

Organizations and efficiency in lighthouse provision: the English case revisited

Oliver Buxton Dunn¹, Dan Bogart², Eduard J Alvarez-Palau³, and Leigh Shaw-Taylor⁴

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Abstract⁵

Complex policy challenges in the infrastructure sector are seen in a fresh light when studying one of the most celebrated historical examples: lighthouses in England. This paper focuses on the cost and pricing differences between various organizational types providing lighthouse services 1822-1832, just before the partial nationalization in 1836. Using rich new data, we pinpoint how some had significantly lower costs and charges, which helps explain why they were favored by the government as national providers after 1836. As a general implication, we show where some organizations provided the more cost-effective service due to service bundling and economies of scale.

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¹ Research Associate in History and Digital Humanities, University of Cambridge, od226@cam.ac.uk

² Professor, Department of Economics, UC Irvine, dbogart@uci.edu

³ Senior Lecturer, Economics and Business, Universitat Oberta de Catalunya, ealvarezp@uoc.edu

⁴ Senior Lecturer, Faculty of History, University of Cambridge, lmws2@cam.ac.uk

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1. INTRODUCTION

Markets for infrastructure services are usually thought of as natural monopolies. Large, fixed costs, combined with low or close to zero operating costs, imply that it is efficient for only one provider to supply a market. For the same reason, price regulation is crucial since a single firm is likely to charge an inefficiently high price. Alternatively, the government can provide infrastructure for free at point of use and use public funds to pay for it. For many practical reasons, the choice between public and private provision is rarely clear, however.

When one looks at history, such complex policy challenges are seen in a fresh light. In the past, infrastructure was provided by different types of organizations, often within the same economy and sector. The selection of the most efficient natural monopolist, as prescribed by theory, was often fraught. Rent-seeking incumbents used their political influence to block restructuring and there were times when governments did not have enough information to determine the most efficient provider. Optimal pricing schemes were also foiled by limited understanding of marginal cost pricing and direct government provision was plagued by the high cost of public funds.⁶

In this paper, we examine one of the most celebrated historical examples of infrastructure provision: lighthouses in England and Wales.⁷ Following the famous article by Coase (1974) much of the focus has been on the performance of private lighthouse providers and comparisons with what became the largest provider, Trinity House (e.g. Taylor 2001,

⁶ There is a vast historical literature on historical infrastructure. For two examples, see Cassis et. al. (2016) and Bogart (2020).

⁷ We refer to both as England. The literature we engage with also considers England and Wales. Scotland and Ireland had different lighthouse authorities and funding arrangements.

Bertrand 2006). But no previous study has systematically examined their differences in costs and pricing. By costs we are referring to maintenance costs and light due collection costs, where light dues were the primary mechanism for making passing ships pay for lighthouse services. Pricing refers to the per ton rate at which light dues were set on ships. Trinity and private providers are compared using a new and rich dataset on financial outcomes and lighthouse characteristics in 1831. We also analyze differences in costs for a third organizational type, harbor authorities, which came to be important, but have been largely ignored in the literature to date due to data limitations.

The motivation for this study is both historical and general. First, we address the reasons behind a major reform in lighthouses, which led to the current structure in the UK. A law in 1836 forced several private lighthouses to sell their assets to Trinity. At that time, Trinity was a guild run by its own officials for the benefit of its members. Today, Trinity is a private charity run by a board of directors, but it holds statutory powers over UK lighthouses. Their stated mission is ‘To deliver a reliable, efficient and cost-effective Aids to Navigation service for the benefit and safety of all mariners’.⁸ In their legal status, the original private providers were similar to Trinity in getting patents authorizing light dues for charging passing ships. However, private owners, or privates, were thought to have higher light due collection costs and charge higher light dues according to a series of influential Victorian parliamentary select committees. The government acted upon this view, and through the 1836 law Trinity became the central actor in providing lighthouses. This begs the question: Why did Trinity rise to prominence over a range of other lighthouse providers whom it eclipsed? We answer this question through analysis of cost and pricing outcomes just before the 1836 reform.

We also shed light on a historical question largely ignored to date, namely why the reform left a third major provider, harbor authorities, untouched. They were different from

⁸ Trinity House, ‘Report and Accounts for the Year Ended 31 March 2020’.

privates and Trinity, since they did not use patents to charge passing ships. Instead, they relied on harbor duties, authorized by acts of parliament, which only collected dues on ships entering their port. They also combined the provision of lighting services with other infrastructure, like docks and piers. Using our new data, we document that harbor authorities provided a large proportion of lights by 1831. We explore the possibility there was a cost advantage unique to harbor authorities which allowed them to continue beyond 1836.

The second motivation is more general and concerns efficacy of lighthouse provision, a classically debated topic. While many previous works have focused on public versus private provision, we think the English case offers more insights. The first issue concerns the scale of organizations that levy light dues. Does it matter if they are levied by one organization or many? The second issue concerns the bundling lighthouses with other services. Bundling has received greater attention from Candela and Geloso (2019), but to our reading the literature has just begun to empirically investigate its role in lowering provision costs.

Our empirical analysis exploits the fact that organizational provision of lighthouses in 1831 was determined decades, and in some cases centuries, before. Lighthouses provided by Trinity are shown to have had significantly lower light due collection costs and charged lower light due rates than private lights in 1831. This holds in regressions which control for lighthouse location and characteristics. We also show that lights provided by harbor authorities had the lowest maintenance costs of any organization type, again accounting for location and characteristics. We attribute some of the lower harbor authority costs to their bundling with other harbor services. Some of Trinity's advantages over privates are attributed to its greater scale. Along with this, Trinity appears to have been driven to prove its efficacy to the government in the early 1830s. It was admonished in the 1820s for charging high dues. We argue that becoming more cost and pricing efficient helped in Trinity's selection as the

near monopolist of the sector. As evidence, we show Trinity lowered its light due rates following a government inquiry in 1822, and it did so along the lines of reducing its profits.

