Received: 14 April 2020 | Accepted: 29 October 2021

DOI: 10.1111/ecin.13060

ORIGINAL ARTICLE

Economic Inquiry

# Organizations and efficiency in public services: The case of English lighthouses revisited

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**Funding information**
National Science Foundation, Grant/Award Number: SES-1260699; Keynes Fund, Faculty of Economics, University of Cambridge, Grant/Award Number: Transport, policy, and the British industrial revolution, 1680-1911; Leverhulme Trust, Grant/Award Number: RPG-2013-093

**Abstract**

Foundational debates about public service provision originate with the study of private lighthouses in England and Wales. We provide a new empirical assessment of cost and technical efficiency of competing lighthouse organizations in the early 1800s. Those with more private control charged ships higher fees and had greater operating costs. Lights with more local representation and funding provided lights of more local use and were most cheaply maintained. Our results help explain why government promoted nonprofit organizations to run lighthouses over private operators. We provide new insights into the role of private enterprise and nonprofit organizations in public service provision.

**KEYWORDS**
lighthouses, organizations, public services, reform, state capacity

**JEL CLASSIFICATION**
O17, 018, 038, 052, H11, H23, H41, H44, H83, N23, N43, N73

## 1 | INTRODUCTION

Lighthouses are one of the oldest public services and much lore has grown up around some magnificent examples. But in economics, lighthouses are prominent because of a debate about public goods. Several economists argued that lighthouse services were non-rivalrous and non-excludable, making them a classical example of a public good.[1]

**Abbreviations:** ATE, average treatment effect; ATET, average treatment effect on the treated; LAN, light aids to navigation; OLS, ordinary least squares; PSM, propensity score matching; SC, select committee.

**Managing Editor:** Nicolas Ziebarth

Coase (1974) disagreed and noted that in England private entrepreneurs built early lighthouses and charged ships entering ports after determining which they had passed on their voyage. Coase started a new literature on which organizations best provide lights in various contexts.[2] The major themes are also linked to the efficiency of public services more generally. Key issues in this literature concern (i) fragmentation versus consolidation of competencies within different levels of public authorities,[3] (ii) profit versus non-profit motives,[4] (iii) representation of local interests and local tax collection,[5] and (iv) bundling of different public services.[6]

This article uses new data to study how organizations impacted lighthouse efficiency in early 19th century England and Wales (henceforth, England). In most countries, lights were provided by a national and public authority and funded using general tax revenues or a uniform tonnage duty upon entering a port (e.g., France had this system from 1792). England was different, where an evolutionary process led to three types of lighthouse providers by the early 1800s. Trinity House of Deptford Strond or "Trinity" was the leading organization. Trinity was a seaman's guild responsible for providing seamarks and financial relief to disabled seamen going back to 1514. Starting in the 1600s, royal patents gave Trinity the authority to collect so-called light dues at ports along the coastline. Trinity gradually built a portfolio of lights, each with its own light dues, and by the early 1800s these fees were a key financial source for its charitable aims.

While Trinity was recognized as an early leader, the demand for lights appears to have been greater than it was willing to supply (Stevenson, 2002). As a result, several individuals obtained royal patents to build lighthouses and collect light dues. They are often referred to as "private" to distinguish profit-seeking actors from charities, or non-profits such as Trinity (Bertrand, 2006; Block & Barnett, 2009; Lindberg, 2013). Privates built most of the lights in England during the 1600s and 1700s with their own resources, and they bore substantial risk.

Harbor authorities were the third provider type, which rose to prominence in the late 1700s and early 1800s. Created through local acts of parliament, these were trusts or commissions with jurisdiction in a particular port. Harbor authorities were different in several respects. First, their perspective was local, as they generally represented the port's mercantile shipping interests. Second, they collected tonnage dues in a single port, preventing them from charging passing ships like Trinity and privates. Third, they "bundled" light provision with broader responsibilities to provide piers, docks, and wharves.

The English monarch and parliament did not play a direct role in developing most early lighthouses outside of the legal structures for patents and acts. The central government's role changed though in the 1820s. There were complaints light dues were too high, and resources were being wasted on collection. A series of parliamentary Select Committees called for change, culminating in a major intervention in 1836. In that year, a new law forced all remaining privates to sell to Trinity. Afterward, Trinity was the main provider of lights alongside harbor authorities, which operated independently for many decades.

In this article, we study this organizational variety and provide the first detailed estimation of how light due rates, costs, and technologies were affected by control under different organizational types. We use a Parliamentary Select Committee (SC) Report in 1834, which classifies lights by organizational type and gives financial data in the early 1830s. The lights in the SC report are digitized and then linked with a new geospatial dataset called LAN, short for Lights and Aids to Navigation in England and Wales from 1514 to 1911.[7] This novel database gives the location and characteristics of English and Welsh historical lighthouses.

The new data are used to compare Trinity and private lights around 1832, when the historical sources are most detailed and just 4 years before the law transferring all remaining privates to Trinity. Trinity is shown to be dominant in certain technologies, like light vessels. If those are excluded, private lights were broadly like Trinity in terms of height and visibility range. In comparing light due rates and operating margins, our expectation is that they will be higher for private lights because of their sharper profit motive. A comparison of unconditional means shows that rates and margins are indeed higher for private lights. These results are also supported by regressions described below that flexibly control for light location and year of construction. We also show that within the same ports, commission rates paid to Trinity light due collection agents were lower than rates paid to private agents. We believe this difference follows from Trinity's larger network size, which gave it greater bargaining power, and from Trinity's greater use of an existing network of customs officials.

We also compare Trinity and privates with harbor authorities around 1832. Based on their structural differences in financing, representation, and service bundling, harbor authorities should provide lights closer to ports and of more local use. The data confirm that harbor authority lights were indeed closer to ports, shorter, and less visible on average. Also, maintenance costs per mile of visibility were lower on average for harbor lights than for both privates and Trinity. Some of this is due to different light locations and technologies, but the finding of lower harbor maintenance costs holds, even after controlling for them.

The last section focuses on the impact of government reforms. We study the evolution of light due rates for consistent groups of private and Trinity lights starting in 1820. Across all groups, it is shown that rates were lower and less variable by 1844. But going into detail, we find that light due rates fell for private and Trinity lights from 1820 to 1834. This is striking because it was a period of increasing pressure for reform, but no major government intervention had yet occurred. By comparison, light due rates changed very little from 1834 to 1844, which is the period after an 1836 act transferred all remaining privates to Trinity. One explanation is that Trinity and some privates tried to demonstrate their efficiency to the government in anticipation of regulation. Those incentives were weakened after the 1836 law.

Revisiting the economic history of English lighthouses offers several insights for public service delivery more generally. First, Trinity's lower collection costs relative to privates speak to scale advantages in organizations. Second, privates' higher dues provide an example of how for-profit motives can undermine efficiency in public service delivery.[8] Third, harbor authority's choice of light location and characteristics illustrates how local representation can better match with local needs, which is one of the main advantages from devolution or decentralization. Fourth, harbor authority's more economical maintenance also illustrates how bundling of services can be more cost efficient, which is a lesson that can be applied in public-private partnerships.[9]

Our analysis also contributes to classic debates in the historical literature, such as whether Trinity or privates were more efficient. Bertrand (2006) argues that Coase over-stated the efficiency of privates, but Lindberg (2013, p. 543), in reviewing the literature, argues their efficiency differences have not been empirically demonstrated. In a series of articles Candela and Geloso (2018a, 2018b) argue that Trinity's rise, and specifically its dominance in light vessels, was based more on politics and rent seeking. We should also add for emphasis that harbor authorities have not entered this historical debate on lighthouse efficiency. Our analysis begins to address that omission.

We show, based on separate analysis of light characteristics, pricing, and costs that Trinity and harbors outperformed other private organizations by the early 1830s. From 1820 the government put pressure on privates and Trinity to reduce perceived excessive rates charged to shipping. Trinity responded, whereas other more entrepreneurial private owners did not. Government finally intervened in 1836, enabling Trinity to take over remaining competing private lighthouses. Harbor authorities were left to develop largely alone.

Why were Trinity and harbors promoted? Our view is they shared a common beneficial trait, which was that neither aimed to maximize profits from light fees—unlike private lights. Rather they provided lighting incidentally to foster wider aims. For Trinity the aim was to benefit the national, mercantile shipping community, which as seaman, were also its members. For harbors, the aim was to benefit local shipping. Trinity and harbors were more efficient because their profit motivation was secondary to such broader aims.

Finally, this article also speaks to the impacts of the government reform in England. The 1836 law has been featured in several studies (Lindberg, 2013; Taylor, 2001), but its impact is not clear. We provide the details of its effect and the surprising impact of pressure for government regulation in the 1820s. More generally, this episode speaks to the evolution of state capacity in England, which is found to be different than other countries before the 20th century (see Johnson & Koyama, 2017).

## 2 | BACKGROUND

We refer to different types of coastal light from harbor lights on piers, docks, or beaches, to towers on cliff tops or lower down near shorelines. Some possessed keepers' houses, but not all. Some had two or three towers and were "leading lights." Light vessels or lightships were another type, different in being manned seaborne lights anchored at a specific point. They could be placed in areas where it was impossible for lighthouses to act as efficient seamarks (Candela & Geloso, 2018b, pp. 485–486).

By the time of our analysis, in the early 1830s, the established lighting technology was based on the Argand lamp. This featured a hollow wick and glass chimney that produced a smokeless steady flame (Hague & Christie, 1975, p. 154; Naish, 1985, p. 105). The efficiency of the lamp was improved by its suitability with parabolic reflectors that amplified and focused the light from multiple oil burners (Stevenson, 2002, p. 231). In optimal conditions, lighthouses with Argand lamps could generate visibility of up to 20 miles, which was a big improvement over earlier open coal fires or reflected candles. Naish (1985, p. 105) estimates that Argand lamps were installed in 80%–90% of general coastal British lights between 1782 and 1823, making this technology the key to mass illumination of the coastline. But lights with more local use did not necessarily have Argand lamps. Their visibility ranges were therefore lower.

