The Report on Sunday trading gives examples of pilfering on boats, especially liquor, wines, and spirits (p. 6). Pilferage was especially problematic when boats were stopped (p. 112).

[32] One witness in the Report on Sunday Trading states that fly boats have valuable Cargoes—Silks, Wines and Spirits, Linen, or what are called Goods and Merchandise (pp. 7-8). Another trader describes Locks, Hinges, Trays, japanned Goods, and every Description of the manufactured Goods from that Neighbourhood [Birmingham] (p. 46). Another witness states woollen Goods, Cotton and Silk, and Yorkshire and Lancashire Goods are carried by fly boat between Bristol and Manchester (p. 55). Another witness describes valuable heavy goods by fly (p. 118).

[33] Report on Sunday trading states fly boats typically trade at the extreme points of the canal (p. 41, 53). Another witness states fly boats were loaded every night in large towns. In Manchester, 3 or 4 were loaded almost every night (p. 92).

The development of fly boats in the early 1800s appears to have been a response to growing demand for quick delivery of valuable manufactured goods. One witness in the Report states that in Manchester "…the different Persons employed by the Factors send in their small Portions of Goods *at the very last Moment*, and the Carriers keep their Boats open, and they are put on board at Night (p. 15)." Another witness states, "there was a great urgency on the part of the traders in London to have their goods up from the country as quick as possible…one carrier would get away the business of another if he delivered his goods two or three hours earlier in the Morning (p. 94)."[34] One reason for such urgency was the growing export trade, where it was vital that goods should arrive for loading onto ships (Hanson 1975, p. 47). An increasing trade in perishables from rural to urban areas was another driving factor.

Fly boats were also fostered by earlier innovations in transport. So-called 'fly machines' were express coaching services using relays of horses and night travel. Fly machines were common on many routes to London by the 1770s (Bogart 2005b). Their success would have been known to public carriers and could have provided a demonstration effect.[35] The case of Pickfords is again insightful because it introduced an express 'fly wagon' service in 1776, more than two decades before its first fly boat (Turnbull, 1972 p. 63).

2.3 Competition and complementarity

The following sections will examine whether canal barges, fly boats, and road wagons were competitors or complements. First, it is useful to review perspectives from contemporaries and previous studies in the literature. Many contemporaries remarked on the cheapness of canal

[34] The Report gives more details on the pressure for quick delivery. It states "There are many of the Factors who during the Week send out Orders to the Mechanics to get their Work completed by the Saturday Morning, and the Factors are anxious to convey the Goods as far as possible ; they have Packers at work, and request the Carriers to attend at from Six to Twelve o'Clock at Night ; these Carriers have their Boats ready at the Wharf to take them off; they are at work till Two or Three o'Clock, or perhaps the whole Night, and then they go off on Sunday Morning (p. 21)". Another witness states, "I understand it is considered extremely important there should be a Delivery of Goods in London every Day, if practicable; at present there are Deliveries Five Days in the Week (p. 41-43)".
[35] Two witnesses in the Report on Sunday trading compared express coaching services with fly boats (p. 47, 99).

transport and the large demand for transport in heavy goods. One witness in the Report stated the principal goods on the canals are ‘not wanted so speedily’ and cite coal, iron, lime, clay, and flints (p. 8, 13, 86). Another stated “the larger Proportion of the Boats passing through the Country are of the Description of Slow Boats (p. 115).” But some traders also noted the disadvantage of canals, “there are so many drawbacks [on canals] that it is a puzzle to me and every other person in the carrying trade…” (quoted in Hanson 1975, p. 26). Another remarked on the preference for road carriers because canal routes were too long:

> “[The Grand Junction Canal] is circuitous in the Neighbourhood of London, and therefore Towns probably only from Thirty to Forty Miles from London by Road, are as much as Sixty by Canal. The Road waggons to such Places at Times have very much interfered with the Canal (Report p. 107)”[36]

Contemporaries also referred to competition between wagons and fly boats. A writer in 1819 touted that [fly] boats “arrive in London with as much punctuality…as the waggons do” (Turnbull, 1972, p. 117). In 1816 a canal company official said, “Such is the strife and competition in every Branch of Trade in the country that everything must give way to [the fly boat’s] accommodation (Hanson, 1975, p. 49).” Another canal official argued that if any impediment was raised to the speed of fly boats then goods traffic would switch to wagons.[37]

Previous studies have also analyzed competition between road and canal carriers. Some scholars argue that road and canal carriers operated in different, complementary markets. For example, Freeman (1980a, 1980b) documents that several textile manufacturing firms used both road and canal carriers. Speed was one consideration favoring roads (1980a, p. 71). Drought and frost were another. Freeman (1980b, p. 25) estimates that canals were stopped due to frost for 20 days or more in half of the years between 1771 and 1831. There are also several examples where in summer canals were closed due to lack of water (p. 26). According to Freeman, volume and

[36] Turnbull (1972, p. 51) made a similar argument with respect to the Derby canal.
[37] See Report on Sunday trading (p. 101).

cost favored canals. One firm shifted to canals when increasing their shipments to export markets and as yarn prices fell (1980a, p. 71).

Maw (2009) has questioned Freeman's conclusion that road carriers were generally competitive. Maw notes that the Manchester textile firm studied by Freeman largely shifted to canal transport after 1815 (p. 213). Maw also provides evidence of substantial and growing traffic on the Rochdale canal, a key route connecting Manchester and Hull. Between 1810 and 1845 the top three commodities by revenue were corn, sundries, and goods (p. 207). Sundries and goods are most interesting because trade in these products was supposedly a niche market for road carriers. Maw (2013, p. 80) also points out that by 1820 canal carriers offered 21 *more* services per week than road carriers between Manchester and London.[38]

Turnbull (1987) emphasizes canal carriers advantages in local trade, especially involving coal. Turnbull argues that coal intensive industries could not locate far from coalfields before canals. The implication is that little coal was shipped by road. As evidence, Turnbull points to changes in regional coal prices and production with the opening of canals.[39] In earlier work, Turnbull (1972) uses the case of Pickfords to argue that road carriers were equally efficient on long distance routes. Pickfords' boats had to pass locks and pay fees to multiple canal companies on the long journey (p. 181-182, 206). Turnbull gives two examples of road carriers that successfully competed with Pickfords' London canal services (p. 202-203).

An alternative view sees road carriers as being competitive with canals over short-distances. The argument is that traders avoided costly transshipment from barge to wagon or cart at the origin and destination. Maw (2013, p. 81) quotes a Bridgewater canal official, who

[38] Maw also uses directories to demonstrate that canal carriers were more common in services between Manchester and Hull, where cotton was exported (2009, p. 213).

[39] Boughey and Hadfield (2012, ch. 5, p. 9) also give an example of a turnpike road between Leicester and Loughborough which saw 35% of its revenues decline after a canal opened nearly parallel to its route. Coal was the dominant commodity in this area so presumably the example reflects the effect of canals on coal transport.

emphasizes trans-shipment costs when explaining why cotton was shipped by road from Manchester to neighboring towns, even though Manchester had many canals.[40]

While informative, previous studies have four shortcomings. First, it is difficult to generalize from the examples and micro-studies. A larger sample identifying the general effects of introducing barge and fly boat services is needed. Second, the theoretical framework for analyzing road and canal competition has not been fully developed. Third, no study has thoroughly investigated the relative speeds of barges, fly boats, and wagons, nor has any study established the relative cost of fly boats. Fourth, the competitive effects of fly boats on road carriers has not been studied in detail. The following sections take up these issues.

3. The relative cost and speed of canal boats, fly boats, and wagons

This section draws on several sources to establish the relative costs and speeds by road and canal. To begin, Turnbull (1972) gives data on freight rates by canal and road for 5 routes into Manchester in 1777.[41] In this year, there were no fly boats and fly wagons on these routes, so these freight rates should reflect freight rates by slow boats and standard wagons. The data are shown in panel A of table 1. There is variation across the routes reflecting the different geography and management practices of canals and carriers. The most relevant for our purposes is the ratio of road to canal rates (see column 3). The average ratio is 2.9, meaning road freight rates were 190% higher in the 1777 sample.

The superintendent on the Thames Navigation, Z. Allnutt, wrote a pamphlet containing road and canal freight rates in 1810. We have selected nine routes for comparison in Panel B of table 1. Appendix tables A2 and A3 provide data on all 17 routes reported. The average ratio of road to canal rates is 2.7 (see column 6). Notice that the ratio of freight rates by road and canal are

[40] Boughey and Hadfield (2012, ch. 7, p. 6) provide an example of road carriers competing with canals between London and Farnham, which is 40 miles by road. The road freight rate was slightly higher.
[41] The canal rates are after a tunnel was built eliminating the need for transshipment (see Turnbull 1972, 79).

similar in the 1777 and 1810 samples. Therefore, we can be reasonably confident that road freight rates were approximately 175% higher than canal freight rates.[42] Of additional interest is the ratio of freight rates for groceries versus heavy goods reported by Allnutt. Calculations show it ranges from 1.07 to 1.11. This suggests a relatively small added cost for valuable goods. It is not clear, however, whether this freight rate applies to fly or slow boats.

Table 1: Comparisons of freight rates by canal and road

Panel A: freight rates by road and canal in 1777	(1)	(2)	(3)
Route	Freight rate by canal in shillings per ton	Freight rate by road in shillings per ton	Ratio freight rate road to canal
Birmingham and Manchester	30	80	2.7
Derby and Manchester	30	60	2.0
Lichfield and Manchester	20	80	4.0
Nottingham and Manchester	40	80	2.0
Wolerhampton and Manchester	25	93	3.7
Average ratio			2.9
Panel B: freight rates by road and canal in 1810	(4)	(5)	(6)
Route	Freight rate by canal, shillings per ton	Freight rate by road, shillings per ton	Ratio freight rate road to canal
London to Basingstoke (goods)	18	35	1.9
London to Swindon (goods)	33	95	2.9
London to Semington (goods)	45	110	2.4
Oxford to Swindon	14	28	2.0
Oxford to Bath	33.5	83	2.5
London to Devizes (heavy goods)	36	110	3.1
London to Devizes (valuable goods)	40	120	3.0
London to Bristol (heavy goods)	49.5	160	3.2
London to Bristol (valuable goods)	53	170	3.2
Average ratio			2.7
Panel C: canal freight rates in 1810 by weight and value in 1810	(7)	(8)	(9)
Canal Group	Freight rate by canal, valuable goods, pence per ton mile	Freight rate by canal, heavy goods, pence per ton mile	Ratio freight rate by canal valuable to heavy
Basingstoke, Kennet & Avon, Wilts & Berks, Thames & Severn, and Stroud canals	5 to 5.75	3.25 to 4	1.54 to 1.44
Grand Junction, Oxford, Birmingham, Staffordshire Worcs, and Grand trunk canals	5.5 to 6	3.75 to 4.25	1.46 to 1.41

[42] This estimate is similar to Maw (2013, p. 76), who compares freight rates by road and canal c.1800.

Average ratio	2.7

Notes: The data for 1777 come Turnbulll (1979, p. 79). The data for 1810 come from Allnut, *A useful and correct account*, pp. 6-12.

In a separate table, Allnutt provides data for freight rates per ton mile on 'valuable goods or perishable or liable to risk' versus 'other goods, course, or heavy etc.' (p. 20). The rates are given for two groups of canals and are listed in Panel C of table 1. They show a 41 to 54% mark-up for valuable goods compared to heavy goods. Allnutt does not explicitly state fly boats shipped the valuable goods, but we know from directories that fly boats were on these routes and generally carried goods fitting this description. On this assumption, it follows that fly boat freight rates were 40 to 54% higher than slow boat freight rates in 1810. This would imply that fly boats were cheaper than wagon rates since the latter were 175% higher than slow boat rates.