Our paper contributes to a lively theoretical and empirical literature on lighthouses. A brief summary goes as follows. In a classic text, *Principles of Political Economy*, Mill proposed that lighthouses are always a ‘public good’ and require government intervention because of the way light is freely emitted out to sea. The market cannot provide lighthouses because users cannot be practically excluded from the service to ensure that the lighthouse owner is paid for lighthouse services. This means any lighthouse businesses would naturally face the problem of passing ships free-riding on the offered services. According to many economists that followed Mill, this was a classic example of market failure and some level of government intervention was required to solve it. Coase (1974) famously disagreed with this classical view. Coase focused on England and argued that the fees collected from ships using lighthouses paid their costs. These were interpreted as examples of successful lighthouses built by ‘private enterprise’.

Coase’s arguments have generated a huge debate, extending to many countries, including the US (Mixon and Shaw Bridges 2018). We briefly summarize the debate about England, as it is most relevant to our paper. Van Zandt (1993) pointed out that private actors could provide public goods but only because the state ensured service fees (tolls) were paid by ships when docked in port and protected property rights. Van Zandt described the English system as a public-private or mixed system rather than a market-based response. Bertrand (2006) argued that the involvement of private individuals in the mixed system was sub-optimal and created incentives for corruption, poor service quality, and high costs. This followed Taylor’s work (2001) that highlighted a movement led by Victorian reformers in the 1820s and 1830s to abolish individual owners who had inherited or acquired lighthouses and made large fortunes and supposedly provided a sub-optimal service. For Taylor, the reform of

1836 finally solved a longstanding market failure characterized by poor performance of private operators. Candela and Geloso (2018, 2019a,b) take a different view arguing that Trinity tried to block the lightship, in order to protect its pilotage monopoly. They also argue that private light ship providers innovated by bundling lights with other navigation services.

We move this literature forward by examining the cost and pricing differences between various organizations. Their structural differences in terms of scale and bundling are also highlighted. This is done using a new geospatial dataset, called Light Aids to Navigation, or LAN, that details all lighthouses (including beacons and light vessels) in operation in 1831 and their geographical, spatial, and technological attributes. The most important source is the *Admiralty List of Lighthouses of the British Islands*⁹ covering UK coastal navigation lighting in 1831, which does not feature in the aforementioned literature. The UK Hydrographic Office published this list with the Admiralty annually. The 1832 edition was the first detailed list of all UK lighthouses, and was published on an annual basis thereafter. We extend Admiralty data by linking lights to parliamentary select committee reports in 1822¹⁰ and 1834, our other main source.¹¹ Select committees or SCs were cross-party groups of MPs or peers were tasked by the Commons or Lords with inquiring into and reporting on specific issues. Their information provides a treasure of organizational, financial and regulatory data on lights.

Our paper also makes a contribution by shedding light on harbor authorities. They are often omitted from English discussions of lights, but as Saito's (2019) study of Japan shows they had a broader presence. We are able to compare harbour authority lights with Trinity and private providers because they were listed by the Admiralty in 1831. Harbor lights will be

⁹ Hydrographic Office, *The Light-Houses of the British Islands Corrected to April 1832*.

¹⁰ Great Britain. Parliament. House of Commons. 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, 1822.

¹¹ Great Britain. Parliament. House of Commons. Select Committee to inquire into State and Management of Lighthouses. London: House of Commons, 1834.

shown to be less powerful, but they filled stretches of coastline nearer ports and allowed ships to sail along the coast more safely in combination with other providers. Harbor authorities provided a key and complimentary service to the lighthouse ‘network’ that we map with GIS, something which is new in the relevant literature.

In the following, we first provide some background and information about our data collection before moving onto description of data and results.

2. BACKGROUND

2.1 The value of lighthouses in the Age of Sail and Steam

Before lighthouses became common in the late 1700s, sailors relied on natural landmarks, buildings like churches, and open fires or candles (Naish 1985, 91; Hague & Christie 1975, 188-194). The emergence of more technologically sophisticated lighthouses after around 1780 coincided with a growth in ship tonnages that continued into the twentieth century. There is a distinct possibility that lighthouses also contributed to productivity improvements in shipping (Bogart et al 2020). The 1834 committee on lighthouses described the importance of coastal lighting to this resource in these terms:

‘Your Committee have throughout been strongly impressed with the paramount necessity of having the best Lighthouses and Floating Light Establishments for this great Naval and Commercial Country which the state of science can afford; and that every necessary expense should be incurred for their maintenance.’ (Select Committee 1834, iii)

The problem lights confronted were enormous losses at sea that were a regular, horrific, feature of the British shipping industry. In 1854, in a particularly bad year 1,549

people lost their lives in 987 wrecks, most within sight of land.¹² In these figures, injuries were entirely unrecorded and missing persons uncounted. For the sake of humanity, but also to prevent crippling financial losses, Victorian reformers strove for a better lighthouse system. They left behind many useful sources, some of which we exploit here.

2.2 What is meant by ‘lighthouses’?

We refer to different types of coastal light using ‘lighthouses’ or lights, from harbor lights on piers, docks, or beaches, to towers on cliff tops or lower down near shorelines. Some possessed houses but many did not. Lighthouses could have two or three towers, used as ‘leading lights’. Light vessels or lightships were another type. These were different from lighthouses in being manned seamarks anchored in a vessel at a specific point. They could be placed in areas where it was impossible for lighthouses to act as efficient seamarks (Candela and Geloso 2018, 485-486).