## 2.1 | Funding and running lighthouses

Various costs went into building, maintaining, and in some cases collecting dues for a lighthouse. The state-of-the art construction cost around 1830 was approximately £3000 to £6000.[10] They were expensive to build compared to some capital goods in the English economy, like steam engines, but pale in comparison to larger projects like canals and dock works.[11] Maintenance costs for lighthouses were not small, and could be £500 to £1000 a year, covering fuel, lightkeeper wages, and repairs.[12] Location would have been one determining factor. Some places had higher wages or more expensive fuel. But organizational structure had some influence too, as we argue below.

Perhaps the most difficult challenge was collecting dues from ships that used the light. The legal authority to collect "light dues," and at what rate, varied. However, in all cases a person needed to be posted at a port and collect dues from ship captains after they disembarked. Based on the ship's origin and destination, a coastal route was determined by the collector, and therefore which lighthouses were passed. Many lighthouse authorities contracted with an agent, who collected dues from ships for a percentage fee, usually between 5% and 20%. Variation in commission rates was partly a function of the local conditions, such as how difficult it was to force ships to pay, but it was also related to scale of the organization, since one agent could collect dues for many lights with similar effort as for a single light. Differences in commission rates will be a key focus in one section below.

### 2.1.1 | Light due rates and the shipping industry

Lights were clearly valuable to ships, and by the early 1800s sailing speeds and safety were much improved.[13] That said, light due rates were a significant cost to shippers. Hausman (1977) estimates they amounted to 4%–7% of total voyage costs in the coastal coal trade in the 18th century. As the profit margins were narrow, a 4%–7% tax could dramatically affect their business. Foreign shipping paid double the rate of coasters, meaning the burden to general shipping profits was likely higher. High light due rates also seem to have modified industry practices, including avoiding stops at small ports.

## 2.2 | Lighthouse organizations

Trinity House Deptford Strond (henceforth Trinity) came to be the most important organization providing lighthouses.[14] Trinity was an ancient guild. Its charter, renewed after political upheaval in 1685, appointed a Master, Wardens and Assistants, and 18 elder brethren, and prescribed the form of their election, and named the seamen and mariners belonging to the guild, called younger brethren. Trinity was granted various rights to tolls including pilotage, loadmanage, primage, lastage, and ballastage. Profits from these tolls were in large meant to be spent on its charitable activities, like payment of pensions to the families of deceased seaman or to the old or injured. Light duties were not originally conferred on Trinity, but rather granted iteratively by royal patents, and occasionally through parliamentary acts. Trinity built few lights in the 1600s and 1700s, but played a more direct role after the 1780s, including taking over privates (Stevenson, 2002).

Trinity's motivations in operating lights were multi-faceted. While sometimes described as "public," it was not truly public in the modern sense (Lindberg, 2013; van Zandt, 1993). The elder and younger brethren were primarily merchant ship captains or owners. Thus, Trinity presumably aimed to improve maritime safety for its own members. Its motives with respect to the level of light due rates were mixed. It needed sufficient revenues to run its charitable operations, but as merchants, the brethren would have wanted to keep dues low.

### 2.2.1 | Private providers

Besides Trinity, private persons utilized patents to build lighthouses and to collect light dues to fund them. Some of these patents were obtained by Trinity who leased to privates. In other cases, patents were obtained directly from the monarch or through acts.[15] These organizations have been described as entrepreneurial (Coase, 1974, p. 375). As early as the 1600s, petitions from local people fed-up with shipwrecks were drawn up to support applications from privates, who responded and took the initiative in often adverse conditions (Hague & Christie, 1975, p. 24; Harris, 1969, p. 184).

By the 1830s, the incomes of private lighthouse providers had grown to politically controversial levels. An 1834 parliamentary Select Committee focused on reducing the dues of the remaining private individual light owners. It recommended centralization of control in Trinity, which it noted as charging lower light dues than privates. In 1836, a key reform was enacted aiming to remove private profit from lighthouse financing and to reduce the costs to shipping. Parliament centralized much lighthouse ownership and management in Trinity, which meant it was handed sweeping powers and was backed by the treasury to buy out all private lighthouses and collect all light dues in England.

### 2.2.2 | Harbor authorities

Harbor authorities were another major provider of lights. They were commonly established by local acts of parliament, which covered general harbor and pier improvements. There were various subtypes, including joint stock companies, but commissions were the most common. According to Jackson (1983), harbor commissions built lights and port infrastructure to improve the commerce of the town and prevent accidents at sea. The Trustees of the Liverpool Docks are a prominent example. Founded in the early 1700s, the trustees were largely members of the municipal corporation, including the mayor and town council. Liverpool ratepayers—many of whom used the port—eventually gained greater say and a degree of control through enfranchisement during the early 19th century.[16] While not all harbor authorities evolved as in Liverpool, they generally served local mercantile shipping interests. They aimed to draw traffic to their port, unlike Trinity who served the national shipping interest. In that way they were competing.

Another key difference is that harbor authority funding did not utilize a patent enabling collection of light dues at different ports around England. Instead, most harbor authorities were authorized by acts to collect a fixed duty when ships arrived at a single port near their light. The acts also specified that harbor duties were meant to pay for piers and docks too. Thus, shippers were paying for a "bundled service": safe passage into the harbor and other infrastructure.

## 3 | DATA SOURCES

A key source is a SC report investigating British lights in 1834. It has over 600 pages of witness testimony and identifies each light then in existence.[17] As noted above, this SC made policy recommendations based on analysis of data presented in tabular form. We use their data and go much further by applying modern quantitative tools to study the effects of organizational type on various outcomes. The SC report was particularly concerned with classifying how each lighthouse was owned and managed. Concerning England and Wales, the Isle of Man, and the Channel Islands, five different types are listed: (1) under Trinity, (2) in private hands, on lease from Trinity, (3), in private hands, on lease from the crown, (4) in private hands under act, and (5) local and harbor.[18] We digitized the report's light list, including the name and organizational structure in which it was held. Group 1 is Trinity (meaning Trinity House Deptford). Group 2, 3, and 4 are combined into "private." Group 5, local and harbor, is heterogeneous as we discuss above, but descriptions in the 1834 report identify most as commissions created by acts, like the Liverpool Dock Trustees.[19] They are treated as one group—harbor authorities. In terms of total lights in 1834, Trinity had 55, privates had 14, and harbor authorities had 55.

The 1834 SC report gives light due rates for each Trinity light and several privates in the early 1830s[20] Rates in pence per registered ton are given, depending on British and foreign ships. Foreign rates were generally twice as high, and therefore, we focus on British ship rates without loss of generality. Light due rates for some privates were missing from the 1834 SC Report. To fill these gaps, we use a US Dept. of Treasury publication.[21]

Aside from light due rates, the 1834 SC report is particularly rich in describing financial outcomes in the year 1832. For each light under Trinity, it provides data on (i) gross revenues, (ii) total collection costs for light dues, and (iii) total maintenance costs.[22] From these, we calculate the operating margin, defined as gross revenue minus collection and maintenance costs, divided by gross revenues. Similar data are given for most private lights in the early 1830s. We combine these to create a cross-section of financial outcomes for individual Trinity and private lights around 1832.

The 1834 SC report additionally provides data on commission rates paid to Trinity agents in 99 ports and rates paid to private agents in 94 ports. We have digitized this data and standardized port names so that within port differences can be studied.[23] The report also gives agent names and for Trinity their affiliation with customs or other offices of state.

Harbor authority revenues and collection costs are not given in any report. However, there is data on their maintenance costs.[24] This category includes spending on wages for lightkeepers, fuel, and repairs but typically only the total is reported. Harbor authority maintenance costs are compared with the same category for privates and Trinity in 1832.

The 1834 SC report is less detailed when it comes to characteristics of lights. We think this omission is significant and has limited the inferences made by contemporaries and historians. This issue is addressed using LAN, whose main source are light lists, published by the UK Admiralty in various years, starting in 1831.[25] The lists are organized by lighthouse, although in some cases it details a cluster of lights operating jointly at a location. Often there is a main light which we focus on. The linking between sources is done by light name and location. We successfully matched 90 out of 92 LAN lights to English and Isle of Man lights in the 1834 SC report.[26]

Several light characteristics are drawn from LAN including (i) latitude and longitude, (ii) visibility range in miles in clear weather, (iii) height in feet measured from seawater, (iv) whether a light was attached to a vessel, (v) whether light was revolving or fixed, (vi) whether the lighthouse operated part time, and (vii) year light was erected. The year erected reported in the Admiralty list is generally the original construction year, or the year a patent or act was first awarded. In a few cases where Stevenson's (2002) definitive lighthouse history suggests it relates to the most recent remodel, we prioritize Stevenson's original construction year. The new variable is called "year light first built."