There is further evidence on fly boat rates from witnesses on the committees for railway bills. Freight rates between Manchester and Hull in 1835 were 30 shillings per ton by canal boat and 40 shillings per ton by fly boat.[43] Another witness reported the freight rates between London and Birmingham were 22.5 to 26.5 shillings per ton by slow boat and 40 to 55 shillings by fly boat.[44] The freight rates on wagons between Birmingham and London were 60 to 100 shillings per ton. Together these examples suggest (1) freight rates by wagons were approximately 50% more than by fly boats and (2) freight rates by fly boat were 50 to 100% more than slow boats.[45]

Concerning speed, a witness for a railway bill stated that fly boats take three days to travel from Birmingham to London in 1833. The slow boats take six or seven days and the fly

[43] The rates between Manchester and Hull are reported by Marshall (1969, p. 20).
[44] The freight rates between Birmingham and London are reported in the Evidence from the Birmingham and London railway bill, printed in Railway Practice, pp. 36-38.
[45] For further observations see the table on freight rates in online appendix 1.

wagons take two to two and a half days.[46] A witness for the Report on Sunday Trading stated that fly boats between Manchester and London travel at 3.5 miles per hour, while slow boats travel at 2 miles per hour (p. 99). Heavy wagons between Derby and Macclesfield travelled at 3.5 miles per hour (p. 115). Turnbull reports that Pickfords fly wagons travelled from Manchester to London in 4 days, and fly boats made the same trip in 5 days (1972, p. 47, 126). These examples imply that (1) total travel speeds by fly boat were approximately 75% faster than slow boats, (2) travel speeds by fly boats were similar to heavy wagons, and (3) travel speeds by fly wagon were 25% faster than fly boats or heavy wagons. These conclusions are further supported by observations listed in appendix A.

4. Modelling mode choice

In this section, we develop a theoretical framework to model a trader's choice of goods transport: wagons, slow boats, or fly boats. The framework yields predictions for the empirical analysis that follows. There are two types of traders $i = \{l, h\}$, where l stands for light-weight goods and h stands for heavy-weight goods. Trader i gets a profit $\pi_i(\cdot)$ from transporting their goods. Profits depends on the trader's type and the speed s measured in miles per hour. Profits are assumed to increase with speed (i.e. ${\pi_i}'(s) > 0$). But speed increases profits more for traders of light weight goods (i.e. $\pi_l'(s) > \pi_h'(s)$ for all s). Traders must pay a freight rate p to ship their goods. We assume the freight rate reduces traders profits by p. The total payoff to trader i from shipping goods by an arbitrary mode is $\pi_i(s) - p$. Lastly, we assume the trader has the option of exiting the market and not transporting. The payoff to exiting the market is $\bar{u}$.

We begin by considering a case where only wagons are available. Wagons have a fixed freight rate p^w and speed s^w. The speed is assumed to be determined by technology. Wagons

[46] See Railway Practice, pp. pp. 36-38.

can travel only so fast. The wagon freight rate is assumed to maximize road carrier profits. The trader chooses whether to transport their goods or exit the market. Trader i will transport by wagon if $\pi_i(s^w) - p^w \geq \bar{u}$, otherwise they exit.

Next, consider the case where a new canal transport mode is introduced. We will call it the slow boat. It has lower freight rates than wagons ($p^{sb} < p^w$) and lower speeds ($s^{sb} < s^w$). The slow boat freight rates and speeds are exogenous. They can vary with distance, geography, and the structure of the canal network. We also assume that wagon speeds and freight rates remain unchanged. It is possible that road carriers lower their freight rates when slow boats enter, but there is no evidence that road carriers could match slow boats on price. Thus, it is reasonable to assume that $p^{sb} < p^w$ even if we endogenize road carrier pricing.

There are two cases with the introduction of slow boats sb. First, trader i, who ships by wagon, but can switch to slow boats. They switch if $\pi_i(s^{sb}) - p^{sb} > \pi_i(s^w) - p^w$, or if their savings in lower prices, $p^w - p^{sb}$, exceeds $\pi_i(s^w) - \pi_i(s^{sb})$, the extra profits from greater speed by wagons. Speed generates less additional profits for the heavy-goods trader h so they are more likely to switch to slow boats. The light weight trader l is less likely to switch because their additional profits from speed are larger. Second, consider a trader who remained out of the market under wagons and now considers entering with slow boats. If their payoffs are $\pi_i(s^{sb}) - p^{sb} \geq \bar{u}$ they earn sufficiently high profits under slow boats to enter the market. Observe that slow boats are more likely to bring heavy-goods trader h into the market because their difference in profits from speed $\pi_h(s^w) - \pi_h(s^{sb})$ is smaller and possibly zero.

Next consider the introduction of fly boats fb. The fly boat has higher freight rates than slow boats but lower freight rates than wagons ($p^{sb} < p^{fb} < p^w$). We assume it has the same speed as wagons ($s^{fb} = s^w$) and therefore $\pi_i(s^w) = \pi_i(s^{fb})$. If the fly boat is introduced, then all traders who used wagons previously will switch to fly boats since $\pi_i(s^{fb}) - p^{fb} = \pi_i(s^w) - p^{fb} > \pi_i(s^w) - p^w$. These would include all the light weight traders in the market. There could also be slow boat users that switch to fly boats. That would include heavy weight traders who earn just enough profit from speed to offset higher freight rates by fly boats.

The model yields several predictions. First, the introduction of slow boats may or may not decrease use of wagons. If the profits from speed are small, then traders who currently use wagons will switch to slow boats. This is the competition effect. But if traders who currently use wagons derive larger profits from speed they will not switch. In this case, canal carriers complement road carriers. The introduction of fly boats should displace wagons under the assumption that fly boats have a similar speed as wagons and lower freight rates. This captures a different version of the competition effect. Route characteristics, like distance, can change some of these predictions. This issue will be addressed in section 7.1

5. Directory sources

To test the model's predictions, we use a series of directories titled *The Shopkeeper's and Tradesman's Assistant* and its later title, *Kent's Original Tradesman's Assistant*. Our directories cover the years 1779, 1790, 1800, 1816, and 1827.[47] Directories provide several useful pieces of information on public carriers. They describe mode, departure times, and pick-up locations for services. Figure 2 is a directory entry for Bristol in the year 1800. The first lines describe coaching services. About halfway through the Bristol entry one sees "Flying Wa. White Bear, Bassinghall street, w, s, A. 4". This indicates there was a fly wagon service which departed at 4 in the afternoon on Wednesday and Saturday. Two lines down there is an entry starting with

[47] These directories were 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).

WA, indicating wagon. Services are listed from 5 London inns and for different days of the week. After wagons the Bristol entry turns to barges, which leave from two wharfs. The final entry contains the letters Ves, which stands for vessels. The vessels depart from several wharfs.

In general, our directories list over two dozen types of road carrier services. The main categories were wagon, cart, van, fly wagon, and post wagon. Carts usually have two wheels and wagons have four wheels. Fly wagons and post wagons were express services like fly boats. Vans often shipped parcels weighing 50 to 100 pounds using guards and trotting horses.[48] We sometimes combine all types into a single category called 'all road carrier services' and in others wagon carriers are separated. In the Bristol example above, we count 22 weekly road carrier services (4 fly wagon and 18 regularly wagon). Note that daily is interpreted as six services a week, because it is unclear whether there was Sunday trading.

Figure 2: 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; ſaracen's head, ſnow-hill, daily, M. 4, A. 3; bolt in tun, fleet-ſtreet, daily, M. ¾ 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; ſaracen's head, friday-ſtreet, daily, A. 5; george and blue boar, holborn, daily, A. ¾ paſt 2; glouceſter coffee-houſe, piccadilly, daily, A. ½ paſt 4; Flying Wa. white bear, baſinghall-ſtreet, *w. f.* A. 4; white ſwan, holborn-bridge, *w. f.* A. 6; Wa. ditto, *t. w. f. ſ.* king's arms, ditto, *th.* 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, alderſgate, *f.* M. 10; Barges, kennet's wharf, thames-ſtreet; Veſ. clouder's and ſymond's wharfs, ſouthwark; brook's wharf, queenhith; hambro' wharf, upper thames-ſt.

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

[48] See Report on Sunday trading (p. 102) and Turnbull (1972, p. 176-179) for details.

The London directories also contain listings for three main categories of water-based services: vessel, barge, and fly boat. The distinction between vessels and barges may seem fuzzy, but it is clear from the directories that vessels refer to coastal vessels because they are commonly found in port cities, but not inland cities away from rivers. Barges refer to canal services because they are commonly found in inland areas and not in some ports. There are a some 'hybrid' cases in which fly boats are paired with road. The most common are: (1) fly boat & wagon and (2) fly boat, van, & wagon. We exclude hybrid services from the count of road freight services because these entries do not include numbers of weekly services, which is our basis for counting road services. Hybrid observations are included in our baseline coding of whether a city had a fly boat service. In our analysis, we also experiment with a definition of fly boat that omits any hybrid service. We call it a canal-only fly boat service.

How reliable are London directories in identifying actual services? While we cannot always be sure of their accuracy, we can confirm their consistency with Pickfords. In 1797 Pickfords introduced a mixed canal and wagon services from Castle Quay (Turnbull, 1972). The 1800 directory states that Manchester had 18 weekly 'canal wagon' services from Castle Wood Street. In 1805 Pickfords introduced its all water fly boat service. In the 1816 directory, our first after 1800, Manchester is listed as having a fly boat service.

London directories contain listings for hundreds of towns and cities. We do not study the entire population and instead focus on services between London and the most populous cities. Corfield (1982) identifies 66 English cities with a population greater than 2500 in 1750. For short we call these 'major cities' because the 2500 population threshold identifies the more important markets. 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 cities that contain at least one entry listing another city for its services. The list of the cities is given in appendix table A1.

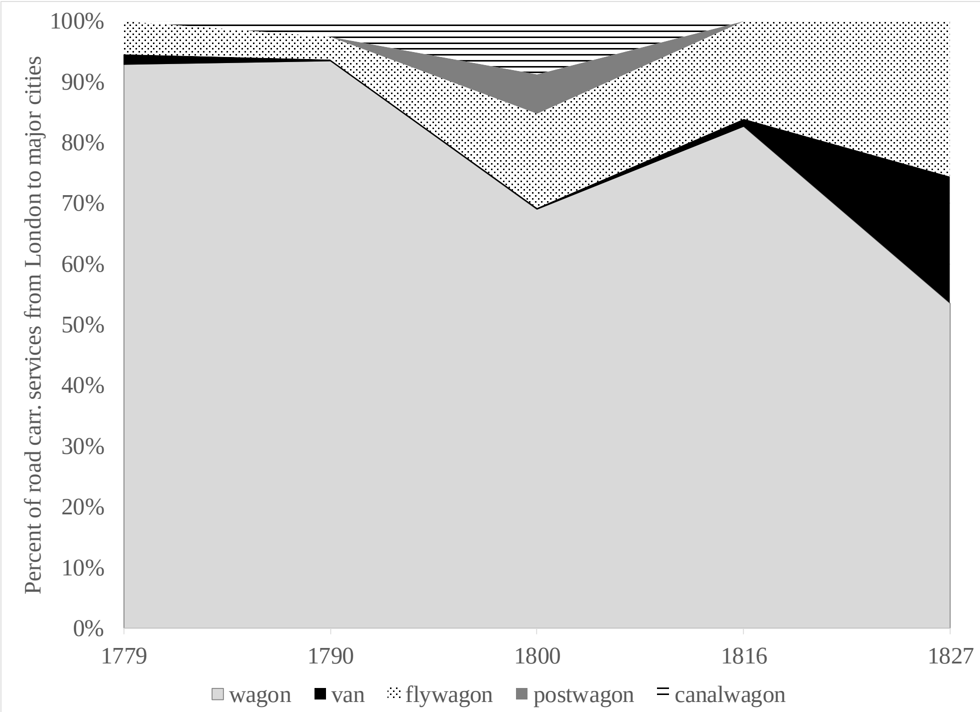
There is one more restriction that we make as a robustness check for our sample of cities. Bates (1969) directory of stage coach services identifies the major routes to London in 1836. Some routes connect several major cities. For example, Bath and Bristol. We identify 25 major cites at the end points of each Bates’ route (see Appendix table A1). We analyze them as a subsample because they cannot be an intermediate to another ‘upstream city’ on a Bates route.