The state of lighting technology and light coverage was revolutionized by the Argand lamp invented in the early 1780s. This featured a hollow wick and glass chimney that produced a smokeless steady flame (Naish 1985, 105; Hague & Christie 1975, 154). The efficiency of the lamp was improved by its suitability with parabolic reflectors that amplified and focused the light from multiple burners (Stevenson 2002, 231). In optimal conditions, lighthouses with Argand lamps could generate visibility of up to 20 miles, which was a big improvement over earlier coal fires or candles. Naish (1985, 105) estimates that Argand lamps were installed in 80-90% of British lights between 1782 and 1823, making this technology the key to mass illumination of the coastline shown later. There were also engineering advancements, notably prefabrication of more durable lighthouses on shore. New

¹² Great Britain. Parliament. House of Commons. The Admiralty Register of Wrecks and other Casualties to vessels which occurred in the seas and on the shores of the United Kingdom during the Year 1854. London: House of Commons, 1855, 3.

lighthouse technology accompanied other advances of the age in safety at sea, such as iron ship hulls and accurate clocks to determine longitude (Ó Gráda & Solar, 2019).

2.3 Funding and running lighthouses

There were various costs that went into building, maintaining, and in some cases collecting dues for a lighthouse. The construction cost for a state-of-the art lighthouse around 1830 was approximately £3,000 to £6,000.¹³ They were expensive to build compared to some capital goods in the English economy, like cotton textile machinery, but they pale in comparison to larger projects like canals and dock works.¹⁴ Maintenance costs for lighthouses were not small, and could be £500 to £1000 a year to pay for fuel, lightkeeper wages, and repairs.¹⁵ Location would have been one determining factor. Some places had higher wages or more expensive fuel sources. But organizational structure had some influence as we argue below.

Perhaps a more difficult challenge was collecting dues from ships which used the light. The legal authority to collect ‘light dues’, and at what rate, varied, but in all cases a person needed to be posted at a port and collect dues from ship captains as they disembarked. Based on the ship’s origin and destination, a coastal route was determined by the collector, and therefore which lighthouses must have been passed. Many lighthouse authorities contracted with an agent, who collected dues from ships and kept a percentage, 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 can 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.

2.4 Institutions and Organizations

¹³ See 1834 Select Committee report, appendix I England, table 26, p. 24.

¹⁴ Canals for example, often required more than £100,000 in investment (Ward 1979).

¹⁵ See 1834 Select Committee report, appendix I England, table 86, p. 86.

2.4.1 Trinity

Trinity House Deptford came to be the most important organization providing lighthouses by the early 1830s. Trinity was regulated by patents – special legal grants from the monarch that privileged the patentee with certain rewards for inventions and investments. Importantly, lighthouse patents guaranteed patentees a proportion of the light dues that ships paid when entering ports. Light dues could be substantial. For example, voyage accounts (Hausman 1977) show they amounted to 4-7% of total voyage costs in the northeast coal trade in the eighteenth century.

Trinity was an ancient guild dating back to the 1500s (Adams and Woodman 2013). Its charter, renewed after political upheaval in 1685, appointed a Master, Wardens and Assistants, and eighteen elder brethren, 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 ancient tolls, known as pilotage, loadmanage, primage, lastage, and ballastage. Profits from these tolls were meant to be spent on its charitable activities, like payment of pensions to the families of deceased mariners or to the old or injured. Therefore, Trinity House had a constituency that was not truly public in the modern sense of the word. It was, and is today, a private institution with public roles, which depended on state support in specific ways (van Zandt 1993, 71).

Light duties were not originally conferred on Trinity, but rather granted iteratively by individual royal patents or acts of parliament. Trinity built very few early lights of the 1600s. But in the 1700s it worked with private groups to build several lights (Stevenson 2002). In this system, Trinity obtained patents and then leased these rights to private investors. Leases extended several years and were often renewed multiple times. Trinity played a more direct role after Argand lamps were developed in the 1780s and shipping volumes increased

(Stevenson 2002). Trinity took over many lights formerly on lease after the 1780s and also built more lights on its own using patents.

2.4.2 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 as discussed above. In other cases, patents were obtained directly from the monarch. A few privates obtained acts of parliament, which appear to be similar to patents in this case. Many originated in the 1600s (Stevenson 2002). These organizations have been described by Coase and others as private and entrepreneurial (1974, 375), because it appears they were willing to take risks. Individual lighthouse builders fulfilled an immediate need. Petitions from local people fed-up with shipwrecks were drawn up to support applications from privates (Hague & Christie 1975, 24; Harris 1969, 184). By the 1830s, the incomes of private lighthouse providers had grown to politically controversial levels, leading to government intervention.

2.4.3 Harbor authorities.

Harbor authorities were another major provider of lights. They were commonly established by local acts of parliament, which covered other harbor and pier improvements. There were various subtypes, including joint stock companies, but commissions were the most common. Commissions (a.k.a. trusts) were widely used organizations in England at this time (Harris 2000, Bogart and Richardson 2011). According to Jackson (1983), commissions built lights to improve local navigation 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. They were the first English lighthouse authority to adopt parabolic reflectors (Stevenson 2002). In Liverpool, the ratepayers – many of whom used the port – eventually gained greater say and a

degree of control through enfranchisement.¹⁶ While not all commissions evolved to be more inclusive, like Liverpool, they all paid attention to local mercantile and shipping interests.

One key difference from Trinity and privates is that harbor authority funding did not utilize a patent, and thus light dues were not collected at ports around England. Instead, most harbor authorities were authorized by acts of parliament to collect a fee only when ships arrived at their facility. Like other cases such as Japan (Saito 2019), English harbor authorities were in contact with ships that arrived and thus could more easily charge them a fee than if passing by compared to patent holders who collected tolls in many ports, often far from the light they were responsible for. Moreover, acts 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 provided in the harbor.

2.5 Government interventions

In the 1830s, British governments began to consider reforms. The Great Reform Act of 1832, which extended the franchise to more males, being the most prominent example. In this context, concerns about growing profits earned by lighthouses caught the attention of select committees. The 1834 SC focused on Trinity. It was investigating and pressurizing Trinity to reduce its light duty rates charged to shipping. The 1834 SC 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 by that time compared to individuals.

In 1836, a key reform was enacted by parliament that abolished the system of private ownership that had grown up around Trinity’s earlier privileges. The 1836 Act aimed to remove private profit from lighthouse financing and to reduce the total costs to shipping to support the industry. Parliament centralized much lighthouse ownership and management in

¹⁶ See Liverpool County History ‘Liverpool: The docks’.