Figure 1 shows light location and visibility ranges for each of three organization types in 1831. There are 13 locations with private lights, 38 with Trinity, and 38 with harbor authorities. There are clear locational and technological differences. Privates tend to be on the east coast, harbors in the north, whereas Trinity lights were more scattered around the coast. Trinity and privates look to have similar visibility ranges, indicated by the size of the circle around each light, while harbors have far less visibility. Trinity was dominant in light vessels, which are show separately in

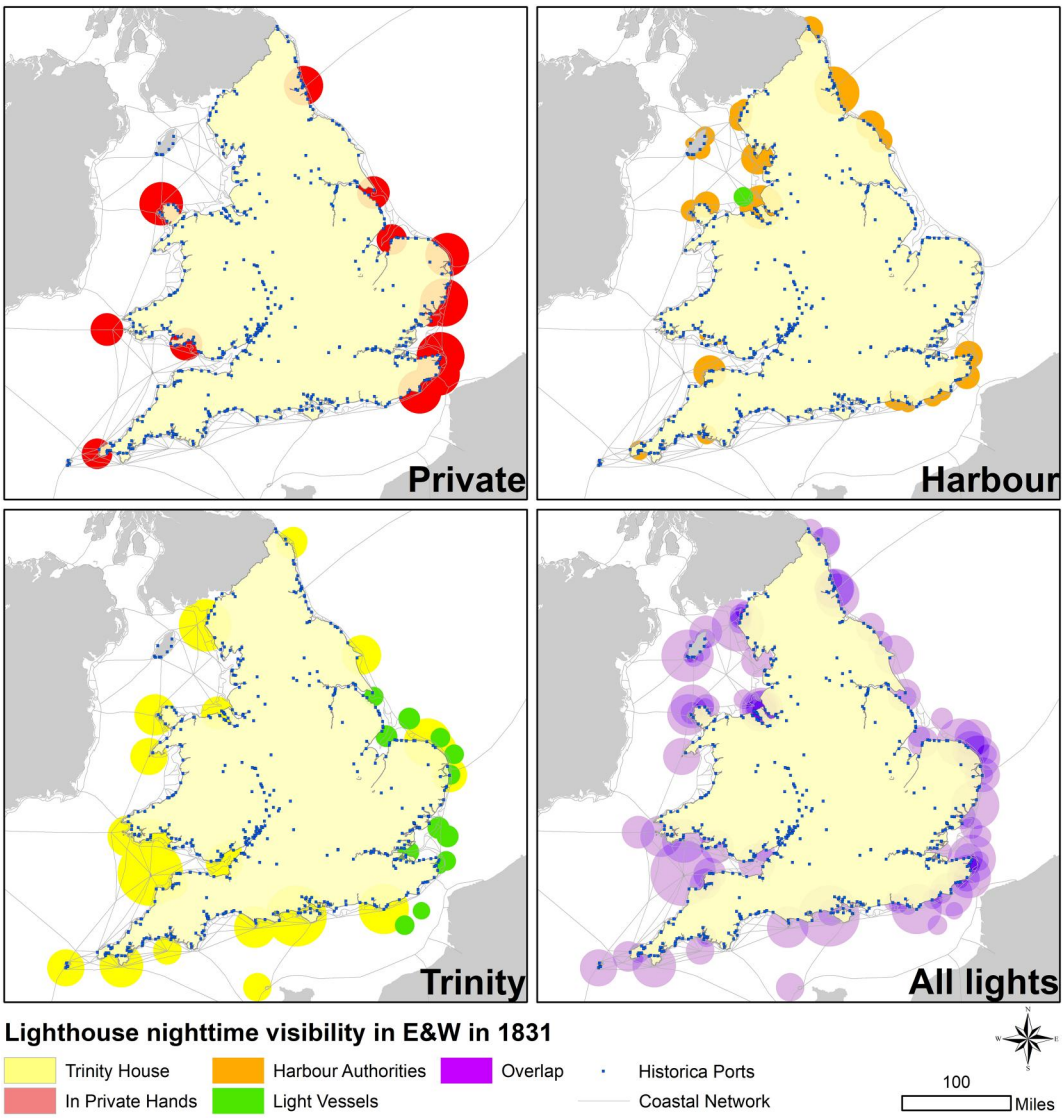


**FIGURE 1** Locations and visibility ranges of lights in 1831 by organizational type. Map created by authors using LAN and organization categories from 1834 SC report

green. The map in the lower right hand corner gives the visibility coverage of all lights. The southeast, near London, has the greatest coverage. The same for portions of the northeast and northwest coast, near Liverpool and Newcastle.

Figure 1 also shows all English and Welsh ports as blue dots (including river ports).[27] These ports were active at some point between 1540 and 1914. As ports are an indicator of services and economic activity, we calculate the distance from each light to the nearest port.

Table 1 gives average light characteristics in 1831 by organizational type. In addition to the patterns noted above, we see that Trinity was more likely to operate revolving lights than the other two. Harbor lights had lower heights, were more likely to operate part time, and were closer to ports. Private lights tended to be first built earlier in time. Conceptually, some of the technical differences, like having a revolving light, are a function of organizational type. Others, like latitude and longitude, might have determined which organization was selected. We will address these issues in our empirical methodology.

### 3.1 | Lighthouse data over time

Some lighthouse-level outcomes can be measured over a longer timeframe. An 1845 SC report gives light due rates levied on British ships for all Trinity lights in 1844, including the formerly private lights.[28] An 1823 SC report gives light due rates for each Trinity and several privates around 1820.[29] The 1834 SC report also has some retrospective data on light rates back to the early 1820s[30] We combine these sources to identify light due rates for 26 lighthouses at three approximate dates: 1820, 1832, and 1844. These will be divided into three groups based on when or if Trinity took control.

The 1845 SC Report gives data on maintenance costs for Trinity lights and harbor authorities in 1844. We matched these lights to LAN which draws on characteristics listed in the 1851 Admiralty list. The 1844 maintenance costs provide a check on the comparability of harbor and Trinity maintenance costs for 1832.

## 4 | THE EFFICIENCY OF PRIVATE VERSUS TRINITY LIGHTS

In this section, we show that in several performance areas private lights were less efficient than Trinity lights in 1832. There are several arguments which point to privates' relative inefficiency. First, using ideas from transaction cost economics, privates had "higher-powered" incentives to maximize profits. Most of the private light holders were lessees, who gained financially when their light was profitable. Therefore, they would benefit directly from charging higher light dues. By contrast Trinity was non-profit and hence its board members could not directly benefit from surplus revenues. Also, its constituents were merchant ship captains, who themselves would want lower rates. The constraint was that Trinity needed enough surplus to fund its charitable activities, like almshouses and pension payments. Overall, Trinity would seem to have less incentive to charge higher light due rates and should have less surplus revenue.

**TABLE 1** Average light characteristics by organization type in 1831

| Light characteristics vars. | Trinity | Private | Harbor |
|---|---|---|---|
| Indicator for light vessel | 0.34 | 0.00 | 0.03 |
| Indicator for revolving light | 0.29 | 0.08 | 0.08 |
| Visibility range in miles | 14.6 | 17.5 | 10.4 |
| Height measured from sea in feet | 127.6 | 140.4 | 58.0 |
| Indicator for part-time operation | 0.03 | 0.00 | 0.46 |
| Year light first built | 1774 | 1674 | 1794 |
| Latitude, Brit. nat. grid | 233.8 | 259.2 | 346.1 |
| Longitude, Brit. nat. grid | 437.6 | 470.6 | 375.8 |
| Distance to nearest port in km | 14.1 | 9.3 | 3.1 |

*Source*: See text.

A second argument relates to collection costs, which equaled all commissions paid to agents collecting light dues at ports. Each commission payment equaled the revenues collected multiplied by the agent's commission rate. The formula for collection costs implies that if private lights had higher revenues, possibly because of higher light due rates, then commission payments would also be higher. We call this the "revenue-collection cost link." The other component of collection costs, agent commission rates, could be lower or higher for privates. With greater revenues at a port, one could imagine that a light authority could bargain with agents for a lower commission rate. This would seem to favor privates if their lights had higher revenues. However, Trinity had a larger network of lights, and hence its agents often collected more revenues in total. So, instead Trinity might have bargained for a lower agent commission rate. We call the latter the "network size-collection cost link."[31] It is also possible that Trinity's political connections allowed it to employ customs officials as agents. The latter might have accepted a lower commission rate because they were more cost effective.[32]

Table 2 (Panel A) shows averages for all private and Trinity lights in several performance areas in 1832.[33] Note that some variables are divided by the visibility range in miles to capture costs or revenues per unit of service provided. Also, the percent of collection costs in gross revenues should be the average of all agent commission rates weighted by revenues collected at each port. Consistent with the arguments laid out above, private lights have higher light due rates, operating margins, and collection costs per mile of visibility. The differences are often quite large. For example, Trinity's average collection costs per mile of visibility are 30% of privates. Also note that Trinity's average light revenue per mile was 43% of the private average, which implies the revenue-collection cost link was large.

Trinity control might have led to higher maintenance costs because its members were ship captains, and therefore they wanted to provide a better service to their colleagues. Consistent with this argument, panel A of Table 2 shows that average maintenance costs per mile of visibility are much lower on average for private compared to Trinity lights. To investigate the role of technology differences, panel B of Table 2 excludes light vessels, where Trinity was dominant. Now maintenance costs for Trinity lights are closer to privates (yet still higher). It seems that light vessels were more expensive to maintain, which partly accounts for the difference in panels A and B. Regarding other performance dimensions, like light due rates, excluding light vessels does not change the conclusions.

One obvious question is whether differences in unconditional means, as reported in Table 2, are biased because of confounding differences in light characteristics. For example, it is possible that governments granted privates higher light due rates originally due to the risk of investment in a lighthouse to individuals, for example, in the 1600s. These rates became fixed in time even though they were wholly unsuited to unforeseen increasing ship numbers and size centuries later. As Trinity tended to build lights later than privates, perhaps governments granted them lower rates.[34] Therefore, it is useful to test whether light rates are lower under Trinity once year first built and other factors are controlled for.

**TABLE 2** Average rates, operating margins, and costs for private and Trinity lights in 1832

| **Panel A: All light types** | **Trinity** | **Private** | **Trinity/Private** |
|---|---|---|---|
| Av. light due rate in pence per ton | 0.392 | 0.672 | 0.58 |
| Av. Operating margin ratio (revenues-costs)/revenues | 0.446 | 0.768 | 0.58 |
| Av. light due collection cost (in £) per mile of visibility | 13.42 | 45.07 | 0.30 |
| Av. light revenues (in £) per mile of visibility | 171.8 | 399.3 | 0.43 |
| Av. 100*(collection cost/gross revenue) | 8.60 | 10.88 | 0.79 |
| Av. maintenance cost (in £) per mile of visibility | 78.84 | 33.83 | 2.33 |
| **Panel B: If not a light vessel** | **Trinity** | **Private** | **Trinity/Private** |
| Av. light due rate in pence per ton | 0.402 | 0.672 | 0.60 |
| Av. operating margin ratio (revenues-costs)/revenues | 0.475 | 0.768 | 0.62 |
| Av. light due collection cost (in £) per mile of visibility | 10.02 | 45.07 | 0.22 |
| Av. light revenues (in £) per mile of visibility | 122.4 | 399.3 | 0.31 |
| Av. 100*(collection cost/gross revenue) | 8.96 | 10.88 | 0.82 |
| Av. maintenance cost (in £) per mile of visibility | 44.62 | 33.83 | 1.32 |

*Source*: see text.