The long-run trends are illustrated by an index for the total numbers of weekly road carrier services between London and major cities. The index increases from a base of 100 in 1779 to 273 in 1800 and 338 in 1827. The expansion was consistent with the high rate of industrial growth in this period.[49] But the index for total road services in 1816 was less than in 1800. As a preview, we think this ‘dip’ partly reflects competition from new fly boat services.

The distribution of road carrier services across types is shown in figure 3. Wagons were dominant in 1779. Fly wagons become more common in 1790 and increasingly afterwards. Canal and post wagons appear in 1790, but then disappear by 1816. They might have been converted into fly wagons or simply exited. Vans are rare before 1816 but then become more common in 1827. Overall there is a compositional shift to higher speed road carrier services. A similar pattern is found for waterway carriers from London to major cities. The vertical axis in figure 4 is the proportion of 53 major cities where directories list availability for each type of waterway service. Vessels were common and show no time trend. Barges become more common from 1790 to 1816. Fly boat services are absent until 1816 but diffuse rapidly after.

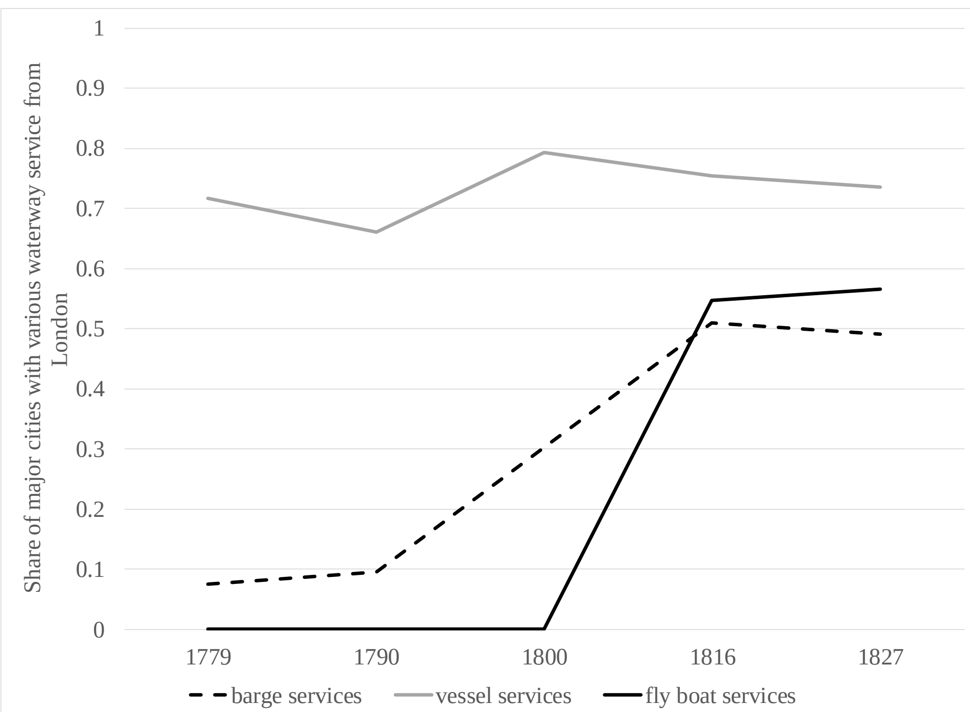
[49] Services to major cities grew at an annual average rate of 2.57% between 1779 and 1827. Broadberry et al. (2015) report that industrial production grew at 2.39% over the same period.

Figure 3: Trends in categories of road carrier services from London to major cities



Source: London directories, see text.

Figure 4: Share of major cities with different waterway services from London



Source: London directories, see text.

6. Empirical framework

The effect of introducing waterway carrier services on road 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 carrier services, α is a city-fixed effect, δ is a time dummy for date of directory publication, and *w* includes indicators for waterway services. City-level fixed effects control for unobserved city-specific factors influencing road-service levels. Time dummies for directory years control for unobserved time effects. Summary statistics for the key variables are shown in table 2.

Table 2: Summary statistics: variables for carrier services from London to major cities

	Mean	Std. Dev.	Min	Max
Number of road carrier services (all types)	12.61	10.68	0	59
Number of wagon carrier services	9.14	7.55	0	39
Number of fly wagon carrier services	2.05	5.74	0	53
indicator for barge services	0.29	0.46	0	1
indicator for vessel services	0.73	0.44	0	1
indicator for any fly boat service	0.22	0.42	0	1
year	1802.4	17.33	1779	1827
N				265

Sources: London directories, see text.

The number of weekly road carrier 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 models. This finding suggests the conditional fixed effects negative binomial regression is more suitable. However, standard statistical packages, like Stata, cannot calculate clustered standard errors for the negative binomial model. We report bootstrap standard errors instead. In most specifications below, bootstrap standard errors are larger than conventional standard errors, so we are more conservative in reporting statistical significance.[50] We also report ordinary least squares (OLS) fixed effects models for comparison.

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.[51] Note that 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.[52]

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.

Omitted variable bias is a potential concern in the regression. For example, growing levels of economic activity in a city likely meant a higher probability of canals being built and carriers 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}. The fly boat could also be endogenous to

[50] We use the xtnbreg command in Stata with the FE or conditional fixed effects option and boostrap standard errors. See https://www.stata.com/manuals13/xtxtnbreg.pdf, accessed June 15, 2018.
[51] 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.
[52] In the mid-18th century, there was variation in freight rates across city pairs due to differential road improvement. See Bogart (2005b) for an analysis of road freight rates in the 18th century.

the composition of a city's trade. If a city started to ship more light-weight goods, then fly-boats might be more likely to enter their market. This shift in demand composition would also affect road carrier 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 barges and road carrier services all else equal. Likewise, if fly boats were introduced in cities with a growing preference for lighter goods we would also expect a positive correlation between fly boats and road carrier services all else equal because roads traditionally served the lighter user. Therefore, if we find that introducing barges of fly boats was associated with lower road carrier services then this would represent stronger evidence that waterway services displaced them. [53]

Omitted variable bias concerns are furthered addressed by testing for a changing trend in road services before barges or fly boats. We do so by adding lead and lag variables for when services were introduced. This regression is:

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

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 road services increased significantly before the introduction of barges or fly-boats. That would suggest an endogeneity issue.

[53] We also worry that in some locations canals were prerequisite to the provision of cheap road materials, 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 works against our hypothesis.

We also address whether barges or fly boats are masking the effects of fly wagons. Fly wagons generally preceded fly boats and could have displaced some wagon carrier services. We check this by estimating the effect of canal services controlling for the number of fly wagons.

7. Estimation Results for services between London and major cities

Panel A in table 3 presents the results of the baseline model for all road carrier services between London and major cities. In columns (1) and (2) the coefficients for barges and vessels are less than one, but neither is 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 road carrier 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). In column (4) we report OLS estimates of equation (1). Note that fixed effects for city and year are included in this model. The introduction of fly boats is estimated to reduce weekly road carrier services by 9.5 on average. Barges and vessels continue to have small and insignificant effects.

Panel B in table 3 repeats the same regressions focusing only on wagon carrier services. In other words, fly wagons, vans, and post wagons are all dropped. In all specifications, the fly boat indicator continues to be significantly less than one and large. Fly boats are estimated to reduce wagon carrier services by 68%. Notice that the fly boat displacement effect is larger for wagons compared to all road carrier services. This is to be expected since fly boats were a stronger substitute for standard wagons.

Table 3: Effects of waterway services on road carrier services: London to major cities

Panel A: All road carrier services VARIABLES	(1) All Major cities Neg. bin. IRR (std. error)	(2) All Major cities Neg. bin. IRR (std. error)	(3) Major cities at end of Bates route Neg. bin. IRR (std. error)	(4) All Major cities OLS Coeff. (std. error)
Vessel indicator	0.932	0.875	1.005	-0.603
	(0.173)	(0.127)	(0.259)	(2.640)
Barge indicator	0.832	0.844	0.929	0.102
	(0.114)	(0.137)	(0.151)	(1.942)
Fly boat indicator		0.515	0.533	-9.561
		(0.075)***	(0.088)***	(1.924)***
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	265	265	120	265
Prob > chi2/within R-square	0.000	0.000	0.000	0.428
Number of cities	53	53	24	53
Panel B: wagon carrier services only VARIABLES	**(5) All Major cities Neg. bin. IRR (std. error)**	**(6) All Major cities Neg. bin. IRR (std. error)**	**(7) Major cities at end of Bates route Neg. bin. IRR (std. error)**	**(8) All Major cities OLS Coeff. (std. error)**
Vessel indicator	0.730	0.731	1.119	-1.807
	(0.103)**	(0.110)*	(0.223)	(1.459)
Barge indicator	0.813	0.845	0.817	-0.909
	(0.155)	(0.148)	(0.225)	(1.627)
Fly boat indicator		0.318	0.3744	-8.213
		(0.082)***	(0.180)**	(1.683)***
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	265	265	120	265
Prob > chi2/within R-square	0.000	0.000	0.000	0.283
Number of cities	53	53	24	53

Notes: The dependent variable is the number of weekly freight services between a major city and London. Columns (1) to (3) report estimates for FE negative binomial model. IRR is the incident rate ratio. Bootstrap standard errors are reported. Column (4) reports estimates from an ordinary least squares model with fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

The preceding results are robust to using a narrower definition of fly boat services. Recall that our fly boat variable takes the value 1 even if a hybrid service like 'fly boat & wagon' or 'fly boat, van, & wagon' is listed in the London directory. We also estimate a model using a fly boat variable that includes canal only-fly boat services. The results are reported in appendix table B1. They show that canal-only fly boats reduced wagon carrier services by 37%. While still significant, we think the smaller effect (37%) is due to measurement error because hybrids were one version of fly boats and omitting them assumes a city did not have any fly boats.

We further examine the robustness using leads and lags in the introduction of barges and fly boats. Column 1 in table 4 reports estimates of the IRRs when the dependent variable is the number of all road carrier services. None of the barge IRRs are significant as before. The IRR one period before fly boats were introduced is indistinguishable from one. This indicates road carrier services were not changing before fly boats were introduced. Importantly, we also find the fly boat IRRs are significantly less than one in the period when fly-boats were introduced. The coefficient implies road carriers decreased by 35%. This supports the finding that fly boats displaced road carrier services between London and major cities. The results also show that road services decreased by 59% one period after fly boats were introduced (IRR =0.414). The later period coincided with the completion of the national canal network. Possibly there was a scale effect helping fly boats attract more traffic from road carriers.