Trinity, which meant it was handed sweeping powers of lighting and was backed by the treasury to buy out all private lighthouses and collect all light dues in England and Wales. However, the 1836 act maintained the system of lights provided by harbor authorities.

2.6 Comparing organizations and institutional structures

This paper studies the cost and pricing differences between organizations and their associated institutional structures in the early 1830s. Our aim is twofold. First, our goal is to empirically investigate claims of the 1834 SC which argued that private providers charged higher light dues than Trinity and operated at greater expense. In doing so, we will make extensive use of the data provided in the 1834 SC report. However, we will go beyond their information by linking lighthouses to the Admiralty lists, which provide technical capabilities of the same lights, linked between the sources. Linking is necessary because light capabilities differ by organization.

Our second aim is to better understand the organizational and institutional characteristics associated with more efficient provision of lighthouses. One argument is that bundling lighthouse services with related navigational services can improve efficiency. In the case of harbor authorities, perhaps by bundling with docks and piers, they were able to provide lights at a lower maintenance cost. Intuitively, the cost of repairing lighthouses and docks jointly should be less than the sum of the costs of repairing lighthouses and docks separately.

A second aspect of interest are potential economies of scale in collecting light dues, which favored a single organization like Trinity over individual private owners. To illustrate simply, suppose there are n ports and m lighthouses. In one institutional setting there are m authorities operating the m lighthouses and the other there is 1 single authority. In the first case, each authority pays a cost c to collect at the n ports, so its total costs of collection are $c * n$. The total cost across all individual lights is $m * c * n$. In the second case, a single lighthouse

authority has agents everywhere, which perform the same collection service, at the same cost regardless of the number of lighthouses m served. If so then its total costs are $c * n$, less than $m * c * n$. In theory this is the scale advantage which Trinity enjoyed.

3. DATA SOURCES

To empirically investigate organizational and institutional differences, this paper draws on a new dataset called LAN, covering navigation lights and their attributes across England and Wales from ‘medieval’ times to 1911.¹⁷ LAN improves on earlier datasets which cover coastal lighting in England and Wales in a partial manner.¹⁸ None comprehensively detail recorded light establishments big and small, nor longitudinally over this time frame. Nor do they give visibility range for a complete list of historical lighthouses. LAN includes several geospatial elements, like latitude and longitude, that record the coverage of different lights. LAN’s main source for 1831 is the Admiralty, which published the first comprehensive list detailing all UK coastal lights in 1831, the year before its publication.¹⁹ The List is organized by lighthouse, although in some cases it details a cluster of lights operating jointly. Several light attributes are given including (i) visibility range in miles under ideal conditions, (ii) height of light measured from seawater, (iii) whether a light was attached to a vessel, (iv) if any light was revolving or fixed, and (v) year of construction.

The 1832 Admiralty List does not identify ownership or managing authority, and so we extend the LAN dataset for this paper. We turn to the parliamentary SC reports investigating British lights in 1834, numbering over 600 pages of witness testimony with

¹⁷ See Alvarez-Palau et. al. 2020.

¹⁸ The Lighthouse Directory: <http://www.ibiblio.org/lighthouse/>; ARLHS World List of Lights (WLOL): <http://wlol.arlhs.com/index.php?mode=zones&zone=ENG>; List of lighthouses in England: https://en.wikipedia.org/wiki/List_of_lighthouses_in_England#Lighthouses (all accessed in October 2019)

¹⁹ The 1831 list is in the British Library: Great Britain. Hydrographic Office, The Light-Houses of the British

reports and appendixes.²⁰ It inquired after lighthouses, light-vessels, buoys, and beacons; their revenues, and expenses, and more. Importantly, the SC report was particularly concerned with classifying how each lighthouse was owned and managed.²¹ Concerning England and Wales, the Isle of Man, and the Channel Islands, five different types are listed in the Report:

1. Under Trinity
2. In private hands, on lease from Trinity
3. In private hands, on lease from the crown
4. In private hands, held under an act of parliament
5. Local or harbor lights.

Trinity is clear. The specific lease and holding terms for ‘private hands’ are explained earlier. One difference is that privates under lease from the Crown or held under an Act were independent of Trinity’s control. The fifth group, local and harbor, is more heterogeneous, but descriptions of each in the 1834 report identifies most of them as commissions created by acts of parliament.²² The Liverpool Dock Trustees highlighted earlier were a leading example.

From the rich description in the 1834 SC report and literature, we define 3 organizational types which financed and managed lights in a common manner. In the list above, group 1 is labelled Trinity. Group 2, 3, and 4 are combined into a single type called private. In other words, we do not regard the lease type as a major distinction. Lastly, all lights in group 5 are labelled harbor authorities.

The 1834 SC report gives financial outcomes by individual lighthouse, or a group operated jointly. For all lights under Trinity, it provides data on (i) gross revenues, (ii)

²⁰ 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’.

²¹ See 1834 Select Committee report, appendix C, list of lights of the UK, p. 186.

²² See ‘Select Committee to inquire into State and Management of Lighthouses’, 172-179.

collection costs for light dues, and (iii) maintenance costs for the years 1820 and 1832.²³

From these, we calculate the operating margin, defined as gross revenue minus collection and maintenance costs, divided by gross revenues. We also calculate the implied commission rate for collection agents, defined as the ratio of light due collection costs to gross revenues, multiplied by 100. Elsewhere in the report similar financial variables are given for most private lights, although in some cases there are missing observations or reported differently. Moreover, the 1834 report details the rates of light dues charged by Trinity and several privates.²⁴ It also lists the commission rates by port for Trinity and several privates.²⁵ For harbor authorities, information on revenues is typically missing. This is probably due to their reliance on harbor dues. Fortunately, maintenance costs were systematically reported for harbor authorities and we can compare these with privates and Trinity.²⁶

There was another SC report in 1822 that compiled financial information for Trinity lights in 1818, 1819, and 1820.²⁷ These have been digitized and are completely linked to the list of lights in the 1834 Report. We make use of this information later as well.