We use regression analysis to address concerns about such confounding factors. Our ordinary least squares (OLS) specifications flexibly control for the year first built, longitude, latitude, and distance to ports. Intentionally, technical characteristics, like range, height, being a light vessel, or being a revolving light are not used as controls. They were partly choices made by the organization once it set up the light. But technical characteristics can be confounders too, so we also consider sub-samples excluding light vessels and revolving lights.

Table 3 reports OLS coefficient estimates with robust standard errors.[35] The outcomes are like Table 2. The main explanatory variable is the indicator for Trinity lights. As harbor lights are excluded, the comparison group are private lights. One can flip the sign on regression coefficients to interpret privates relative to Trinity. One main finding is that after conditioning, light due rates in logs were between 0.40 and 0.49 lower for Trinity (see columns 1–3). The estimated

**TABLE 3** Differences between Trinity and private light due rates, margins, and costs c1832, OLS estimates

| | **Ln Light due rates** | | | **Operating margin ratio** | | |
|---|---|---|---|---|---|---|
| | **(1) Coeff (St. err.)** | **(2) Coeff (St. err.)** | **(3) Coeff (St. err.)** | **(4) Coeff (St. err.)** | **(5) Coeff (St. err.)** | **(6) Coeff (St. err.)** |
| Trinity 1 versus Private 0 | −0.488 | −0.424 | −0.396 | −0.266 | −0.224 | −0.296 |
| | (0.112)*** | (0.124)*** | (0.107)*** | (0.058)*** | (0.161)*** | (0.068)*** |
| Controls | Y | Y | Y | Y | Y | Y |
| Exclude light vessel | N | Y | Y | N | Y | Y |
| Exclude revolve light | N | N | Y | N | N | Y |
| *N* | 36 | 29 | 20 | 47 | 36 | 25 |
| $R^2$ | .559 | .633 | .761 | .298 | .308 | .387 |
| | **Ln collection cost per mi. of visibility** | | | **Ln revenues per mi. of visibility** | | |
| | **(7) Coeff (St. err.)** | **(8) Coeff (St. err.)** | **(9) Coeff (St. err.)** | **(10) Coeff (St. err.)** | **(11) Coeff (St. err.)** | **(12) Coeff (St. err.)** |
| Trinity 1 versus Private 0 | −0.934 | −1.070 | −1.205 | −0.860 | −1.002 | −1.104 |
| | (0.413)** | (0.426)** | (0.460)*** | (0.298)*** | (0.291)*** | (0.321)*** |
| Controls | Y | Y | Y | Y | Y | Y |
| Exclude light vessels | N | Y | Y | N | Y | Y |
| Exclude revolve lights | N | N | Y | N | N | Y |
| *N* | 46 | 34 | 23 | 47 | 36 | 25 |
| $R^2$ | .384 | .491 | .531 | .419 | .539 | .622 |
| | **100*(collection cost/gross revenue)** | | | **Ln maint. cost per mi. of visibility** | | |
| | **(13) Coeff (St. err.)** | **(14) Coeff (St. err.)** | **(15) Coeff (St. err.)** | **(16) Coeff (St. err.)** | **(17) Coeff (St. err.)** | **(18) Coeff (St. err.)** |
| Trinity 1 versus Private 0 | −1.988 | −1.971 | −1.934 | 0.481 | 0.259 | 0.300 |
| | (1.612) | (1.68) | (2.00) | (0.223)** | (0.216) | (0.255) |
| Controls | Y | Y | Y | Y | Y | Y |
| Exclude light vessels | N | Y | Y | N | Y | Y |
| Exclude revolve lights | N | N | Y | N | N | Y |
| *N* | 45 | 34 | 23 | 46 | 35 | 24 |
| $R^2$ | .297 | .285 | .325 | .419 | .356 | .539 |

*Note*: Controls include latitude, longitude, latitude*longitude, distance to port, year built, and year built^2. Robust standard errors are reported.

Abbreviations: OLS, ordinary least squares; St. err., standard error.

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Harbor lights are excluded.

effect gets smaller when light vessels and revolving lights are excluded, but nevertheless Trinity is found to charge much lower light due rates than privates. A 0.40 log reduction is nearly 50% less.

Turning to other results, operating margin ratios are between 0.22 and 0.30 lower for Trinity lights after conditioning (see columns 4–6). The higher mark-ups imply higher profits per unit of revenue. They also imply higher light due rates charged by privates were not offset by lower revenues or higher costs. The middle panel of Table 3 shows strikingly lower collection costs for Trinity. After conditioning, they are between 0.93 and 1.20 lower in logs. Much of this difference was due to higher revenues per mile as shown in (10)-(12), or the revenue-collection cost link. The bottom panel of Table 3 shows collection costs per unit of revenue were just under 2 percentage points lower for Trinity. But the differences are not statistically significant. The implications for interpreting agent commission rates will be discussed in the next sub-section. Lastly, maintenance costs per mile of visibility are lower for privates when all lights are considered. But they were not significantly different between Trinity and privates if light vessels are excluded.

As robustness, propensity score matching (PSM) is also used to address confounders. In this approach, organizational control by Trinity is the "treatment," and its selection is based on observables, like year built, longitude, and distance to ports. PSM estimates are reported in Appendix A and largely replicate OLS estimates (see supplementary files). For example, making a non-vessel Trinity light private (or the ATET) would increase their log light due rates by 0.49, a 63% increase.

The significant differences in light due rates and operating margins between Trinity and privates has two implications. First, they imply that privates charged users more than was necessary to cover fixed and operating costs. This means private were less efficient in this context, which confirms some of the critiques made by Bertrand (2006) against Coase's favorable description of private lighthouse provision. Second, the higher light due rates charged by privates had significant implications for the economy. We estimate that if all Trinity lights were held by privates in 1831, and hence equal to their higher average rate, then the overall average light due rate in England & Wales (weighted by each light's revenues share) would have been 0.705 pence per ton, instead of the actual rate of 0.615 pence per ton. In other words, light due rates paid across all ships would have been 15% higher, which would have reduced shipping profitability and likely raised transport costs in the wider economy. The 15% figure under-states the total effect since the revenue shares of Trinity lights would rise with higher rates. Also because of the revenue-collection cost link, collection costs would go up by approximately 1.5%, which is a pure deadweight loss. Overall, these counterfactual calculations illustrate the potential magnitudes of having a fully private light house system in the absence of Trinity, a nonprofit.

## 4.1 | Comparison of port-level trinity and private commission rates

In this section, we further examine collection costs as they speak to some of Trinity's structural advantages. Recall the percent of collection costs in gross revenues for Trinity lights was lower than privates by about 2 percentage points, but this estimate is not precise in Table 3. However, it is possible that imprecision is due to agent commission rates being lower where port-level revenues were higher. More generally, there could be some unobserved factors associated with the ports where private and Trinity agents operated.

To examine the organizational differences more closely, we use our port-level commission rate dataset obtained from the 1834 SC report. The specification is the following regression, $y_{ij} = \beta_1 \text{trinity}_i + \beta_2 \text{port}_j + \varepsilon_{ij}$, where $i$ is a lighthouse provider, which includes Trinity and five private owners reporting data, and $j$ is a port where dues are collected for $i$. The dependent variable, $y_{ij}$, is the commission rate for lighthouse provider $i$ in port $j$. In terms of explanatory variables, $\text{trinity}_i$ is the dummy for Trinity (the omitted group are the five privates reporting data) and $\text{port}_j$ is a fixed effect for port $j$. The standard errors are clustered on ports.

Table 4 shows the results where commission rates are measured in levels and natural logs. Focusing on columns (1) and (2), Trinity's commission rates are estimated to be 2.9 percentage points lower with no port fixed effects and 3.23 lower after controlling for port fixed effects. To help interpret these results note the average commission rate is 16.0% and the standard deviation is 4.3%. Thus, the Trinity control effect is reasonably large.

There could be various explanations as to why Trinity agents got lower commission rates than private agents. The 1834 SC report provides some support for the network size-collection cost link explained above. It recommended that Trinity should collect the duties on behalf of other lighthouse owners, including the Scotland based Northern Lighthouse Commission, to, "render the Collection at once more economical..." (SC 1834, p. xvi). The SC reported that 10 private light holders together had 682 separate light due collection accounts; contrastingly, Trinity had 102 separate accounts for collectors across its 39 lights (SC 1834, p. xvi). Some agents had multiple accounts across privates, but nonetheless it is clear that Trinity funded more lighthouses, with fewer agents. It had a scale advantage.

**TABLE 4** Differences in Trinity and private commission rates across ports c1831, OLS estimates

| | Commission rate in % | | Ln commission rate | |
|---|---|---|---|---|
| | (1) Coeff (St. err.) | (2) Coeff (St. err.) | (3) Coeff (St. err.) | (4) Coeff (St. err.) |
| Trinity (1 vs. 0) | −2.931 | −3.233 | −0.224 | −0.244 |
| | 0.473*** | 0.543*** | 0.033*** | 0.043*** |
| Controls | | | | |
| Port fixed effects | N | Y | N | Y |
| *N* | 358 | 358 | 358 | 358 |
| $R^2$ | .097 | .755 | .11 | .736 |

*Note*: Standard errors are clustered on ports.

Abbreviations: OLS, ordinary least squares; St. err., standard error.

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Agent names and occupations in the 1834 SC report are also revealing on Trinity's advantages in collection. It shows Trinity's agents were generally customs officers.[36] Private agents are given no occupation, but they were nearly always different from Trinity based on their names. Thus, it would seem Trinity had greater access to England's powerful fiscal bureaucracy, which probably helped it get lower commission rates. Our takeaway is that Trinity had a scale advantage, but we cannot rule out the impact of government connections.