In column 2 of table 4 we analyze leads and lags in a model with only wagon carrier services as the dependent variable. Importantly, we find wagon carrier services significantly declined one period before the introduction of fly boats. We think the pre-treatment effect of fly boats on wagon carriers is masking the effects of fly wagons, which were often introduced before fly boats. In column 3 we include a variable for the number of fly wagon services between

London and the major city. The estimates confirm that fly wagons are negatively correlated with wagon services. One extra fly wagon service is associated with 5.4% fewer wagon services. Moreover, the IRR on the indicator one period before fly boats start becomes smaller and is no longer significant. Thus, once we account for fly wagons, there is no significant pre-treatment effect of fly boats.

Table 4: Pre and post effects of waterway services on road carrier services: London to major cities

VARIABLES	(1) All road carrier services IRR (std. error)	(2) wagon carrier services only IRR (std. error)	(3) wagon carrier services only IRR (std. error)
One period before barge starts	1.076 (0.132)	1.064 (0.154)	1.012 (0.162)
Period barge starts	1.007 (0.191)	1.077 (0.243)	1.057 (0.230)
At least one period after barge starts	0.901 (0.160)	1.235 (0.351)	1.149 (0.286)
One period before fly boat starts	0.991 (0.166)	0.723 (0.098)**	0.819 (0.127)
Period fly boat starts	0.652 (0.093)***	0.328 (0.083)***	0.419 (0.090)***
One period after fly boat starts	0.414 (0.073)***	0.218 (0.078)***	0.294 (0.102)***
Number of fly wagon services			0.946 (0.021)***
Vessel indicator	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	265	265	265
Prob > chi2	0.000	0.000	0.000
Number of cities	53	53	53

Notes: The dependent variable is the number of weekly freight services between a major city and London. Columns (1) to (3) report estimates for FE negative binomial model. IRR is the incident rate ratio. Bootstrap standard errors are reported. *** p<0.01, ** p<0.05, * p<0.1

A placebo test using passenger coaches provides a final robustness check. 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 appendix B and the results of a similar model are reported in table B2. Briefly, the analysis shows that fly boats and barges did not significantly affect the number of passenger services between London and major cities.

Before moving on, it is useful to summarize the estimates 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 total number of road carrier services from London over time. In the counterfactual without barges an index for road carrier services rises from a base value of 100 in 1779 to 380 by 1827. The actual index of road carrier services increases from 100 to 337. Thus, barges have a small overall effect. By contrast, in the counterfactual without barges and fly boats the road service index rises from 100 to 490. In other words, there would have been 153 percentage points (490-337) more road carrier services without fly boats, according to our model.

8. Heterogeneity due to route characteristics

Route characteristics have the potential to change the competitive effects of barges and fly boats. In this sub-section, we examine this issue in more detail. Geography and the structure of the canal network meant that some inland waterways were very circuitous. Recall from section 2 that some contemporaries thought that road carriers were more competitive if the length of the waterway was great relative to the road distance.[54] To investigate this issue, we create a

[54] See Report on Sunday trading (p. 197).

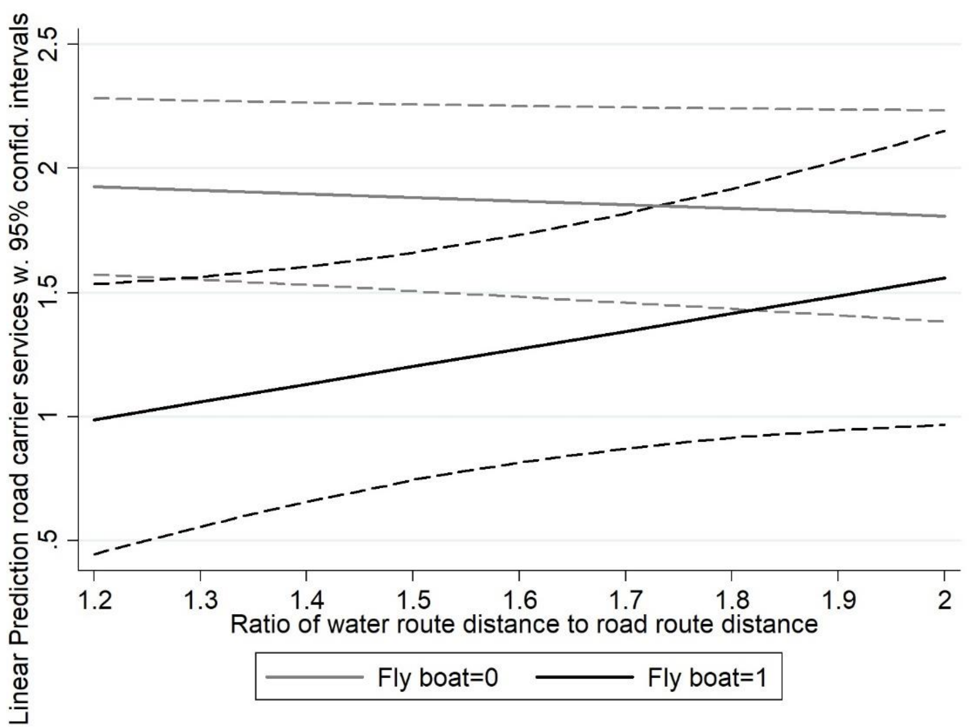
variable for the ratio of waterway to road distance to London $\frac{waterdist_{it}}{roaddist_i}$. The water distance is the shortest route between London and the major city by canal. It can change over time as new canals are built. Road distance is by turnpike road in 1830.[55] We include the ratio of water to road distance as its own variable and interacted with the fly boat and barge indicators to test whether a more circuitous waterway route changes the effects. The specification is shown in (3).

$$r_{it} = \alpha_i + \delta_t + \beta \cdot w_{it} + \gamma \cdot w_{it} \cdot \frac{waterdist_{it}}{roaddist_i} + \mu \cdot \frac{waterdist_{it}}{roaddist_i} + e_{it} \quad (3)$$

Equation (3) is estimated using the conditional fixed effects negative binomial model as above. The coefficient estimates are reported in appendix table B3. The results show that a greater waterway distance relative to road distance does not directly affect road carrier services (i.e. μ is insignificant). However, the results do show that a greater waterway to road distance diminishes the competitive effects of fly boats (i.e. γ is significant). Figure 5 summarizes the results with a graph.[56] It plots the predicted number of road carrier services with and without fly boats and depending on the ratio of waterway to road distance. The ranges 1.2 and 2 are the minimum and maximum ratios in the sample. Consider the case where the ratio of water to road distance is low or close to 1.2. The predicted number of carrier services is twice as large when there are no competing fly boats compared to when there are competing fly boats. Next consider the case where the ratio of water to road distance is close to 2. Now the predicted number of road carrier services is only marginally higher without competing fly boats.

[55] GIS data on waterway and road networks provide information to construct the distance by road and by water. See Satchell (2017) and Rosevear et. al. (2017) for a full description of the inland waterways and road GIS.
[56] We use the margins command in Stata. It produces statistics calculated from predictions of a previously fit model at fixed values of some covariates and averaging or otherwise integrating over the remaining covariates.

Figure 5: Heterogeneity I: Circuitous waterway routes



Sources: see text.

The total route distance is another potential factor affecting competition. Turnbull (1987) argued that greater distance increased the number of canal companies passed and raised canal carrier costs. As a result, road carriers were more competitive at greater distances. A different argument suggests an advantage for road carriers on short distance routes. Freeman (1980a, p. 72) notes that traders had to cart goods to the canal and load them onto boats at the wharf. Then at the destination goods needed to be reloaded onto carts and sent to market. Wagons might have reduced such costs by loading at or near the workshop or delivering at or near the market. Thus, in theory road carriers may have been more competitive on both long and short distance routes.

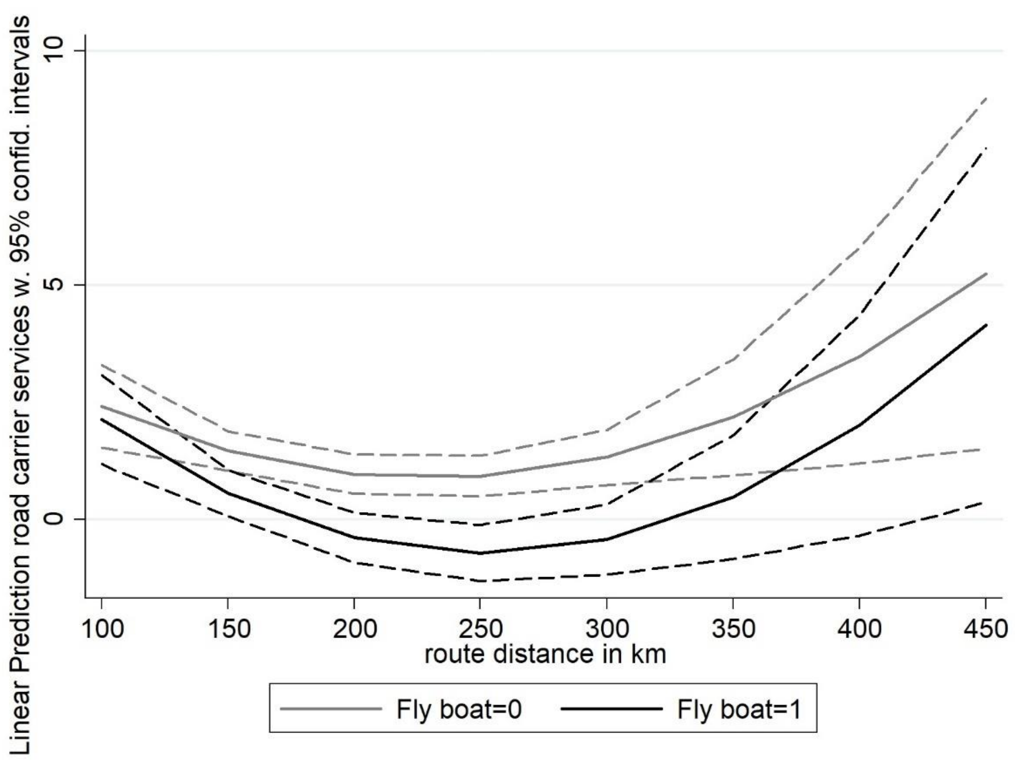
We test how distance affected competition by including a 2^{nd} degree polynomial in distance and its interaction with either the barge or fly boat indicators—a specification that allows for flexible effects of distance. Road carriers could be more competitive in both short and long distance for example. We use 1830 road distance between the major city and London because here we want to abstract from the length of waterway route studied above. We also want a simple measure of distance that is constant across time. Our model specification is shown in equation (4) where $dist_i$ is road distance between major city *i* and London.

$$r_{it} = \alpha_i + \delta_t + \beta \cdot w_{it} + \gamma_1 \cdot w_{it} \cdot dist_i + \gamma_2 \cdot w_{it} \cdot dist_i^2 + \mu_1 dist_i + \mu_2 dist_i^2 + e_{it} \quad (4)$$

Estimates of (4) are again obtained using the conditional fixed effects negative binomial model. The coefficients are shown in appendix table B4. The impact of distance and fly boats on wagon carriers is summarized in figure 6. At 100 to 150 km distance the predicted number of wagon carrier services with and without a competing fly boat service is statistically the same. The same is true beyond 350 km distance (50 km more than the distance from Manchester to London). However, in the intermediate range (200 to 350 km) the predicted number of wagon carrier services is significantly larger if there are no competing fly boats compared to when there are competing fly boats. Thus, based on these results, wagon carriers were more competitive with fly boats on shorter and longer route distances. By contrast our results do not identify any distance range at which wagon carries were significantly *less* competitive than barges.