The linking between lights in the 1834 SC report and 1831 Admiralty list is a key step in creating our new dataset. The linking was done by name of light and location. In the Admiralty list under ‘England’ and ‘Isle of Man’ 92 lights were listed.²⁸ We were able to successfully match 90 to lights described in the 1834 report. Table 1 shows the total number of lights managed by each organizational type and the number of unique authorities within each. Trinity, a single organization, managed the most at 39. There were 13 privates operating in 1831, all independently. There were as many lights managed by harbor

²³ See 1834 Select Committee report, appendix I England, table 86, p. 86.

²⁴ For Trinity light due rates, see 1834 Select Committee report, appendix I England, table 12, p. 15.

²⁵ For Trinity commissions, see 1834 Select Committee report, appendix I England, table 12, p. 11.

²⁶ See 1834 Select Committee report, appendix D, list of private, local, and harbor lights, p. 190.

²⁷ See 1822 Select Committee report, appendix A, A return of the Gross Sums, p. 340.

²⁸ Several Isle of Man lights were managed by the Commission on Northern lights in Scotland, which we do not study in its totality.

authorities as Trinity. In a few cases, several harbor lights were managed by the same authority, for example, the Liverpool trustees who managed 7 lights.

Table 1: Number of lighthouses by organization type in 1831

Organization type	(1) Number of lights managed	(2) Number of unique authorities
Trinity	39	1
Private	13	13
Harbor	38	28

Sources: see text.

Table 2 reports average financial and pricing outcomes by organizational type.²⁹ Some striking differences are seen. Harbors have substantially lower maintenance costs than privates, and especially Trinity. Trinity has much lower light due collection costs, commission rates, gross revenues, light dues rates, and operating margins than privates.

Table 2: Lighthouse financial outcomes by organizations in 1831

	(1) Trinity	(2) Private	(3) Harbor	(4) N
Financial outcomes from 1834 SC report				
Av. maintenance cost in pounds	966	543	196	76
Av. light due collection costs in pounds	182	731		46
Av. commission rate light due collection in %	8.6	10.9		45
Av. gross revenues in pounds	2,315	6,666		47
Av. light due rate in pence per ton	0.398	0.714		32
Av. operating margin	0.446	0.768		48

Sources: see text.

Some of the financial differences across organizations are due to the characteristics of lights which they operated. As a preview of these variables, Panel A in Table 3 gives descriptive statistics by organizational type using our linking to the Admiralty list. Again,

²⁹ 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.

there are some striking differences. Harbor authorities operated lights with less visibility and lower heights than Trinity or privates. Harbor lights were also constructed later in time on average. Compared to privates and harbors, Trinity was more likely to operate revolving lights as opposed to fixed lights and it was much more likely to operate a light vessel.

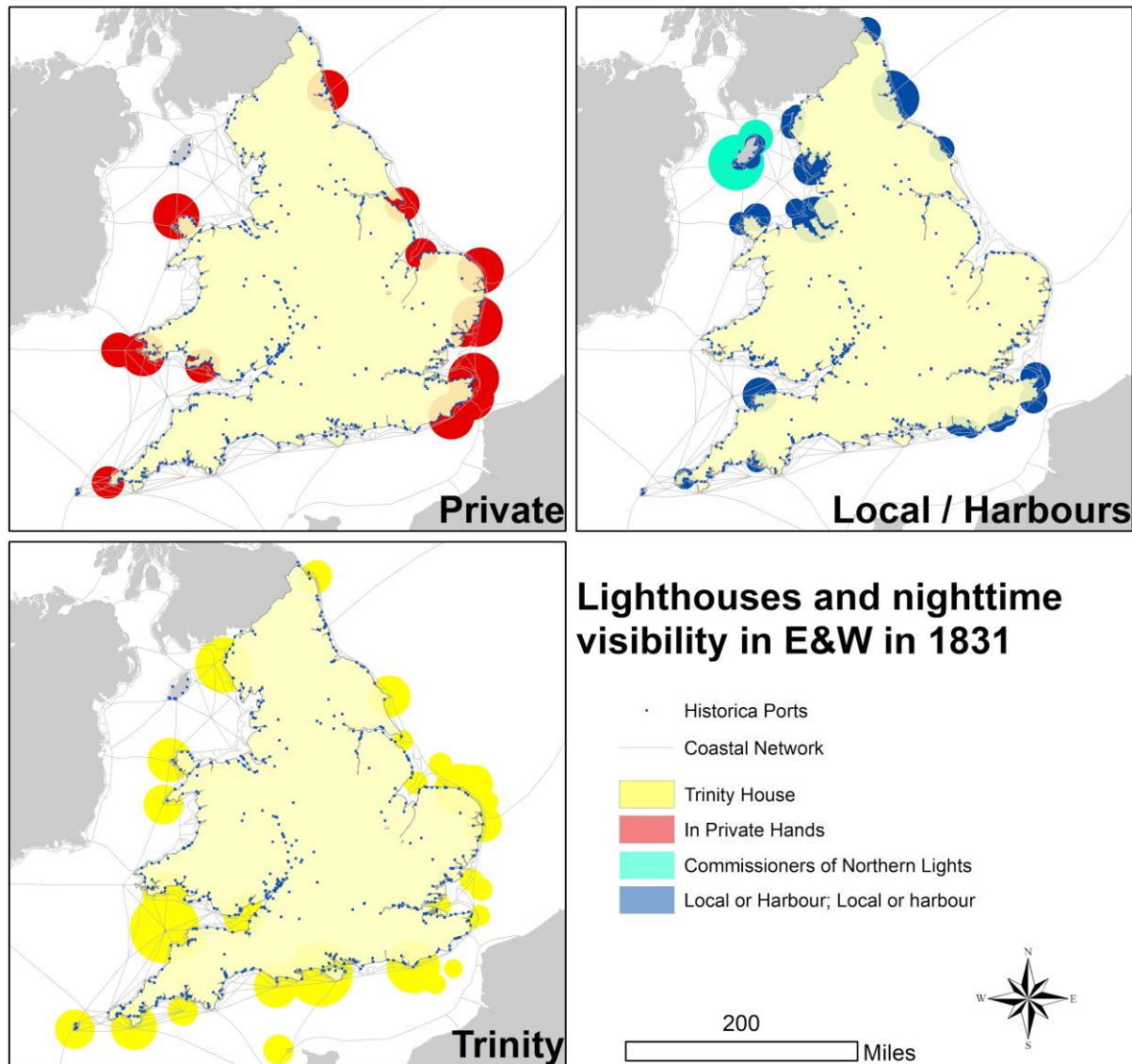
Table 3: Lighthouse characteristics by organizations in 1831