## 5 | THE RELATIVE EFFICIENCY OF HARBOR AUTHORITY LIGHTS

In this section, we examine light and cost differences between harbor authorities on the one hand and privates or Trinity on the other. English harbor authorities have been largely ignored in the literature, and so this section gives the first evaluation of their relative performance. It also reveals how alternative funding and structural features mattered. Recall harbor authorities generally paid for lighthouses with harbor dues levied at a single port. This meant they could not collect from passing ships like Trinity and privates did with collectors around the coast. On this basis, we should expect harbor authorities to provide lights near ports where they could collect. We call this the "harbor dues effect." The incentives were compounded by a "harbor representation effect." The commissions and trustees which ran these authorities tended to be local shippers. As a result, they should have built lights more tailored to local needs. Harbor authorities should have also prioritized cost minimization since the financial burden was met by its close constituents and clientele. Principal agent problems, which could affect a large, national focused organization, like Trinity, were less relevant for harbor authorities.

Another key difference is that harbor authorities generally bundled lights with provision of docks, piers, and related services. In theory, bundling creates economies of scope and reduces the costs of any individual service in the bundle (Buso, 2019). In our context, Candela and Geloso (2019a) argue Trinity's bundling of lights with pilotage services had efficiency gains. They also suggest privates could have bundled if not stifled by Trinity (Candela & Geloso, 2019a). These arguments suggest harbor authorities may have provided lights at a lower cost because of bundling. For example, harbor authorities could procure fuel in greater quantity as it was used for lights and gas lamps in the harbor. They could use the same workers to repair lights and docks. The bundling activities of harbor authorities also suggests they would tend to provide lights near ports, where there was complementary infrastructure.

We find support for harbor dues, representation, and bundling effects in Table 1, shown earlier. The first key fact to recall is that harbor authority lights were closer to ports on average. Also harbor lights had on average lower heights, were less visible, and were more likely to have part-time operation, which suggest they were more useful to ships entering a harbor during an active season, rather than passing ships.

While the data show harbor authorities provided different light services than privates and Trinity, we should stress they were not entirely different: 25% of the Trinity and private lights had visibility ranges less than 14 miles, while 25% of harbor lights had ranges greater than 12.5 miles. Moreover, 25% of Trinity and private lights had a distance to ports less than 2.1 miles, while 25% of harbor lights had distances to ports greater than 1.5 miles.

An organizational map of lights (Figure 2) near the major ports of the northwest coast illustrates the differentiation in services, but also the potential overlap. Several lighthouse authorities are shown, and some, like Liverpool, controlled multiple lights. In some areas, harbors or Trinity dominated, like Isle of Man, Walney, and Bardsey. Bardsey is in the most isolated coastal region, and is a classic Trinity light, which provided remoter services to passing ships. But in other areas, harbor authorities, Trinity, and privates are close, and sometimes provided similar visibility ranges. Liverpool is one example of a harbor authority that provided extensive light range; and nearby there is a Trinity light, Point of Ayr, that did the same. Near Whitehaven, harbors and Trinity also overlap, but here Trinity's light was much more visible out to sea.

This map raises the question of whether lights providing relatively similar services were more economical under harbor authority control versus privates or Trinity. While there is limited information on harbor authorities, the 1834 SC report gives maintenance costs in £ around 1832, which we divide by visibility range to increase comparability. Excluding light vessels, the average maintenance cost per mile of visibility is 2.11 for harbor authorities and the average

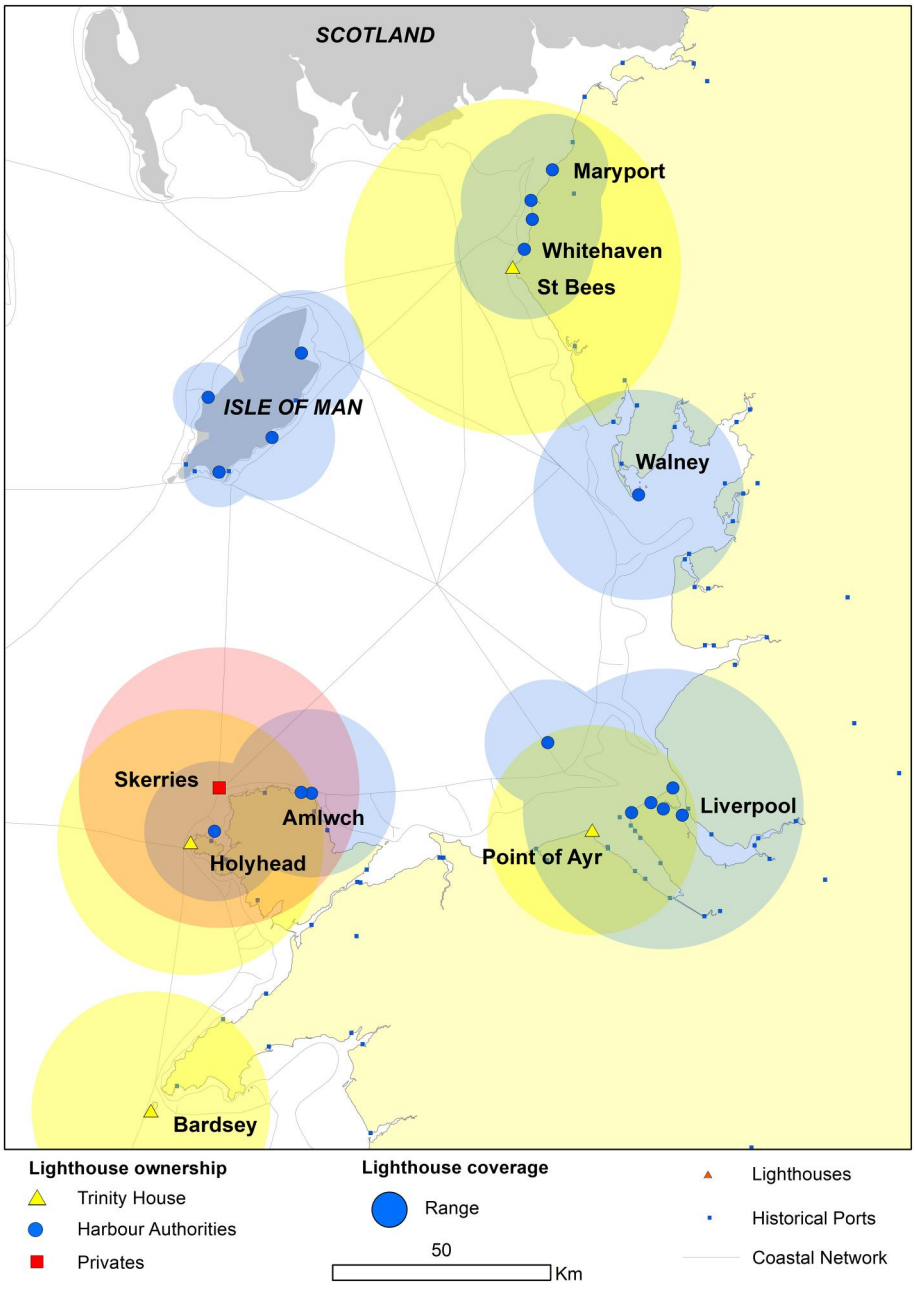


**FIGURE 2** Lights and organizations in the northwest of England, 1831. *Source*: map created by authors

for Trinity and privates is 3.53. In other words, harbor light maintenance costs per visibility mile were 56% of Trinity's level, which is a significant difference.

There are potential concerns about confounding differences between harbor, Trinity, and private lights. For example, harbor authorities were more common in the north, where industrialization was greater. Thus, light location might be a confounder, as could be distance to ports and year first built. Table 5 reports OLS estimates which address potential confounders and sample restrictions. Estimates in (1) to (3) show that in logs maintenance costs per visibility mile were between 1.02 and 1.21 lower for harbor authorities, depending on excluding revolving lights and those operating part-time. Excluding privates in (4) produces a slightly lower and less precise estimate.

Employing an alternative method, Appendix B reports PSM estimates, where harbor authority is the treatment (see supplementary files). To summarize, the average treatment effect in logs is a 1.59 reduction in maintenance costs per mile of visibility, and the average treatment effect on the treated (ATET) is a 1.16 reduction. A further robustness check replicates regressions in Table 5 using data on harbor authority and Trinity lights in the year 1844. The results shown in Appendix C more strongly favor harbor authorities. Their log maintenance costs per visibility mile is estimated to be between 1.36 and 1.61 lower and are significant. Finally, it is useful to remark on Mumbles light, which is the only one to switch from private to harbor authority between 1832 and 1844. In logs, Mumbles' maintenance per visibility mile was 0.68 *above* the overall average in 1832 when it was private. In 1844, after it had switched to a harbor authority, its log maintenance per visibility was 0.71 *below* the overall average.

Together these estimates suggest that given similar location and age of light, control by harbor authority organization led to maintenance costs savings. As a counterfactual, we estimate how much higher maintenance costs would have been if all harbor authority lights switched to Trinity or privates in 1832. The ATET estimate just reported suggest that total maintenance costs for all lights, except light vessels, would be 35% higher. While there would have been less economy in light maintenance, it is also likely that lights would have been more technically advanced and of higher quality if Trinity had taken over all harbor lights. We do not currently have the data to value these technical advances, but it is possible the economic gains from better Trinity lights would have outweighed the cost savings from harbor authorities. Future research may shed light on this.

## 6 | LIGHT DUE RATES IN THE ERA OF REFORM, 1822–1836

Limited government involvement in England's early lighthouse system contributed to the organizational variation we analyzed in the previous sections. This began to change in the early 1820s when government pressure for reform increased and eventually led to major intervention in 1836 where all private lights were transferred to Trinity.

**TABLE 5** Differences in Ln maintenance cost per mile of visibility for harbor authorities versus Trinity or private lights c.1832, OLS estimates

| | (1) Coeff (St. err.) | (2) Coeff (St. err.) | (3) Coeff (St. err.) | (4) Coeff (St. err.) |
|---|---|---|---|---|
| Harbor 1 versus Trinity and Private 0 | −1.186 | −1.217 | −1.018 | |
| | (0.329)*** | (0.422)*** | (0.556)* | |
| Harbor 1 versus Trinity 0 | | | | −0.942 |
| | | | | (0.634) |
| Controls | Y | Y | Y | Y |
| Exclude revolve light | N | Y | Y | Y |
| Exclude partial operation lights | N | N | Y | Y |
| Exclude private lights | N | N | N | Y |
| *N* | 62 | 48 | 35 | 25 |
| $R^2$ | 0.473 | 0.449 | 0.405 | 0.559 |

*Note*: Controls include latitude, longitude, latitude*longitude, distance to port, year built, and year built^2. Robust standard errors are reported.