We have some additional evidence that road carriers were competitive on short distance routes. In an extension, we study road carrier services between London and smaller towns within 50 miles of the capital. 50 miles is approximately the maximum distance at which smaller towns extensively traded with larger cities by road (Turnbull 1977). Some of these small towns got fly boat and barge services by being close to the Grand Junction and Basingstoke canals. The analysis is described in the online appendix. Briefly, we find that road carrier services decreased after fly boats were introduced but the estimated effects are small and statistically insignificant. Also, there was no change in road carrier services in response to barges.

Figure 6: Heterogeneity II: Route distance



Sources: see text.

In another extension, we study whether fly boats affected road carrier services to smaller towns through the hub-and-spoke system. Such services would often first connect through a major city which acted as a hub. We call the smaller towns subsidiary because they drew their carrier services from a nearby hub. The analysis of subsidiary towns is explained in the online appendix. Briefly, we find that when a fly boat service was introduced to a major hub city, it reduced connecting services to nearby towns operating through spokes. Thus, the displacement effects of fly boats went beyond the major cities we study above.

9. Interpretation of the results

One key finding is that fly boats displaced road carrier services between London and major cities. Earlier, we also showed that fly boats were cheaper and offered similar speeds to wagon services. These findings are consistent with fly boats providing strong competition to wagons. According to our mode choice model, some traders should shift from wagons to fly boats if fly boats offered cheaper freight rates and similar speed. Traders with high value goods would be most likely to shift to fly boats because they were the main users of wagon services.

It may be surprising that fly boats did not completely displace wagon users. The estimates in column 2 of table 3 show that fly boats reduced wagon carrier services by 68%. While a large effect, displacement was not 100%. One explanation is that using fly boats involved additional costs that did not always apply to wagons. On short distance routes the fixed costs of transshipment and carting at the origin and destination favored road carriers to some degree. On long distance routes the transaction costs of passing multiple canal companies and locks also favored road carriers to some degree. Another related explanation is that fly boats did not stop at many smaller markets along the route to major cities. Some wagon carriers could have survived by taking more loadings at the smaller markets. Also in the major cities, wagon carriers could collect the goods which missed the tight fly boat departure times.

Another key finding is that canal barge services did not significantly displace road carrier services. Nevertheless, many canals had significant traffic, so they were providing a service to some traders. These findings can be rationalized by our mode choice model. Consider the trader with heavy goods. They earn less profits from speed and are more sensitive to costs. Prior to the canal they would have had the option of shipping some of their goods by roads. However, it is likely that their profits were so low that few shipped by road more than a short distance. Using our model's terminology, the heavy goods traders would have exited the medium to long distance transport market if only wagons were available. If this was the case, then the introduction of barges should have little effect on the shipment of heavy goods by road because it wasn't happening by road to any significant degree.

Why didn't traders in light weight goods shift to canal barges once they were introduced? Our model suggests that if light weight trader's profits were very sensitive to travel speed then they might stick with road wagons because the extra profits from speed were more important than the savings from lower freight rates by canal. Recall that trader i will switch from wagons to slow boats if their savings in lower freight rates, $p^{w} - p^{sb}$, exceeds $\pi_i(s^{w}) - \pi_i(s^{sb})$, the extra profits they get from the greater speed of wagons.

10. Conclusion and future directions

This paper has several main points. First, we provide new econometric evidence that barges did not displace wagon services when they competed along the same route. Instead it was fly boats that significantly reduced wagon services when they came into direct competition. Wagons remained competitive with fly boats in some contexts, particularly routes where waterway distance was long, over short distances, and over long distances. Future research could use similar data and methodologies to test whether barges and fly boats had the same effects in provincial transport markets. Second, this paper serves as a reminder that new transport technologies may not be totally dominant over their predecessors just because their costs are lower. Speed, reliability, and security also matter. Third, much of the literature on the transport revolution focuses on the effects of technology and infrastructure. While both are clearly important, innovations in services were another key driver of productivity growth. In this paper we show that public carriers innovated by creating fly boats (and fly wagons and vans) which expanded the variety of services. Future research should explore the drivers of service innovation in more detail, perhaps focusing on models of creative destruction.

Fourth, our findings suggest that inland transport of heavy goods over medium to long distances did not exist prior to canals. In other words, this form of transport was similar to a 'new good.' If so, then our findings have implications for estimates of the social savings from canals. The standard social savings estimate assumes the new transport technology displaces the incumbent technology when they directly compete. We do not think this assumption applies to heavy goods traffic by canal because there was no displacement. Canals created this service. Therefore, following the methodology of valuing new goods, the social savings should equal the entire consumer surplus generated by canal's transportation of heavy goods. Future studies on the contribution of canals to England's economic growth should incorporate their new goods features.

References

Aghion, Philippe, and Peter Howitt, Peter, 1992. A model of growth through creative destruction. Econometrica 60, 323-351.

Albert, William., 1972. The Turnpike road system in England: 1663-1840. Cambridge University Press, Cambridge.

Armstrong, John. 2009. The Vital Spark: The British Coastal Trade, 1700-1930. Oxford University Press, Oxford.

Arnold, A. J., and McCartney, S. 2010. 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, 214-236.

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

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

Berg, Maxine, and Hudson, Pat., 1992. Rehabilitating the industrial revolution. The Economic History Review. 45, 24-50.

Bogart, Dan., 2005a. Did turnpike trusts increase transportation investment in eighteenth-century England? Journal of Economic History. 65, 439-468.

Bogart, Dan., 2005b. Turnpike trusts and the transportation revolution in 18th century England. Explorations in Economic History. 42, 479-508.

Bogart, Dan. Bogart Lefors and Satchell London road and canal carriers Explorations in Economic History Paper Data. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-08-22. https://doi.org/10.3886/E105544V1

Boughey, Joseph, and Hadfield, Charles., 2012. British Canals: The Standard History. The History Press, London.

Broadberry, Stephen, Campbell, Bruce, Klein, Alexander, Overton, Mark, and Van Leeuwen, Bas., 2015. British economic growth, 1270–1870. Cambridge University Press, Cambridge.

Chartres, John A., 1977. Road carrying in England in the seventeenth century: myth and reality. The Economic History Review. 30, 73-94.

Corfield, Penelope J., 1982. The impact of English towns, 1700-1800. Oxford University Press, Oxford.

Crafts, Nicholas., 2004. Productivity growth in the industrial revolution: A new growth accounting perspective. The Journal of Economic History. 64, 521-535.

Fishlow, Albert., 1965. American Railroads and the Transformation of the Ante-bellum Economy. Harvard University Press, Cambridge MA.

Fogel, Robert William., 1964. Railroads and American economic growth: essays in econometric history. Johns Hopkins Press, Baltimore.

Fogel, Robert William., 1979. Notes on the social saving controversy." The Journal of Economic History. 39, 1-54.

Freeman, Michael J., 1977. The carrier system of South Hampshire, 1775-1851. Journal of Transport History. 4, 61-85.

Freeman, M.J., 1980a. Transporting methods in the British cotton industry during the industrial revolution. Journal of Transport History. 1, 59-74.

Freeman, M. J., 1980b. Road transport in the English Industrial Revolution: An interim reassessment." Journal of Historical Geography. 6, 17-28.

Gerhold, Dorian., 1988. The growth of the London carrying trade, 1681-1838." The Economic History Review. 41, 392-410.

Gerhold, Dorian., 1996. Productivity change in road transport before and after turnpiking, 1690-18401. The Economic History Review. 49, 491-515.

Gerhold, Dorian., 2014. The development of stage coaching and the impact of turnpike roads, 1653–1840. The Economic History Review. 67, 818-845.

Grossman, Gene M., and Helpman, Elhanan., 1993. Innovation and growth in the global economy. MIT press, Cambridge.

Hadfield, Charles., 1981. The canal age. David & Charles Publishers, London.

Hanson, Harry., 1975. The canal boatmen, 1760-1914. Manchester University Press, Manchester.

Hawke, Gary Richard., 1970. Railways and economic growth in England and Wales, 1840-1870. Clarendon Press, London.

Herranz-Loncán, Alfonso., 2006. Railroad impact in backward economies: Spain, 1850–1913.

The Journal of Economic History. 66, 853-881.

Leunig, Timothy., 2006. Time is money: a re-assessment of the passenger social savings from Victorian British railways. The Journal of Economic History. 66, 635-673.

Leunig, Timothy, and Voth. H. J., 2001. Spinning welfare: the gains from process innovation in cotton and car production. CEP Discussion Paper No 1050.

Marshall, John., 1969. The Lancashire & Yorkshire Railway. Vol. 1. AM Kelley, London.

Maw, Peter., 2009. Water Transport in the Industrial Age: Commodities and Carriers on the Rochdale Canal, 1804–1855. The Journal of Transport History. 30, 200-228.

Maw, Peter., 2013. Transport and the industrial city: Manchester and the canal age, 1750–1850. Manchester University Press, Manchester.

Mokyr, Joel., 2009. The Enlightened Economy: An Economic History of Britain 1700-1850. Yale University Press, New Haven.

Pawson, E., 1977. Transport and Economy: The Turnpike Roads of Eighteenth Century Britain. Academic Press, New York.

Rönnbäck, Klas., 2012. The speed of ships and shipping productivity in the age of sail. European Review of Economic History. 16, 469-489.

Rosevear, A., Satchell, A.E.M., Bogart, D., Shaw Taylor, L., 2017. Turnpike roads of England and Wales.

Satchel, A.E.M. 2017. Navigable waterways and the economy of England and Wales 1600-1835.

Schumpeter, Joseph., 1975. Capitalism, Socialism, and democracy. Harper, New York.

Solar, Peter M., and Luc Hens., 2015. Ship speeds during the Industrial Revolution: East India Company ships, 1770–1828. European Review of Economic History. 20, 66-78.

Stigler, George J. 2003. Memoirs of an unregulated economist. University of Chicago Press, Chicago.

Turnbull, Gerard., 1987. Canals, Coal and Regional Growth during the Industrial Revolution. Economic History Review. 40, 537-560.

Turnbull, Gerard L., 1972. Pickfords 1750-1920: a study in the development of transportation. PhD thesis University of Glasgow, Glasgow.

Turnbull, G. L., 1977. Provincial road carrying in England in the eighteenth century. The Journal of Transport History. 1, 17-39.

Turnbull, Gerard L., 1980. Traffic and Transport: An Economic History of the Pickfords.

Ward, John Robert., 1974. The finance of canal building in eighteenth-century England. Oxford University Press, Oxford.

Willan, Thomas Stuart., 1964. River navigation in England, 1600-1750. Psychology Press, London.

Appendix A: Directory and Primary sources

The shopkeeper's and tradesman's assistant being a new and correct alphabetical list of all the stage-coaches, carriers, coasting vessels, &c. 1779. Eighteenth Century Collections Online. Gale. UC Irvine. (Accessed 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. 1790. Eighteenth Century Collections Online. Gale. (Accessed 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. 1800. Eighteenth Century Collections Online. Gale. UC Irvine. (Accessed 26 Oct. 2017).

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

Kent's directory, 1827. The Making Of The Modern World. (Accessed 26 Oct. 2017.)

Allnutt, Zachariah. Useful and correct accounts of the navigation of the rivers and canals west of London, 1810. (Accessed 15, June 2018).