	(1)	(2)	(2)
Panel A: Characteristics from Admiralty list	Trinity	Private	Harbor
Av. visibility range in miles	14.78	17.46	10.39
Av. height measured from sea in feet	125.3	136.5	58.0
Av. dummy var. for revolving light	0.27	0.08	0.06
Av. dummy var. for light vessel	0.34	0.00	0.03
Av. year construction	1782	1777	1802
Panel B: Characteristics from GIS	Trinity	Private	Harbor
Av. latitude, Brit. nat. grid	440.1	470.6	375.8
Av. longitude, Brit. nat. grid	378.6	259.2	346.1
Av. distance to nearest port in km	14.1	9.3	3.1
Panel C: Construction from Stevenson	Trinity	Private	Harbor
Av. year original construction	1774	1674	1794

Source: see text.

The GIS coordinates in LAN also allow us to map the locations of all lights by organizational type, including their visibility range in 1831 (see figure 1). Trinity and privates are both broadly distributed around the coast and with lights of similar range, but they are not in the exact same locations. Harbor authorities are more concentrated near Liverpool, at the entrance to the Bristol channel, the southeast, and near Newcastle in the northwest. We confirm spatial differences by calculating the average latitude and longitude across organizations in panel B of table 3.

Figure 1: Lighthouse locations by organizational type in 1831



Notes: Map created by authors using LAN and organization categories from 1834 SC Report.

Figure 1 also shows all ports as blue dots drawn from LAN (Alvarez-Palau & Dunn 2019). This list of ports goes beyond the main customs ports and includes all documented landing locations. We call all ports for short. It is notable that some lights were close to ports and some more distant, for example on islands in the sea. To study location more precisely, we calculate the distance between each light in 1831 and the nearest port. As their name suggests, harbor authorities were generally closer, on average 3.1 km. Our mapping of harbor

authority shows the extent to which their lights covered wider areas and so not likely meant solely for harbor navigation. This explains why the 1831 *Admiralty List* includes them as part of a national lighting network. Serving different areas, privates and Trinity were farther away from the nearest ports.

We also know when a lighthouse was originally constructed at the location for each light operating in 1831. Stevenson's (2002) 'encyclopedia' of lights describes which type of organization first built the lighthouses, and when, with a focus on privates and Trinity. We match lighthouses described in Stevenson to the Admiralty list of 1831. Finally, using this additional information from Stevenson, we added a variable for the year a light was originally constructed at each 1831 light location.³⁰ The key implication is that private lights in 1831 generally had original construction dates in the 1600s, whereas Trinity lights in 1831 mainly had original construction dates in the late 1700s. We make use of this fact below for our instrument.

4. FINANCIAL COMPARISONS IN 1831

4.1 Maintenance costs

The first step in our analysis is to compare maintenance costs across all organizations. Maintenance costs were the most significant component of operating costs, and included items like wages for light keepers, fuel, and materials for repair. Our hypothesis is that harbor authorities had lower maintenance costs in part because they could bundle light services with related harbor services. This hypothesis is supported by the much lower average maintenance costs for harbors shown in table 2. However, it is unclear whether this is due to the different

³⁰ Note this date differs from the year of construction in the Admiralty list, which applies to the most recent structure.

locations and characteristics of harbor lights. We don't expect any difference between privates and Trinity once we account for locations and characteristics. Nevertheless, we still test for their differences in maintenance costs.

The following regression shows our specification:

$$y_i = \beta_1 harbor_i + \beta_2 trinity_i + \beta_3 x_i + e_i$$

where $y_i = \ln(\text{maintenance cost}_i)$ is the natural log of maintenance costs in pounds for lighthouse i . Natural logs are used to minimize outliers and assist in interpretation of the β coefficients. The explanatory variables include $trinity_i$ and $harbor_i$, which are dummy variables for lighthouse i being provided by Trinity and harbor authorities. A dummy variable $private_i$ is the omitted organizational type. x_i is a vector of potential controls. Location controls include longitude, latitude, and natural log distance to the nearest port. Light characteristic controls include log of visibility range, log of light height, a dummy for being a light vessel, a dummy for revolving lights instead of fixed, and year of construction. Light characteristics might be considered 'bad' controls in that they are a function of organization type. Therefore, specifications with no controls are also reported for comparison.

The identifying assumption in these regressions is that organizational control was determined long before 1831 and can be treated as exogenous, especially once we control for location and light characteristics. However, one concern is that regression comparisons are obscured by harbor authority lights because they were different from privates and Trinity in location and technical characteristics. Therefore, we also use propensity score matching to control for these differences. Matching is done using a logit regression of harbor authority status on all controls. The resulting re-weighted sample is much more balanced between organizations, particularly on visibility range, height, nearest port distance, and latitude.

The estimates are shown in table 4. Robust standard errors are reported along with the two main coefficients. In (1), which includes no controls, harbor authorities are estimated to have significantly lower maintenance costs than privates. Trinity is estimated to have significantly higher maintenance costs than privates. The specifications in (2) and (3) successively add location and light characteristics controls. Harbor authorities are still estimated to have lower maintenance costs, although the difference with privates is now smaller. Trinity is now estimated to have maintenance costs statistically and economically similar to privates. In (4) we treat privates and Trinity as the comparison group and again find that harbor authorities had lower costs. In (5) the treatment effect of harbors using propensity score matching is reported. The -0.580 log point estimate implies harbors had 44% lower maintenance costs when making a balanced comparison.