*, **, *** indicates statistical significance at the 10%, 5%, and 1% confidence levels, respectively. Light vessels are excluded.

Lighthouse reform has been discussed by Taylor (2001), Bertrand (2006), and Lindberg (2013), but its impacts remain unclear. Therefore, it is useful to close our study with an analysis of how reforms contributed to changes in Trinity and private light due rates. It will shed more light on the role of government.

To give a brief background, the reform period began in 1822, when a SC issued a report investigating lighthouses. They concluded light dues were too high and the revenues of lighthouse authorities, including Trinity, were beyond what was necessary to maintain effective lights (p. 13). The 1822 SC report did not lead to any major intervention, but it signaled a potential restructuring of the industry if changes were not made (Taylor, 2001). Twelve years later in 1834 another SC report addressed lighthouses. They noted some reduction in rates and economies since 1822, but not enough. They boldly recommended private lights be transferred to Trinity (p. xxv). The SC anticipated that "large reductions" in light due rates and collection expenses would follow from eliminating private lights. They also expected reduced variation in light due rates around the coast (p. xxvii). In 1836, a major recommendation of the 1834 SC was followed, when an act implemented the Trinity takeover. The government used its powers of compulsory purchase, negotiating a transfer price for each private light. But it did not call for government funding. Instead, Trinity was forced to pay for the lights it now controlled by borrowing. These debts were not extinguished until the early 1850s (1845 SC report).

We now make clear how individual light due rates were affected by these reforms. Our first observations are for lights in 1820, just before the reform period began. There is limited information until 1832–1834, where we observe rates for many lights as shown earlier. The 1834 cross-section comes at the end of a period of increasing government pressure, but no major intervention. We can also identify a few lights that switched from private to Trinity by 1834 because long-term leases expired. The third date is eight years after the 1836 act and a good moment to evaluate the effects of this major intervention.

Lights are divided into three groups. The first group "Always Trinity" has 13 lights that were under Trinity in all three years. The second "Switchers I" had four lights that were private in 1820 and switched to Trinity by 1834 and remained under Trinity in 1844. The third "Switchers II" has nine lights that were private in 1820 and 1834, but then switched to Trinity by 1844 because of the 1836 act. Note we exclude light vessels from these groups because none were subject to ownership/control changes. Also, we exclude lights with missing rates in any year, or which came into operation after 1820. Thus, the composition of lights does not change in the three groups. In total, 26 lights are analyzed.

Histograms of light due rates for each group and year, along with the mean and standard deviation, are shown in Figure 3. They reveal substantial changes over time and across groups, especially from 1820 to 1834. In 1820 light due rates were highest for Switchers I and Switchers II, both of which included private lights only. The 1820 distribution of rates is also wide across and within groups.

Turning to 1834, light due rates are highest for Switchers II. As these were the only private group, this is consistent with what we found in previous sections. However, what is new and striking is that the mean light due rates declined for all groups to some degree from 1820 to 1834. The largest decline was for Switchers I, which is significant as they switched from private to Trinity. From the 1834 SC report, it can be established that the rates for three of four declined immediately after they came to be controlled by Trinity.[37] Rates also declined significantly for the Always Trinity group, particularly at the top end. But even in the Switchers II group there was some decline in rates from 1820 to 1834. Thus, even private lights reduced their dues in these years.

Regarding our last year, the data show that rates changed little between 1834 and 1844. One light in Switchers II lowered its rate; the rest were kept constant. That means rates changed little for these privates after the 1836 act switched them to Trinity. For Always Trinity and Switchers I light due rates did not change at all from 1834 to 1844.

A map showing light due rates in each year for the 26 lights reveals the changes in different coastal regions (see Figure 4). There is a wide distribution of rates in 1820 along the east coast, where much of the trade was focused on London. One could interpret the higher rate lights near London as "holding-up" shippers, since they had to pass by to reach the capital. Notably, by 1834, most of the high rates fell on the east coast and led to more uniformity or an end to the hold-up problem. On the southern coast, where most lights fell into the Always Trinity group, rates were more uniform in 1820 and changed little by 1834. The western coast was different. The rates were higher and remained more variable by 1844. For example, there were large rate differences on lights approaching Bristol and Liverpool.

Several conclusions emerge from this analysis. First, the period of reform was generally successful in reducing the average light rate and reducing the variation of rates across lights. Lower variation can be seen in the narrower

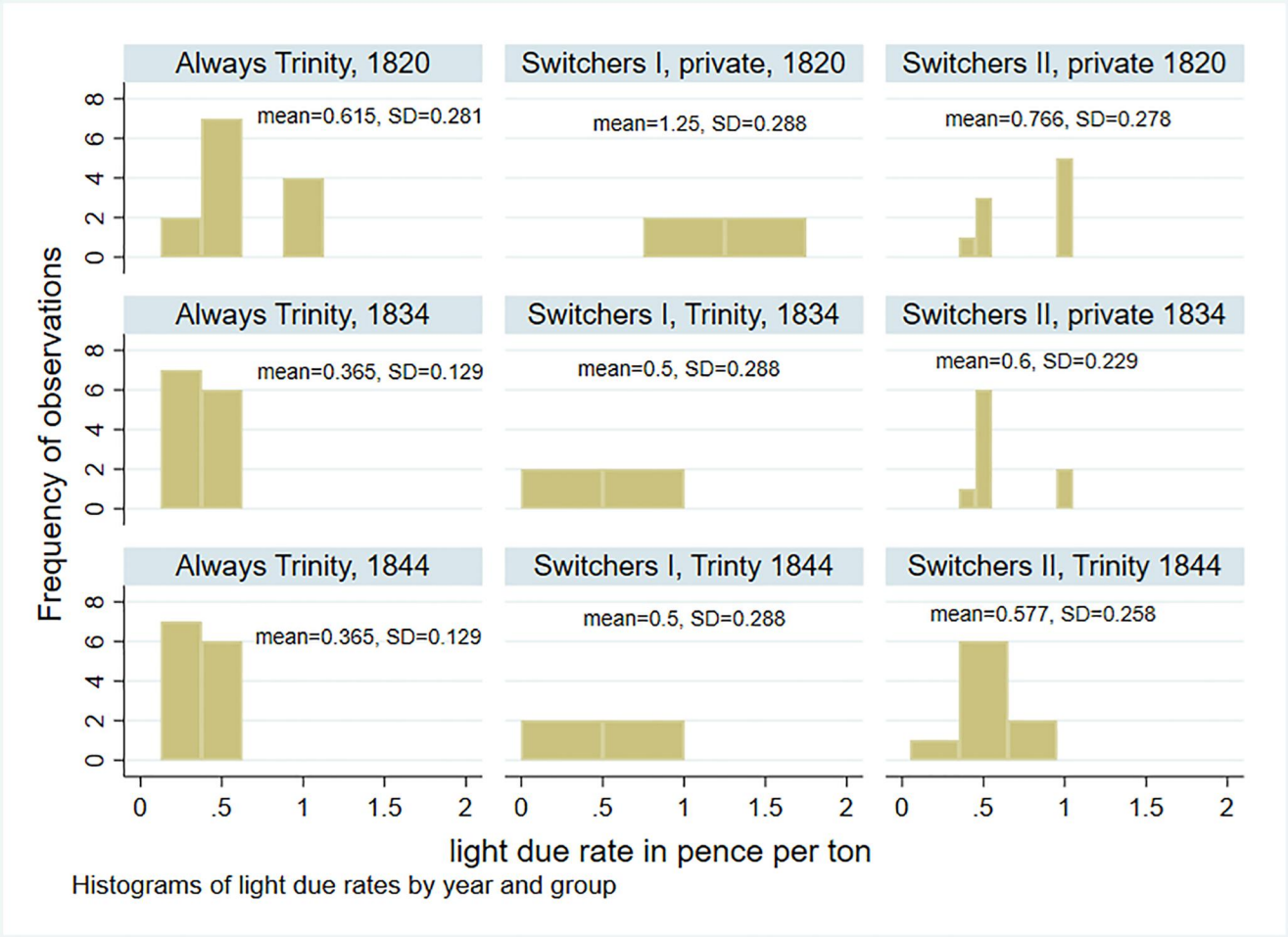


**FIGURE 3** The distribution of light due rates across groups in 1820, 1834, and 1844. *Source*: see text

distributions plotted in Figure 3 and across space in Figure 4. Second, the greatest decline and equalization of rates was from 1820 to 1834 before major intervention. Control changes for Switchers I lights contributed, but change was broader than in this group alone. While we cannot be certain, it seems the common element was the increasing government pressure for reform. In such a context, Trinity and privates may have voluntarily lowered rates as a demonstration of their potential. The 1834 SC report makes it clear that some government officials were noting which lighthouses had change their light due rates. Third, there is no clear effect of the 1836 takeover of privates. The anticipation that rates would fall for lights in the Switchers II group was not realized. The reasons why await future research, but it is worth noting that according to the 1845 SC report, Trinity did not lower rates further because it was forced to take on the large debts associated with the compulsory purchase of private lights (p. vii).

As it is of broader relevance, it is worth remarking on how the reform of light due rates speaks to England's particular evolution in state capacity. Most national governments in Europe were increasing their provision of public services in the 19th century, exploiting the fiscal development of previous centuries (Johnson & Koyama, 2017). But England's government did not follow this path as much as others, especially France. Instead, the English state chose to enable private actors, many of which had experience in providing such services and who represented local interests who demanded them (Bogart & Richardson, 2011; Harris, 2000; Lindberg, 2013). Trinity, privates, and harbor authorities exemplify this kind of state-private partnership very well (Lindberg, 2013). But this is not to say that English government never spearheaded change. As shown here, parliamentary SCs investigated lighthouses in the 1820s, and as a result it stimulated the large, non-profit, Trinity to change its light due rates. The English government also showed a willingness to use its powers of compulsory purchase by forcing a Trinity takeover of privates in 1836. While it did not immediately change light due rates, the 1836 act shows ways in which the English state sometimes restructured markets that had a significant element of public service provision.