House of Lords Report, Sunday Trading on Canals, in The Sessional Papers Printed by the Order of the House of Lords or Presented by Royal Command, 1841, Vol. XXI. Reports from Select Committees of the House of Lords and Evidence, (Accessed on Google Books 15 June 2018).

Railway Practice: A Collection of Working Plans and Practical Details of Construction in the Public Works of the Most Celebrated Engineers Volume 3, (Accessed on Google Books 15 June 2018).

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

Table A1: List of 53 major cities in sample with summary information on 1827 services

City	End of Bates route to London	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	0	1	0	18	330
Canterbury	Y	0	1	0	27	290
Oxford	N	1	0	0	37	244
Birmingham	N	1	0	1	11	198
Bristol	Y	1	1	1	53	168
Bath	N	1	1	0	45	162

Liverpool	Y	1	1	1	16	144
Colchester	N	0	1	0	18	132
Shrewsbury	Y	1	1	1	10	126
Reading	N	1	0	0	37	124
Ipswich	N	0	1	0	15	117
Coventry	N	1	0	1	21	114
Manchester	Y	1	1	1	19	114
Portsmouth	Y	0	1	0	36	114
Cambridge	N	0	0	0	30	108
Northampton	N	0	0	1	8	102
Exeter	Y	1	1	0	33	99
Leicester	N	1	0	1	20	97
Salisbury	N	1	1	0	34	96
Norwich	N	0	1	0	45	90
Warwick	N	1	0	1	19	90
Plymouth	N	0	1	0	56	81
Nottingham	N	0	1	1	3	72
Gloucester	N	1	1	1	21	66
Chester	Y	0	1	1	8	60
Sheffield	N	0	1	1	9	60
Southampton	Y	1	1	0	24	58
Bury St. Ed.	N	0	1	0	33	57
Carlisle	Y	0	1	1	6	54
Hull	Y	0	1	1	22	54
Kendal	Y	0	1	1	6	54
Macclesfield	N	1	1	1	24	54
Taunton	Y	1	1	0	31	51
Derby	N	1	1	1	6	48
Hereford	Y	1	1	1	9	48
Lichfield	N	1	0	1	6	48
Newcastle	Y	1	0	1	6	48
Worcester	Y	0	1	1	10	48
York	N	0	1	1	15	48
Durham	N	0	1	1	6	42
Halifax	Y	1	1	1	9	42
King's Lynn	Y	0	1	0	32	39
Yarmouth	Y	0	1	0	18	36
Leeds	Y	0	1	1	15	36
Berwick	N	0	1	0	6	32
Chichester	N	1	1	0	15	30
Ely	N	0	1	0	6	30
Boston	Y	0	1	0	21	28
Bedford	N	0	0	1	9	24
Lincoln	N	0	1	1	6	24
Banbury	N	1	0	1	6	21

Frome	N	1	0	0	29	17
Cirencester	N	1	0	1	16	15

Sources: see text.

Tables A2 through A3 show observations on canal and road freight rates from several sources. When available the observations distinguish vessel or vehicle type and the commodity.

Table A2: Freight rates by inland waterway

Year	Route	Vessel type	Commodity if given	Cost per ton in pence	Cost per ton mile in pence	Source
1840	London to Birmingham	boat	coal		0.25	Report, Sunday Trading on Canals, p. 102
1840	London to Birmingham	boat	iron		0.5	Report, Sunday Trading on Canals, p. 102
1780	Birmingham to Manchester	boat		360	4.3	Turnbull (1972), p. 79
1780	derby to Manchester	boat		360	5.9	Turnbull (1972), p. 79
1780	Lichfield to Birmingham	boat		240	3.5	Turnbull (1972), p. 79
1780	Nottingham to Manchester	boat		480	7.2	Turnbull (1972), p. 79
1780	Wolverhampton to Manchester	boat		300	4.3	Turnbull (1972), p. 79
1835	Manchester to Hull	boat		360	3.7	Marshall (1969), p. 20
1835	Manchester to Hull	fly boat		480	4.9	Marshall (1969), p. 20
1810	Thames west of London	river barges			2.3	Allnutt (1810), p. 4
1810	London to Reading	river barge		180	2.3	Allnutt (1810), p. 4
1810	London to Oxford	river barge		336	2.8	Allnutt (1810), p. 4
1810	London to Weybridge			96	3.2	Allnutt (1810), p. 7
1810	London to Guildford			144	3.1	Allnutt (1810), p. 7
1810	London to Godalming			162	3.2	Allnutt (1810), p. 7
1810	London to Basingstoke	barge		216	3.1	Allnutt (1810), p. 8
1810	London to Reading	river barge	heavy goods	180	2.3	Allnutt (1810), p. 10
1810	London to Reading	river barge	Non-heavy goods	216	2.8	Allnutt (1810), p. 10
1810	London to Newbury	river barge	heavy goods	216	2.2	Allnutt (1810), p. 10
1810	London to Newbury	river barge	Non-heavy goods	300	3.1	Allnutt (1810), p. 10
1810	London to Swindon by Wilts and Berks. Canal	barge		396	2.9	Allnutt (1810), p. 12
1810	London to Bath by Wilts and Berks. Canal	barge		630	3.6	Allnutt (1810), p. 12
1810	London to Bristol by Wilts and Berks canal	barge		660	3.4	Allnutt (1810), p. 12

1810	London to Bath by Kennet and Avon Canal	barge	heavy goods	564	3.7	Allnutt (1810), p. 12
1810	London to Bath by Kennet and Avon Canal	barge	Non-heavy goods	600	3.9	Allnutt (1810), p. 12
1810	London to Bristol by Kennet and Avon canal	barge	heavy goods	594	3.5	Allnutt (1810), p. 14
1810	London to Bristol by Kennet and Avon canal	barge	Non-heavy goods	636	3.7	Allnutt (1810), p. 14
1810	Brimscombe port to London	barge		420	2.4	Allnutt (1810), p. 18
1827	Manchester to Nottingham	canal	thread	540	8.1	Freeman (1980a), p. 70

Sources: see table.

Table A3: Freight rates by road

Year	Route	Vehicle type	Commodity if not goods	Cost per ton in pence	Cost per ton mile in pence	Source
1780	Birmingham to Manchester	wagon		960	13.6	Turnbull (1972), p. 79
1780	derby to Manchester	wagon		720	11.8	Turnbull (1972), p. 79
1780	Lichfield to Birmingham	wagon		960	14.1	Turnbull (1972), p. 79
1780	Nottingham to Manchester	wagon		960	14.4	Turnbull (1972), p. 79
1780	Wolverhampton to Manchester	wagon		1116	15.8	Turnbull (1972), p. 79
1815	Manchester to derby	fly van		3360	55	Turnbull (1972), p. 123
1838	Leeds to London	wagon		1440	7.4	Turnbull (1972), p. 178
1838	Leeds to London	van		2880	14.8	Turnbull (1972), p. 178
1822	Manchester to London	van		5600	30.1	Turnbull (1972), p. 178
1825	Manchester to London	van		3804	20.6	Turnbull (1972), p. 178, 180
1835	Manchester to Hull	land		600	6.1	Marshall (1969), p. 20
1810	London to Reading	wagon		600	14.8	Allnutt (1810), p. 4
1810	London to Oxford	wagon		780	8.6	Allnutt (1810), p. 4
1810	London to Weybridge	wagon		300	13.9	Allnutt (1810), p. 7
1810	London to Guildford	wagon		420	14.3	Allnutt (1810), p. 7
1810	London to Godalming	wagon		480	14.3	Allnutt (1810), p. 7
1810	London to Basingstoke	wagon		420	8.9	Allnutt (1810), p. 8
1810	London to Reading	wagon	heavy goods	480	11.9	Allnutt (1810), p. 10
1810	London to Reading	wagon	Non-heavy goods	540	13.3	Allnutt (1810), p. 10
1810	London to Newbury	wagon	heavy goods	840	14.7	Allnutt (1810), p. 10
1810	London to Newbury	wagon	Non-heavy goods	900	15.7	Allnutt (1810), p. 10
1810	London to Swindon by Wilts and Berks. Canal	wagon		1140	13.7	Allnutt (1810), p. 12
1810	London to Bath	wagon		1476	13.9	Allnutt (1810), p. 12
1810	London to Bristol	wagon		1800	15.3	Allnutt (1810), p. 12

1810	London to Bath	wagon	heavy goods	1680	15.8	Allnutt (1810), p. 12
1810	London to Bath	wagon	Non-heavy goods	1800	17	Allnutt (1810), p. 12
1810	London to Bristol	wagon	heavy goods	1920	16.3	Allnutt (1810), p. 14
1810	London to Bristol	wagon	Non-heavy goods	2040	17.3	Allnutt (1810), p. 14

Sources: see table.

Tables A4 through A5 show observations on canal and road travel times and speeds from several sources. When available the observations distinguish vessel or vehicle type and the commodity. Note journey miles per hour are calculated as road distance in 1831 divided by number of days travelled times 24 to get hours (i.e. distance/(time in days*24)).

Table A4: inland waterway speeds

Year	Route	Vessel type	Time in days	Speed in journey miles per hour	Source
1840	London to Manchester	boat	5.5	1.4	Report, Sunday Trading on Canals
1840	Stafford to Liverpool	boat	2	1.5	Report, Sunday Trading on Canals, p. 16
1840	Liverpool to London	boat	14	0.5	Report, Sunday Trading on Canals, p. 21
1840	London to Manchester	fly boat	4.5	1.7	Report, Sunday Trading on Canals, p. 43
1840	Birmingham to London	fly boat	2.5	2.1	Report, Sunday Trading on Canals, p. 46
1840	Birmingham to London	slow boat	5	1	Report, Sunday Trading on Canals, p. 49
1840	Wolverhampton to London	fly boat	3	1.8	Report, Sunday Trading on Canals, p. 50
1840	London to Birmingham	fly boat	2	2.3	Report, Sunday Trading on Canals, p. 50
1840	Manchester to Bristol	not clear	5	1.4	Report, Sunday Trading on Canals, p. 52
1840	Stourport to Manchester	boat	6	0.6	Report, Sunday Trading on Canals, p. 54
1840	Liverpool to Bristol	fly boat	5	1.4	Report, Sunday Trading on Canal, p. 55
1840	Manchester to Runcorn	vessels, flats	0.5	3	Report, Sunday Trading on Canals, p. 72
1840	Liverpool to Manchester	vessels, flats	0.75	2.7	Report, Sunday Trading on Canals, p. 75
1840	Manchester to London	fly boat	5	1.5	Report, Sunday Trading on Canals, p. 94
1840	Northampton to London	market boats with perishables	1.5	2	Report, Sunday Trading on Canal, p. 98
1840	London to Daventry	fly boat	1.5	2.16	Report, Sunday Trading on Canals, p. 101
1840	Manchester to London	boat	6	1.3	Report, Sunday Trading on Canals, p. 111
1806	Birmingham to London	fly boat	4	1.2	Turnbull (1972), p. 126
1806	Manchester to London	fly boat	7	1.1	Turnbull (1972), p. 126

1820	Manchester to London	fly boat	5	1.5	Turnbull (1972), p. 126, note date is uncertain
1834	Leeds and Liverpool	van boat	0.4	5.8	Letter to Carriers and Traders on the navigations connecting Liverpool and Manchester, p. 15
1834	Glasgow and Edinburgh	van boat	0.4	5.3	Letter to Carriers and Traders on the navigations connecting Liverpool and Manchester, p. 16
1830	Birmingham to London	slow boat	6.5	0.71	Hanson (1975), p. 52
1840	Bristol to London		1.5	3.2	Boughey and Hadfield (ch. 7 p. 11).
1835	Manchester to hull	boat	6	0.7	Marshall (1969), p. 20
1835	Manchester to hull	fly boat	4	1	Marshall (1969), p. 20
1810	Thames west of London, downstream	river barges		1.25	Allnutt (1810), p. 4
1810	Thames west of London, upstream	river barges		1	Allnutt (1810), p. 4
1810	Godalming to London	river barges	2.5	1.7	Allnutt (1810), p. 7
1810	London to Godalming	river barges	3.5	1.2	Allnutt (1810), p. 7
1810	London to Basingstoke	barges	3.5	0.8	Allnutt (1810), p. 8
1810	Wiltshire and Berkshire canal	barges		0.9	Allnutt (1810), p. 11
1810	Kennet and Avon canal	barges		0.7	Allnutt (1810), p. 13
1810	Lechlade to London	barges	9	0.7	Allnutt (1810), p. 15
1810	River Severn	barges		1.25	Allnutt (1810), p. 18

Sources: see table.