Table 4: Effect of organization on maintenance costs in 1831

	OLS (1)	OLS (2)	OLS (3)	OLS (4)	PS Match (5)
Variable	Coeff. (st. err.)	Coeff. (st. err.)	Coeff. (st. err.)	Coeff. (st. err.)	Coeff. (st. err.)
Harbor authority	-1.622 (0.291)***	-1.089 (0.347)** *	-1.064 (0.363)** *	-1.104 (0.298)***	-0.580 (0.260)**
Trinity	0.554 (0.211)**	0.466 (0.202)**	0.056 (0.287)		
Controls for location	N	Y	Y	Y	Y
Controls for light characteristics	N	N	Y	Y	Y
R-square	0.55	0.64	0.69	0.69	
N	76	74	69	69	69

Notes: *, **, *** represents statistical significance at the 10, 5, and 1% levels. Robust standard errors are reported. For definitions of controls see the text.

What explains these results? Harbors perhaps faced lower wages since they drew upon pre-existing labor markets near ports. Being near port infrastructure also implies that harbors had lower fuel costs since oil and coal were presumably more available in ports. However, when we control for distance to ports in specifications (2), (3), (4), and (5), the cost

difference for harbors remains much lower, and so it is not simply being near ports. Our favored explanation is that harbor authorities realized cost savings from bundling maintenance of lights and harbor infrastructure like docks and piers. Here we should note that bundling seems to have been the preferred approach to providing navigation lights around the world, for example Japan (Saito 2019). Thus, it is perhaps natural that harbor service bundling offered some advantages in terms of delivering lower maintenance costs.

4.2 Light due collection costs and commission rates

The second step in our analysis is to compare light due collection costs for Trinity and privates. The 1834 SC reported that recent yearly expenditure on light due collections in English ports amounted to over a third of all light maintenance costs (£16,914 of £45,013) (SC 1834, xvi). Commission rates were identified as a priority area for reform because collections of Trinity, and more so privates, were seen to have been highly inefficient in this regard.

The 1834 SC reported total collection costs by summing over all ports where a lighthouse collected light dues. At each port, collection costs equal light revenues collected multiplied by the commission rate for the agent. This implies that the average commission rate for a lighthouse, across all its ports, is the total collection costs divided by gross revenues. It appears from the SC reports that Trinity had lower collection costs because its local agents received lower commission rates. We focus on the rates as we think Trinity could exploit its greater scale when negotiating rates with agents. Note in this analysis harbor authorities are dropped since they do not report collection costs separately outside of Liverpool, which is a special case.

Here we have two datasets to test our hypothesis. One is a lighthouse level cross-section of average commission rates for Trinity and privates in 1831. The second is a

lighthouse-authority, port-level cross section of commission rates in 1831. The latter comes from the 1834 SC providing commission rates in different ports covering Trinity and several privates. The main specification using the lighthouse-level cross-section is the following:

$$y_i = \beta_1 trinity_i + \beta_2 x_i + e_i$$

where y_i is the average light due commission rate for lighthouse i , estimated by total collection costs divided by total gross revenues. The controls x_i are the same as the analysis above. The main identifying assumptions are the same too, namely that management by Trinity was determined long before 1831, and once location and lighthouse characteristics are controlled for the estimated effect of Trinity might be regarded as causal. We relax this assumption using an instrumental variable: the year when a lighthouse was originally constructed. The idea is that Trinity built few lights in the 1600s and early 1700s, leaving this role was taken by privates under patents from the monarch. With no mechanism to remove privates, their control persisted until 1831. If we regard conditions in the 1600s and early 1700s as exogenous to 1831, then the original construction year would be a valid instrument for Trinity versus other private in 1831.

The results are shown in table 5. In (1) with no controls we find Trinity had lower average commission rates by 2.286%. But the coefficient estimate is marginally significant at the 10% level. In (2) and (3) with controls the estimate is similar, and still implies Trinity had lower average commission rates. In (4) we use the year when a lighthouse was originally constructed as the instrument (IV) for Trinity. The IV is moderate in strength having a first stage Kleibergen-Paap statistic of 7.03. Nevertheless, the results offer some insights if ownership by Trinity is assumed to be endogenous. We confirm using (4) that Trinity did have lower average commission rates than privates. The estimate is larger than OLS and implies lower rates by 4.265%.

Table 5: Effect of organization on average light due commission rates in 1831

	OLS	OLS	OLS	IV
	(1)	(2)	(3)	(4)
Variable	Coeff.	Coeff.	Coeff.	Coeff.
	(st. err.)	(st. err.)	(st. err.)	(st. err.)
Trinity	-2.286 (1.170)*	-2.238 (1.280)*	-2.782 (1.511)*	-4.265 (1.568)***
Controls for location	N	Y	Y	Y
Controls for light characteristics	N	N	Y	Y
Kleibergen-Paap rk Wald F statistic				7.034
R-square	0.127	0.201	0.366	
N	45	45	42	41

Notes: *, **, *** represents statistical significance at the 10, 5, and 1% levels. Robust standard errors are reported. For definitions of controls see the text.

The second dataset gives us the opportunity to identify differences between Trinity and privates in commission rates at the port-level. The specification is the following regression, $y_{ij} = \beta_1 trinity_i + \beta_2 port_j + e_{ij}$, where i is a lighthouse provider, which includes Trinity and 6 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, $trinity_i$ is the dummy for Trinity and the omitted group are the remaining 6 privates. They can be identified separately but the results are similar. $port_j$ is a fixed effect for port j . There were 94 ports in total and thus identification of Trinity's difference in commission rates comes from within port variation, controlling for unobserved local conditions affecting rates.