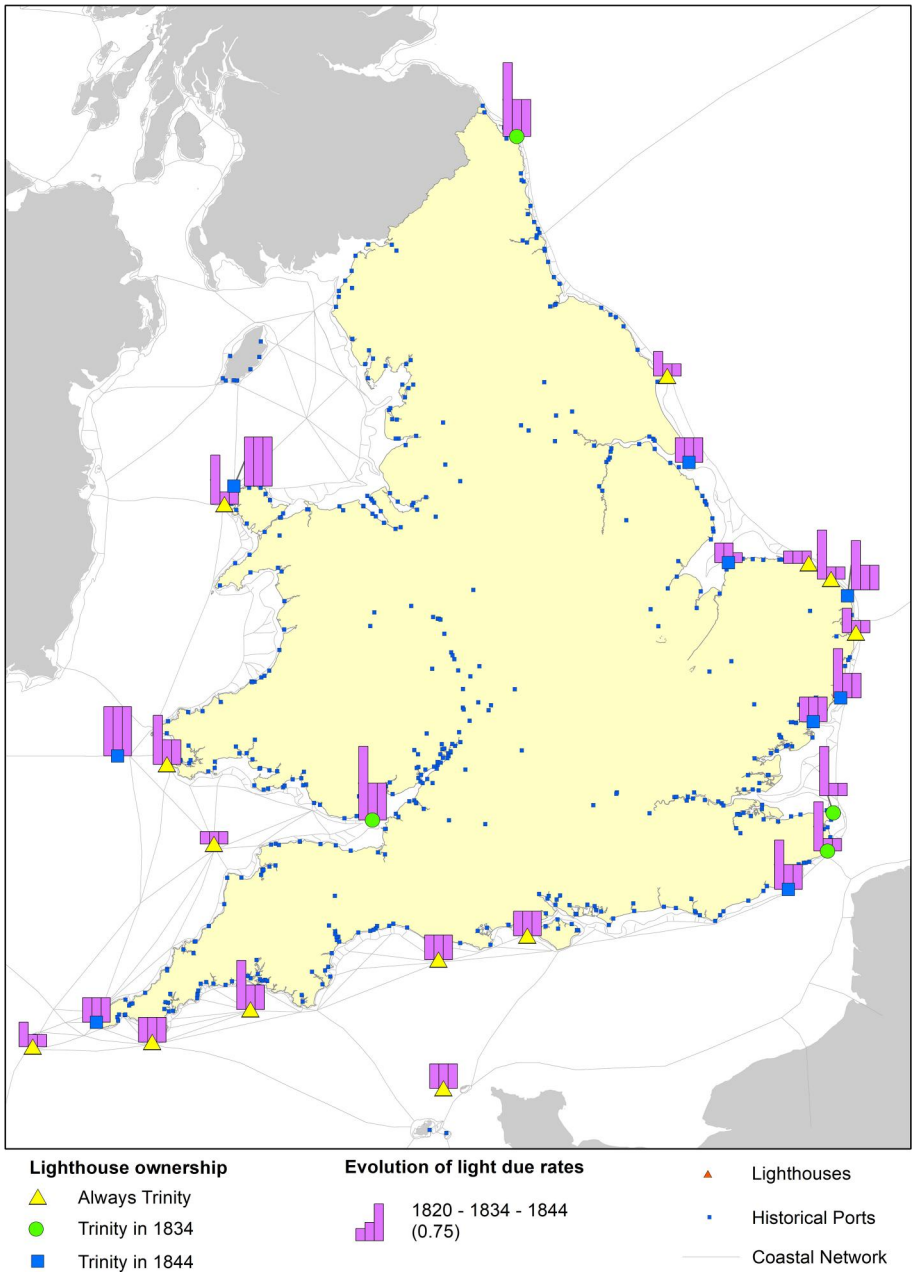


**FIGURE 4** Light due rates across groups and coastal regions in 1820, 1834, and 1844. *Source*: see text

## 7 | SUMMARY CONCLUSIONS

While much attention is paid to the benefits of public services, there are many questions concerning how they can be efficiently provided. A recurring issue concerns which types of organizations best provide public services. For example, many would argue that the private sector can be useful partners, but at the same time there are potential pitfalls. The private sector prioritizes profits, which can result in sub-optimal outcomes like exceptionally high fees (Engel et al., 2014). It has been further suggested that sub-national authorities should be involved, as they tend to provide services more in line with local demands (Kimenyi, 2018).

Starting with Coase's seminal paper, many issues central to public service delivery have been discussed in the context of English lighthouses during the first half of the 19th century. An evolutionary process led to three main types of lighthouse providers. Trinity was the leader by 1830, but privates had been crucial for centuries, and harbor authorities were emerging. Yet, no previous study has rigorously analyzed the differences between these three organizational types.

Our primary focus is on lighthouse fees, costs, and technologies in the early 1830s. We make use of new data drawn from a SC report in 1834 and a new geospatial dataset called LAN. Our analysis shows that privates and Trinity performed differently. One key finding is that privates had higher light due rates and operating margins, even after controlling for differences in light characteristics. Therefore, the most private, profit motivated, organizations were less efficient because they charged shippers more than was needed to cover their costs. We also show that in some cases harbor authorities provided similar lights to privates, but at a much lower maintenance cost. Together these results suggest that private involvement in lighthouse services resulted in some market failure.

Trinity and harbor authorities provided light on a non-profit basis as part of wider operations. If left to profit-seeking enterprise, the already high per-ton cost of lighting in 1820 would have continued to rise as shipping tonnages rose over the following decades. Our study shows how high costs can arise from private provision of public services. Here the solution to market failure was found by government pressure on private providers followed by actual regulation to exclude the less efficient. It should be noted that Trinity and some privates lowered light due rates between 1820 and 1834, and so it is possible that before 1820, when regulatory pressure was less, the efficiency differences between privates and Trinity were also less. Future research will need to address that issue.

This article also contributes to debates about how organizational features affect public service delivery. Trinity's lower collection costs relative to privates suggest consolidation of authority, enabling scale economies, is possibly beneficial. One caveat is that Trinity also relied on customs agents to collect light dues, which can be interpreted as an operational subsidy by the government rather than a scale advantage. Our finding that harbor authorities had the lowest maintenance costs is also revealing. While there are other potential explanations, it is noteworthy that harbor authorities bundled different public services. Future studies should identify bundling effects more carefully than we are able to here. Harbor authorities are further revealing of the potential gains that come from local representation. In sum, the optimal organizational structure involves a weighting of different aspects. Perhaps the most important lesson from our reassessment of English lighthouses is that one size does not fit all; multiple organizations can achieve better efficiency.

## ACKNOWLEDGMENTS

The authors thank Tom Perrigo and Elianna Proud for their research assistance and data collection. This article and supporting data were funded from a grant from the Keynes Fund at Cambridge University, Transport, policy, and the British industrial revolution, 1680-1911. Earlier grants from the Leverhulme Trust grant (RPG-2013-093) Transport and Urbanization c.1670-1911 and NSF (SES-1260699), Modelling the Transport Revolution and the Industrial Revolution in England helped develop prior data. We thank seminar participants at George Mason, UC Irvine, and Cambridge Universities. All errors are our own.

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## ENDNOTES

[1] See, for example, Mill (1848), Sidgwick (1901), Pigou (1938), and Samuelson (1964).

[2] See Saito (2019) on Japan, Mixon and Bridges (2018) on early America, and Candela and Geloso (2019b) on England.

[3] See Krawchenko (2021) for an empirical review on organizational scale and productivity. Scale is also relevant in the literature on "global" public goods, see Buchholz and Sandler (2021). The edited volume by Savas (2019) has several chapters on scale and related themes.

[4] Williamson (1985) is the seminal work on organizational incentives. Schiff and Weisbrod (1991) analyze for and non-profit competition.

[5] The edited volume Kimenyi (2018) provides essays on decentralization in public services. Martínez-Vázquez et al. (2017) provides survey on fiscal decentralization. Reynolds (2004) also provides an insightful overview.

[6] See Li et al. (2015) and Buso (2019) for works on bundling.

[7] See Dunn and Alvarez-Palau (2020) for details on LAN.

[8] Hart, Shleifer, and Vishny (1997) provide a related and illustrative analysis of private prisons.

[9] Bundling's importance has been noted for pilotage and lightships by Candela and Geloso (2019a). For the link with public private partnerships see Hart (2003), Martimort and Pouyet (2008), Iossa and Martimort (2015).

[10] See 1834 Select Committee report, appendix I England, table 26, p. 24.

[11] Canals, for example, often required more than £100,000 in investment (Ward, 1974).

[12] See 1834 Select Committee report, appendix I England, table 86, p. 86.

[13] For evidence on speeds and safety, see Solar and Hens (2016), Bogart et al. (2021), Kelly, Ó Gráda, and Solar (2021). For a discussion of lights effects on wrecks see Candela and Geloso (2019a).

[14] There were other organizations called Trinity House, but the 1834 SC report describes them as local or harbor authorities. Therefore, we consider Trinity House Deptford Strond as the main Trinity.

[15] Adams and Woodman (2013, pp. 120–122), point to the fact that some Trinity Brethren were actually owners of some of the private leases, suggested not all were independent of Trinity.

[16] See Victoria County History (1911).

[17] See "Report from the Select Committee Appointed to Consider the Means of Improving and Maintaining the Foreign Trade of the Country" and "Select Committee to inquire into State and Management of Lighthouses."

[18] See 1834 Select Committee report, appendix C, list of lights of the UK, p. 186.

[19] See 1834 Select Committee report, pp. 172–179.

[20] See 1834 Select Committee report, appendix I England, table 12, p. 15.