Table A5: road carrier speeds

Year	Route	Vehicle type	Time in days	Speed in journey miles per hour	Source
1760	Manchester to London	wagon	9.5	0.8	Turnbull (1972), p. 34
1777	Manchester to London	fly wagon	5	1.5	Turnbull (1972), p. 43
1800	Manchester to London	fly wagon	4	1.9	Turnbull (1972), p. 47
1820	Manchester to London	fly van	1.5	5.1	Turnbull (1972), p. 116
1830	Manchester to London	fly van	1.4	5.3	Turnbull (1972), p. 133
1830	Macclesfield to London	fly van	0.3	7.1	Turnbull (1972), p. 176
1825	Sheffield to London	fly wagon	3.3	2.3	Turnbull (1972), p. 180
1820	Sheffield to Nottingham	fly wagon	0.7	2.1	Turnbull (1972), p. 181

Sources: see table.

Appendix B. Additional regression results

Table B1 reports results from models using a fly boat variable that includes canal only-fly boat services. Recall that our fly boat variable takes the value 1 even if a hybrid service like ‘fly boat & wagon’ or ‘fly boat, van, & wagon’ is listed in the London directory. For comparison column (1) reports estimates using our inclusive measure of flyboats. Columns (2) and (3) use the canal only fly boat.

Table B1: Effects of fly boats on wagon carrier services excluding fly boats with wagons

VARIABLES	(1) All Major cities Neg. bin. IRR (std. error)	(2) All Major cities Neg. bin. IRR (std. error)	(3) All Major cities OLS Coeff. (std. error)
Vessel indicator	0.731	0.701	-1.946
	(0.110)*	(0.085)***	(1.227)
Barge indicator	0.845	0.857	-1.480
	(0.148)	(0.154)	(1.671)
Fly boat indicator	0.318		
	(0.082)***		
Fly boat canal only indicator		0.634	-3.605
		(0.160)*	(1.905)*
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	265	265	265
Prob > chi2/within R-square	0.000	0.000	0.175
Number of cities	53	53	53

Notes: The dependent variable is the number of weekly wagon freight services between a major city and London. Columns (1) to (2) report estimates for FE negative binomial model. IRR is the incident rate ratio. Bootstrap standard errors are reported. Column (3) reports estimates from an ordinary least squares model with fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

The main text focused on categories of freight services. We also measure passenger services in London directories. The main categories are ‘Post-Coach,’ ‘Coach,’ ‘Diligence,’ and

‘Machine’. Coaches were generally lager and slower vehicles. They could have 6 inside and outsider passengers. Post-coaches operated by relays, 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.’ For simplicity, we focus on all coach services.

We use coaches in a ‘placebo’ analysis. Table B2 shows the results focusing on passenger services as the outcome instead of road carrier services. The model is otherwise the same as equation (1) in the text. Notice that barges and fly boats do not significantly affect passenger services.

Table B2.: Waterway services and road passenger services: London to major cities

VARIABLES	All Major cities (1) Neg. Bin. IRR (std. error)	All Major cities (2) Neg. Bin. IRR (std. error)	Major cities at end of Bates route (3) Neg. Bin. IRR (std. error)
Vessel indicator	1.083	1.083	1.039
	(0.348)	(0.181)	(0.569)
Barge indicator	0.915	0.915	0.919
	(0.086)	(0.074)	(0.110)
Fly boat indicator		1.074	1.045
		(0.105)	(0.182)
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	265	265	120
Prob > chi2	0.000	0.000	0.000
Number of cities	53	53	24

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

Table B3 reports the coefficients for the models that interact fly boats and barges with the ratio of waterway to road distance. Notice that the ratio of waterway to road distance has no direct effect, but it does have a significant interaction effect. The quantitative impact of fly boats and the ratio of waterway to road distance is shown in the text.

Table B3: Heterogeneity I: waterway to road distance and competition effects

	All road carrier services	All road carrier services
VARIABLES	IRR (std. error)	IRR (std. error)
Vessel indicator	0.834	0.885
	(0.151)	(0.145)
Barge indicator	0.152	0.993
	(0.085)***	(0.172)
Barge indicator*(water distance/road distance)	3.151	
	(1.149)***	
Fly boat indicator	0.569	0.138
	(0.069)***	(0.080)***
Fly boat indicator*(water distance/road distance)		2.370
		(0.893)***
water distance/road distance	0.869	0.860
	(0.089)	(0.092)
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 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 B4 reports the coefficients for the models that interact fly boats and barges with a 2^{nd} degree polynomial in road distance. The dependent variable is wagon carrier services. Distance and its interactions have significant effects. The quantitative impact of fly boats and route distance is shown in the text.

Table B4: Heterogeneity II: Route distance and competition effects

	wagon carrier services only	wagon carrier services only
VARIABLES	IRR (std. error)	IRR (std. error)
Vessel indicator	0.787	0.742
	(0.141)	(0.123)
Barge indicator	3.275	0.924
	(2.524)	(0.122)
Barge indicator*road distance	0.989	
	(0.006)	
Barge indicator*road distance*road distance	1.000018	
	(0.000012)	
Fly boat indicator	0.351	4.273
	(0.051)***	(2.289)***
Fly boat indicator* road distance		0.979
		(0004)***
Fly boat indicator* road distance* road distance		1.000033
		(8.13e-06)***
road distance	0.973	0.959
	(0.010)***	(0.0148)***
road distance* road distance	1.000059	1.00009
	(0.000025)***	(0.00003)***
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 the number of weekly wagon services between a major city and London. IRR is the incident rate ratio. Bootstrap standard errors are reported in column 2 only. *** p<0.01, ** p<0.05, * p<0.1

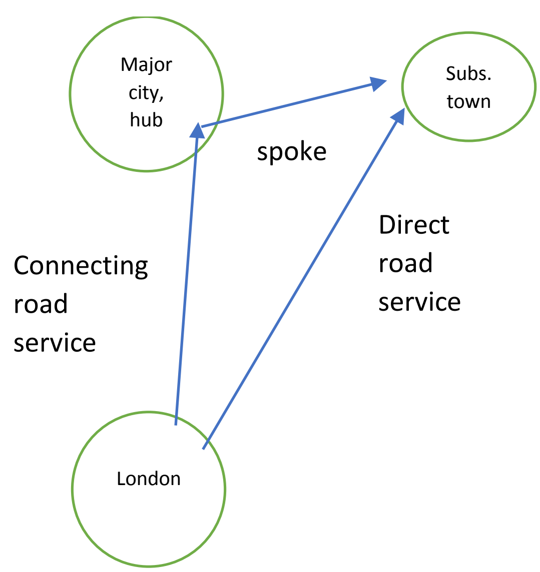
Online Appendix for Canal Carriers and Creative Destruction

Dan Bogart, Michael Lefors, and A.E.M. Satchell

Hub and Spoke Services between London and subsidiary towns

Many towns had road carrier services to London. Some of these connected to major cities through the hub and spoke system. Online appendix Figure 1 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.

Online Appendix Figure 1: Illustration of road services to subsidiary towns direct and through connections



In this appendix we examine road transport services to what we call subsidiary towns, near the 53 major cities and towns. 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 a reasonable subsidiary to each major city. They are listed in online appendix table 1. 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.

Online Appendix Table 1: List of 53 major cities that served as hubs and the subsidiary city

City	Its subsidiary city	City	Its subsidiary city	City	Its subsidiary city
Rochester	Maidstone	Norwich	None	Newcastle	Sunderland
Canterbury	Ashford	Warwick	Stratford	Worcester	Droitwich
Oxford	Bicester	Plymouth	Liskeard	York	Knaresborough.
Birmingham	Bromsgrove	Nottingham	Newark	Durham	
Bristol	None	Gloucester	Stroud	Halifax	
Bath	None	Chester	Mold	King's Lynn	Swaffham
Liverpool	Wigan	Sheffield	Rotherham	Yarmouth	
Colchester	Sudbury	Southampton	Romsey	Leeds	Bradford
Shrewsbury	Wem	Bury St. Ed.	None	Berwick	
Reading	Reading	Carlisle	Cockermouth	Chichester	Arundell
Ipswich	Basingstoke	Hull	Beverley	Ely	
Coventry	Hinckley	Kendal	None	Boston	Sleaford
Manchester	Oldham	Macclesfield	Buxton	Bedford	Sandy
Portsmouth	Fareham	Taunton	Bridgwater	Lincoln	Horncastle
Cambridge	Newmarket	Derby	Ashbourne	Banbury	Shipston
Northampton	Daventry	Hereford	Bromyard	Frome	Bruton
Exeter	Tiverton	Lichfield		Cirencester	Tetbury
Leicester	Melton M.				
Salisbury	Amesbury				

Sources: see text.

The method for counting road carrier services is slightly different for subsidiary towns. 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 online appendix figure 2 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.

Online Appendix Figure 2: 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. ſ.* M. 9; Poſt Wa. bull and mouth, near alderſgate, daily, A. 4

Boſton [Lincoln. 114] C. ſaracen's head, ſnow-hill, *m. w. ſ.* A. 4; Wa. horſeſhoe, goſwell-ſtreet, *w. ſ.* M. 10; bloſſom's inn, lawrence-lane, *t. f.* A. 2; vine, biſhopſgate within, *w. ſ.* N. 12; Poſt Wa bull and mouth, near alderſgate, daily, A. 4; Veſ. gun and ſhot and ſtanton's wharfs, ſouthwark

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

How did fly boat services affect road services to subsidiaries? We address this question using the same difference in differences framework used in the main text. 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.[57] 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 online appendix table 2. 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-

[57] 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.

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).

Online Appendix Table 2: 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)
Barge indicator (to nearest major city)	1.127	0.980
	(0.483)	(0.374)
Fly boat indicator (to nearest major city)	0.102	0.728
	(0.069)***	(0.297)
Vessel indicators	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
Observations	166	195
Prob > chi2	0.000	0.000
Number of cities	38	39

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

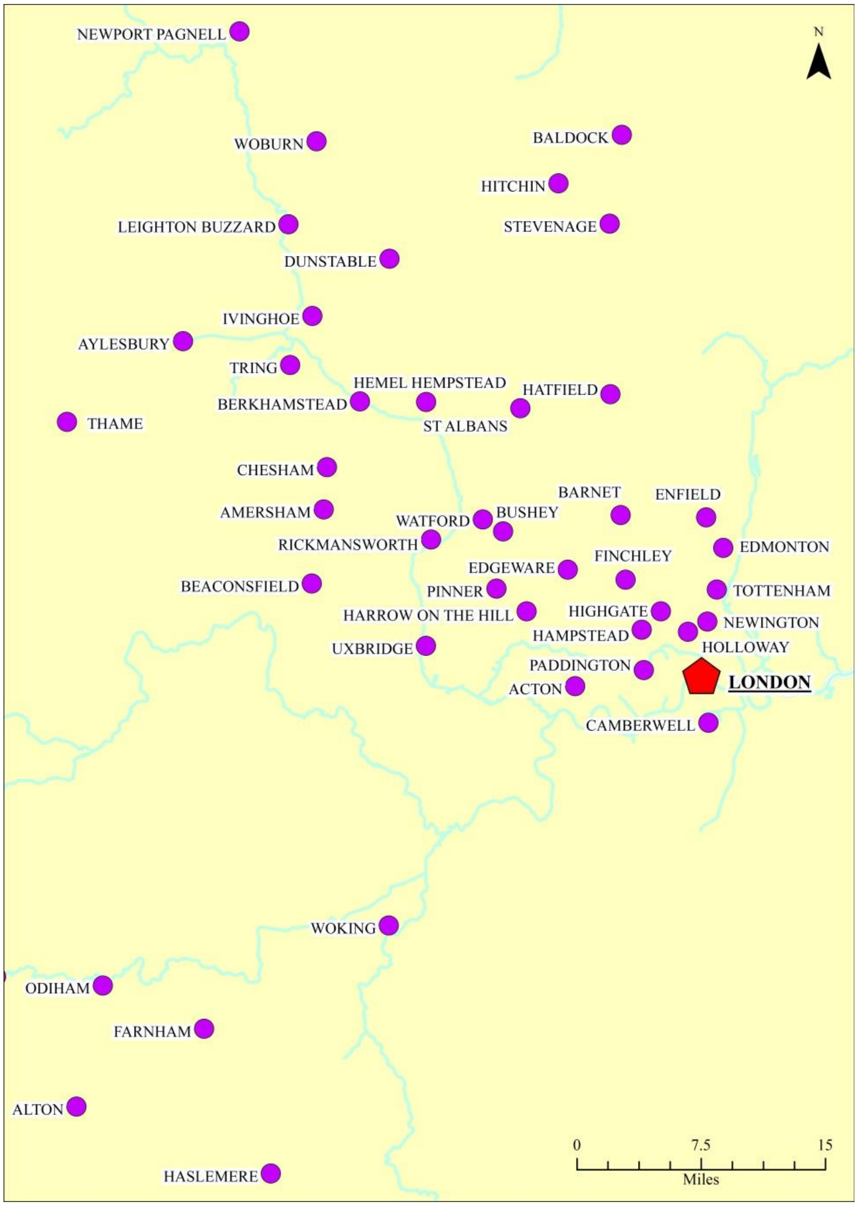
The broader implication is that fly boats had further displacement effects through the hub-and-spoke structure. When a fly boat service was introduced to a major city, it not only reduced road freight services to the major city, it also reduced connecting services to nearby towns operating through spokes.

Short-distances services between London and towns within 50 miles

We examine how inland waterway services affected road freight services in a sample of towns within 50 miles of London. We focus on 43 market towns on or near the Grand Junction and Basingstoke canals. Both canals were important links from London to the northwest and southwest. The two canals and the sample towns are shown in appendix figure 4.1. The Thames is the other major waterway shown in the middle left of the map. It is less interesting for our purposes because most towns on the Thames already had a barge service in 1779.

Here we face a double-listing problem, in which listed services to some smaller towns contain services destined for larger towns elsewhere. As a refinement, we use information in the 1800 Tradesman's Assistant which lists all carriers and their main destination (1800 is the first time such information is provided). 27 of the 43 towns in the short distance sample are found to be a main destination for at least one carrier. This sub-sample is arguably less affected by the double listings problem. Online appendix table 3 lists the towns included in the short distance sample and which ones had direct services.

Online Appendix Figure 3: Sample cities near the Grand Junction and Basingstoke canals



Online Appendix Table 3: List of 43 sample towns in London hinterland

Town	Towns with at least one carrier with a main destination in 1800	Distance to London in miles
Acton	1	5
Alton		47
Amersham		26
Bbarnet		12
Basingstoke	1	48
Berkhampstead	1	26

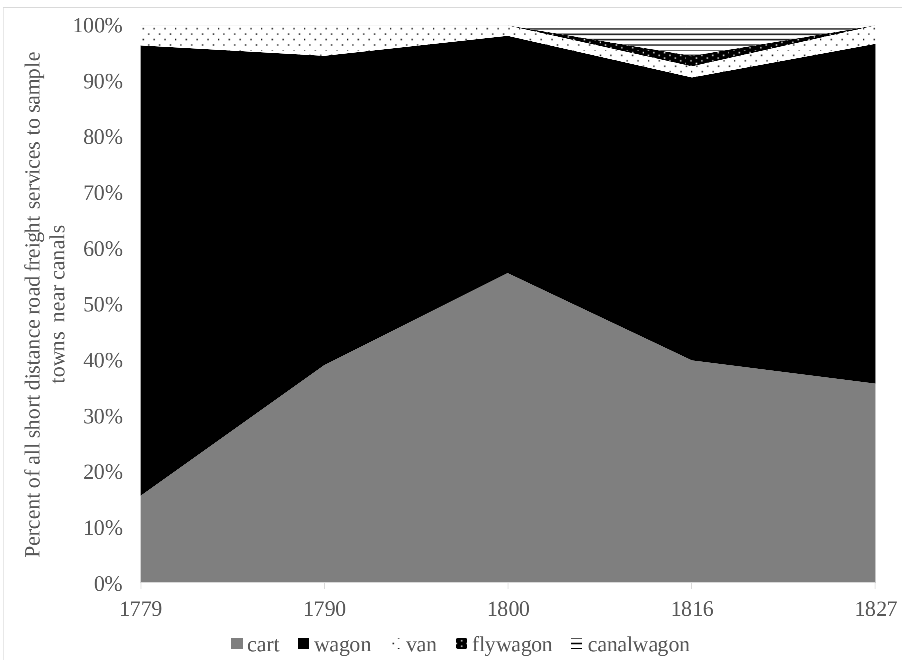
Bushey		12
Camberley or Camberwell		4
Chesham	1	29
Edgeware		8
Edmonton	1	6
Enfield		11
Farnham SY	1	37
Finchley		7
Hampstead		4
Harrow on the hill	1	9
Haslemere		43
Hatfield	1	20
Hemel Hempstead	1	23
Highgate	1	3
Holloway		
Newington	1	3
Odiham		41
Paddington		3
Pinner		14
Rickmansworth	1	17
St. Albans	1	21
Tottenham		5
Tring	1	31
Uxbridge	1	14
Watford	1	14
Woking SY		27
Ivinghoe	1	33
Leighton buzzard	1	41
Newport pagnell	1	51
Aylesbury	1	43
Beaconsfield	1	27
Baldock	1	38
Dunstable	1	34
Hitchin	1	24
Stevenage	1	32
Thame	1	44
Woburn	1	42

Sources: London directories, see text.

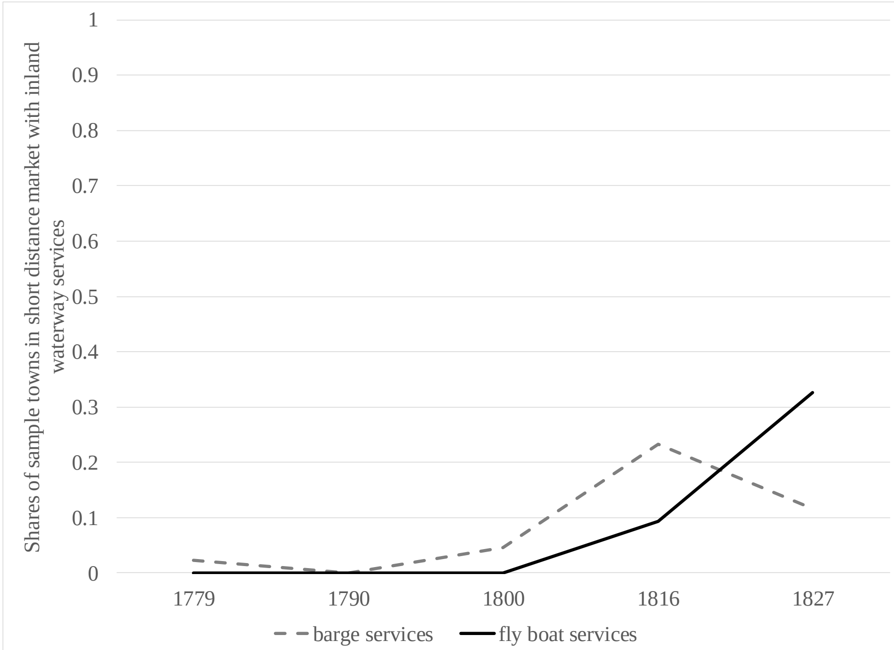
Online appendix Figure 4 shows the percentage of long distance services of different types from London to the sample of smaller towns near canals. Wagons are most common in

1779 and 1790 and by 1827. But carts become more common over time. There are far fewer van, fly wagon and other express services in the short-distance market. Appendix figure 5 shows the diffusion of waterway services in the sample of towns with short distance services to London. The levels of diffusion for barges and fly boats are lower. Also fly-boat services are slower to diffuse and appear more often in 1827. Recall that in long distance services fly boats appear more often in 1816.

Online Appendix figure 4 Share of town cities less than 50 miles from London with different types of road freight services to London



Online Appendix Figure 5: Share of cities with different types of waterway services to London



Source: see text.

The empirical model for studying the effects of fly boats and barges on short distance carrier services is the same in the main text. We use the conditional fixed effects negative binomial model to test how barges and fly boats affected the number of weekly road carrier services between the sample small towns and London. The results are shown in online appendix table 4. The introduction of barges and fly-boats did not significantly affect road carrier services according to the baseline model in column (1). In column (2) the pre and post variables suggest a more nuanced story. Short distance road carrier services increased significantly one period before fly-boats were introduced. In other words, fly-boats were introduced when road freight services already started to increase. In column (3) the same analysis is run for towns having a main destination for at least one carrier in 1800. While smaller, this sample is more reliable in terms of double-counting. Here the results are similar except road freight services did not significantly increase before fly boats.

Turning to barges, road carrier services in the short distance market increased after they were introduced and not before, but the effect is not statistically significant. In column (3) using the smaller sample of towns the increase is larger. It is difficult be conclusive here, but this could indicate a positive external effect of fly boats in this market. The overall conclusion is that barges and fly boats did not displace road carrier services within 50 miles of London.

Online Appendix table 4: Pre and post effects of inland waterways on road freight services: London to towns within 50 miles

VARIABLES	All short distance towns (1) IRR (std. error)	All short distance towns (2) IRR (std. error)	Short distance towns having main destination for at least one carrier (3) IRR (std. error)
Barge indicator	1.209 (0.237)		
Fly boat indicator	0.810 (0.170)		
One period before barge starts		0.917 (0.153)	0.861 (0.146)
Period barge starts		1.059 (0.217)	0.973 (0.259)
At least one period after barge starts		1.631 (0.525)	2.101 (0.555)***
One period before fly boat starts		1.327 (0.178)**	1.276 (0.238)
Period fly boat starts and after		0.979 (0.192)	1.038 (0.274)
Vessel indicator	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	200	200	135
Prob > chi2	0.000	0.000	0.000
Number of cities	42	42	27

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