[21] See, *the Digest of the Existing Commercial Regulations of Foreign Countries, with which the United States Have Intercourse; as Far as They Can be Ascertained*, pp. 187–188.

[22] See 1834 Select Committee report, appendix I England, table 86, p. 86.

[23] For agent commissions rates see 1834 Select Committee report, appendix I England, tables 51–54, pp. 48–57.

[24] See 1834 Select Committee report, appendix D, list of private, local, and harbor lights, p. 190.

[25] The 1831 list is in the British Library: Great Britain. Hydrographic Office, The Light-Houses of the British.

[26] Several Isle of Man lights were managed by the Commission on Northern lights in Scotland, which we do not study in its totality.

[27] The ports are described in Alvarez and Dunn (2019) and Alvarez et al. (2019).

[28] See Report from the select Committee on Lighthouses together with Minutes of Evidence, Appendix, and Index, 1845. Appendix Table no. 5, p. 402.

[29] See "Report from the Select Committee appointed to consider of the means of improving and maintaining the foreign trade of the country. Lights, harbour dues, and pilotage," Appendix A.

[30] See 1834 SC report appendix I England table 21, p. 21, table 73, p. 80

[31] There is also argument that privates were forced to use Trinity's agents, but they had to pay a higher commission rate (Candela & Geloso, 2018b, p. 484). This argument has the same prediction as the network size-collection cost effect, although clearly a different interpretation.

[32] Another possibility is that Trinity used its market power to raise private agent rates, making itself look better.

[33] Sample sizes differ across outcomes, but generally its 26–34 Trinity and 11–13 privates. There are some cases where outcomes are recorded for single authority operating multiple lights in multiple locations. Here we divide the financial outcome by the number of locations which it applies to. We will control for these cases below.

[34] A different argument would say because of inflation lights built later should have higher rates. However, we checked this using a GDP deflator and found it did not influence rates once year first built is controlled for.

[35] Note we also estimated Conley S.E.s with various distance cutoffs. The standard errors change little.

[36] For agents see 1834 Select Committee report, appendix I England, table2 51–54, pp. 48–57.

[37] See 1834 SC report appendix I England table 73, p. 80.

## REFERENCES

Adams, A. & Woodman, R. (2013) *Light upon the waters: the history of Trinity House 1514–2014*. London: The Corporation of Trinity House.

Alvarez-Palau, E.J. & Dunn, O. (2019) Database of historic ports and coastal sailing routes in England and Wales. *Data in Brief*, 25, 1–15.

Alvarez-Palau, E.J., Dunn, O., Bogart, D., Satchell, M. & Shaw-Taylor, L. (2019) *Historic ports and coastal sailing routes in England and Wales, 1540-1914*. [Data collection]. UK Data Service.

Bertrand, E. (2006) The Coasean analysis of lighthouse financing: myths and realities. *Cambridge Journal of Economics*, 30(3), 389–402.

Block, W. & Barnett, W. (2009) Coase and Bertrand on lighthouses. *Public Choice*, 140(1-2), 1–13.

Bogart, D., Dunn, O., Alvarez-Palau, E. & Shaw-Taylor, L. (2021) Speedier delivery: coastal shipping times and speeds during the age of sail. *Economic History Review*, 4(1), 87–114.

Bogart, D. & Richardson, G. (2011) Property rights and parliament in industrializing Britain. *The Journal of Law and Economics*, 54(2), 241–274.

Buchholz, W. & Todd, S. (2021) Global public goods: a survey. *Journal of Economic Literature*, 59(2), 488–545.

Buso, M. (2019) Bundling versus unbundling: asymmetric information on information externalities. *Journal of Economics*, 128(1), 1–25.

Candela, R. & Geloso, V. (2018a) The lighthouse debate and the dynamics of interventionism. *Review of Austrian Economics*, 1(26), 1–26.

Candela, R. & Geloso, V. (2018b) The lightship in economics. *Public Choice*, 176, 479–506.

Candela, R. & Geloso, V. (2019a) Why consider the lighthouse a public good? *International Review of Law and Economics* (60).

Candela, R.A. & Geloso, V. (2019b) Coase and transaction costs reconsidered: the case of the English lighthouse system. *European Journal of Law and Economics*, 48(3), 331–349.

Coase, R. (1974) The lighthouse in economics. *The Journal of Law and Economics*, 17(2), 357–376.

Dunn, O.B., Eduard, J. & Alvarez-Palau (2020) Dataset for historical lighthouses and light aids to navigation (LAN). England and Wales, 1514–1911. *Data in Brief*, 31, 105991.

Engel, E., Fischer, R.D. & Alexander, G. (2014) *The economics of public-private partnerships: a basic guide*. Cambridge: Cambridge University Press.

Great Britain. (1822) *Parliament. Select committee on foreign trade. Report from the select committee appointed to consider the means of improving and maintaining the foreign trade of the country: lights, harbour dues, and pilotage*. London: House of Commons.

Great Britain. (1834) *Parliament. Select committee to inquire into state and management of lighthouses*. London: House of Commons.

Great Britain. (1845) *Parliament. Select committee on lighthouses*. London: House of Commons.

Hague, R. & Christie, D.B. (1975) *Lighthouses. Their architecture, history, and archaeology*. Dyfed: Gomer Press.

Harris, G. (1969) *The Trinity House at Deptford: 1514–1660*. The Athlone Press.

Harris, R. (2000) *Industrializing English law: entrepreneurship and business organization, 1720–1844*. Cambridge: Cambridge University Press.

Hart, O., Shleifer, A. & Vishny, R.W. (1997) The proper scope of government: theory and an application to prisons. *The Quarterly Journal of Economics*, 112(4), 1127–1161.

Hart, O. (2003) Incomplete contracts and public ownership: remarks, and an application to public-private partnerships. *The Economic Journal*, 113, C69–C76.

Hausman, W.J. (1977) Size and profitability of English Colliers in the eighteenth century. *The Business History Review*, 51, 460–473.

Hydrographic Office of Great Britain. (1832) *The light-houses of the British Islands*. London: William Clowes.

Iossa, E. & Martimort, D. (2015) The simple microeconomics of public-private partnerships. *Journal of Public Economic Theory*, 17(1), 4–48.

Jackson, G. (1983) The Ports. In: Aldcroft, D. & Freeman, M. (Eds.) *Transport and the industrial revolution*. Manchester: Manchester University Press.

Johnson, N.D. & Koyama, M. (2017) States and economic growth: capacity and constraints. *Explorations in Economic History*, 64, 1–20.

Kelly, M., Gráda, C.Ó. & Solar P.M. (2021) Safety at sea during the industrial revolution. *The Journal of Economic History*, 81(1), 239–275.

Kimenyi, M.S. (Ed.) (2018) *Devolution and development: governance prospects in decentralizing states*. London: Routledge.

Krawchenko, T. (2021) *Public sector and productivity: Governing at the right scale. Background paper for the OECD-EC high-level Expert Workshop series "Productivity policy for places."*

Li, S., Sun, H., Yan, J. & Yu, J. (2015) Bundling decisions in procurement auctions with sequential tasks. *Journal of Public Economics*, 128, 96–106.

Lindberg, E. (2013) From private to public provision of public goods: English lighthouses between the 17th and 19th centuries. *Journal of Policy History*, 25(4), 538–556.

Martimort, D. & Jerome, P. (2008) To build or not to build: normative and positive theories of public–private partnerships. *International Journal of Industrial Organization*, 26(2), 393–411.

Martínez-Vázquez, J., Santiago, L.-P. & Sacchi, A. (2017) The impact of fiscal decentralization: a survey. *Journal of Economic Surveys*, 31(4), 1095–1129.

Mill, J.S. (1848) *Principles of political economy*. London: Appleton.

Mixon, F.G. & Bridges, S.R. (2018) The lighthouse in economics: colonial America's experience. *Journal of Public Finance and Public Choice*, 33(1), 81–101.

Naish, J.S. (1985) *Their history and development*. London: Stanford Maritime.

Pigou, A.C. (1938) *Economics of welfare*. London: Macmillan & Co.

Reynolds, L. (2004) Taxes, fees, assessments, dues, and the get what you pay for model of local government. *Florida Law Review*, 56, 373.

Saito, K. (2019) Lighthouse provision in premodern Japan. *Economic Inquiry*, 57(3), 1582–1596.

Samuelson, P.A. (1964) *Economics: an introductory analysis*. New York: McGraw-Hill.

Savas, E.S. (Ed.) (2019) *Alternatives for delivering public services: toward improved performance*. London: Routledge.

Schiff, J. & Weisbrod, B. (1991) Competition between for-profit and nonprofit organizations in commercial markets. *Annals of public and cooperative economics*, 62(4), 619–640.

Sidgwick, H. (1901) *The principles of political economy*. New York: Macmillan.

Solar, P.M. & Luc, H. (2016) Ship speeds during the industrial revolution: East India Company ships, 1770–1828. *European Review of Economic History*, 20(1), 66–78.

Stevenson, D.A. (2002) *The world's lighthouses before 1820*. London: Oxford University Press.

Taylor, J. (2001) Private property, public interest, and the role of the state in 19th-century Britain: the case of the lighthouses. *The Historical Journal*, 44(3), 749–771.
Van Zandt, D.E. (1993) The lessons of the lighthouse: 'government' or 'private' provision of goods. *The Journal of Legal Studies*, 22(1), 47–72.
Victoria County History. (1911) Liverpool: the docks. In: Farrer, W. & Brownbill, J. (Eds.) *A history of the county of Lancaster*. London: Victoria County History, Vol. 4.
Ward, J.R. (1974) *The finance of canal building in eighteenth-century England*. London: Oxford University Press.
Williamson, O.E. (1985) *The economic institutions of capitalism*. New York: Simon and Shuster.

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**How to cite this article:** Bogart, D., Dunn, O.B., Alvarez-Palau, E.J. & Shaw-Taylor, L. (2021) Organizations and efficiency in public services: the case of English lighthouses revisited. *Economic Inquiry*, 1–20. Available from: https://doi.org/10.1111/ecin.13060