Table 6 shows the results. Trinity is estimated to have 3.2% lower commission rates if we do not control for port fixed effects and 3.408% lower commission rates if we do control for port fixed effects. Clustering on ports increases the standard errors, but the Trinity coefficient remains highly significant.

Table 6: Effect of organization on light due commission rates at the port-level in 1831

	OLS	OLS	OLS
	(1)	(2)	(2)
Variable	Coeff.	Coeff.	Coeff.
	(st. err.)	(st. err.)	(st. err.)
Trinity	-3.210 (0.341)***	-3.408 (0.203)***	-3.408 (0.471)***
Fixed effects for ports	N	Y	Y
Clustered SEs on ports	N	N	Y
R-square	0.140	0.386	0.386
N	540	540	540

Notes: *,**,*** represents statistical significance at the 10, 5, and 1% levels. See table for standard errors. For definitions of ports see the text.

The port-level data demonstrates the degree to which Trinity charged lower commission rates, a key factor in it having lower light due collection costs than privates. There could be many reasons, but Trinity’s greater scale would seem to be one factor. The 1834 SC provides some insights here. It recommended that in future Trinity should collect the duties on behalf of other lighthouse owners, including the Scottish-focused Northern Lighthouse Commission, in order: ‘to render the Collection at once more economical and more convenient to the Public...’ (SC 1834, xvi). What did they mean? The SC reported that privates employed 682 collectors for their 11 lighthouses; contrastingly, Trinity employed 102 collectors for its 39 lights (SC 1834, xvi). Trinity, therefore, funded more lighthouses, with fewer agents, whom it paid less commission to do the work.

It is easy to see why the SC recommended a general adoption of Trinity’s more efficient collection network based on this kind of evidence. The 1834 SC strongly recommended to centralize all collection in Trinity, the SC’s chosen provider of light dues collection services everywhere outside harbors.

4. 3 Gross revenues and light due rates

The third step in our analysis is to compare gross revenues and light due rates for Trinity and privates. Reported gross revenues are summed over all ports where an authority collected light dues. At each port, light due rates are applied to registered tonnage of ships based on certain categories, mainly: British coastal and fishing, and foreign vessels. The volume of tonnage in each ship category and the light due rate, together, determined the gross revenues at each port and in total. The 1834 SC report remarked that Trinity had lower gross revenues than privates because it was charging lower light duty rates. But were they comparing apples and pears? There was no effort to control for the variety of light types owned by the providers. In this section, we confirm Trinity's light due rates were indeed lower once we control for location and light characteristics, which shows this provider was indeed the lower cost organization.

We use the earlier regression specification implementing a cross-sectional analysis for lighthouses operating under Trinity versus privates. The dependent variable, y_i , is the natural log of the light due rate for British coasting vessels for lighthouse i . Here our sample size is smaller since some privates did not report light due rates. An extension uses the natural log of gross revenues as the dependent variable, which are generally reported for all privates. The limitation is that gross revenues introduce variation in shipping volumes, and so it is a less direct test of the claim that Trinity charged lower light due rates.

The results where the log of light due rates is the dependent variable are reported in Table 7. In (1), (2), and (3) the conclusion is Trinity had significantly lower light due rates. The estimate in (3) is -0.879 in log points or 58% lower. In (4) we address concerns about Trinity ownership being endogenous using our IV, the year of original light construction. The estimates are similar, although they imply a larger difference for Trinity.

Table 7: Effect of organization on average light due rates in 1831

	OLS	OLS	OLS	IV
	(1)	(2)	(3)	(4)
Variable	Coeff.	Coeff.	Coeff.	Coeff.
	(st. err.)	(st. err.)	(st. err.)	(st. err.)
Trinity	-0.799	-0.904	-0.879	-1.122
	(0.166)***	(0.169)***	(0.256)***	(0.276)***
Controls for location	N	Y	Y	Y
Controls for light characteristics	N	N	Y	Y
Kleibergen-Paap rk Wald F statistic				16.7
R-square	0.352	0.483	0.505	
N	31	30	27	27

Notes: *, **, *** represents statistical significance at the 10, 5, and 1% levels. Robust standard errors are reported. For definitions of controls see the text.

Findings in unreported specifications are worth noting. Low light due rates charged by Trinity should have led to lower gross revenues, all else equal. That is what we find in a specification similar to (3) in Table 7 with the log of gross revenues as the dependent variable. The estimate is that Trinity had 75% lower gross revenues than privates. Low light due rates charged by Trinity should have also led to lower operating margins, defined as the difference between gross revenues and operating costs divided by gross revenues. Again, that is what we find. First, in the raw averages reported in table 2, Trinity had an average margin of 0.466 versus 0.768 for privates. Second, in a specification similar to (3) in Table 7 (not shown), the estimate is that Trinity had 37% lower margins than privates.

Our results are consistent with Trinity choosing to charge lower light duty rates, rather than simply having lights in different locations or characteristics, which necessitated lower rates. This raises the question of what Trinity was aiming for in setting rates. One possible reason is that Trinity was more public-spirited than privates and was willing to accept lower surpluses. Another possibility is that it aimed to publicly demonstrate its willingness to

charge lower dues in order to gain greater control of the lighting industry, which is what happened with the reform of 1836. We explore these explanations further in the next section

5. GOVERNMENT INTERVENTION AND TRINITY'S RATES

Trinity's key pricing changes occurred in the 1820s after they were prompted by the government from the late 1810s. The 1822 SC report gives financial data for all 20 lights operated by Trinity in 1818, 1819, and 1820. The average operating margin was 0.545. For these same 20 lights, the average operating margin was 0.481 in 1832, indicating a decline in margins over time. Moreover, Trinity lights with the highest revenues in 1820 also tended to have the highest margins. The top five out of twenty lights in terms of gross revenues had an average margin of 0.658 from 1818 to 1820. The average operating margin for those same lights in 1832 was 0.425, showing an even greater decline than the average Trinity light.

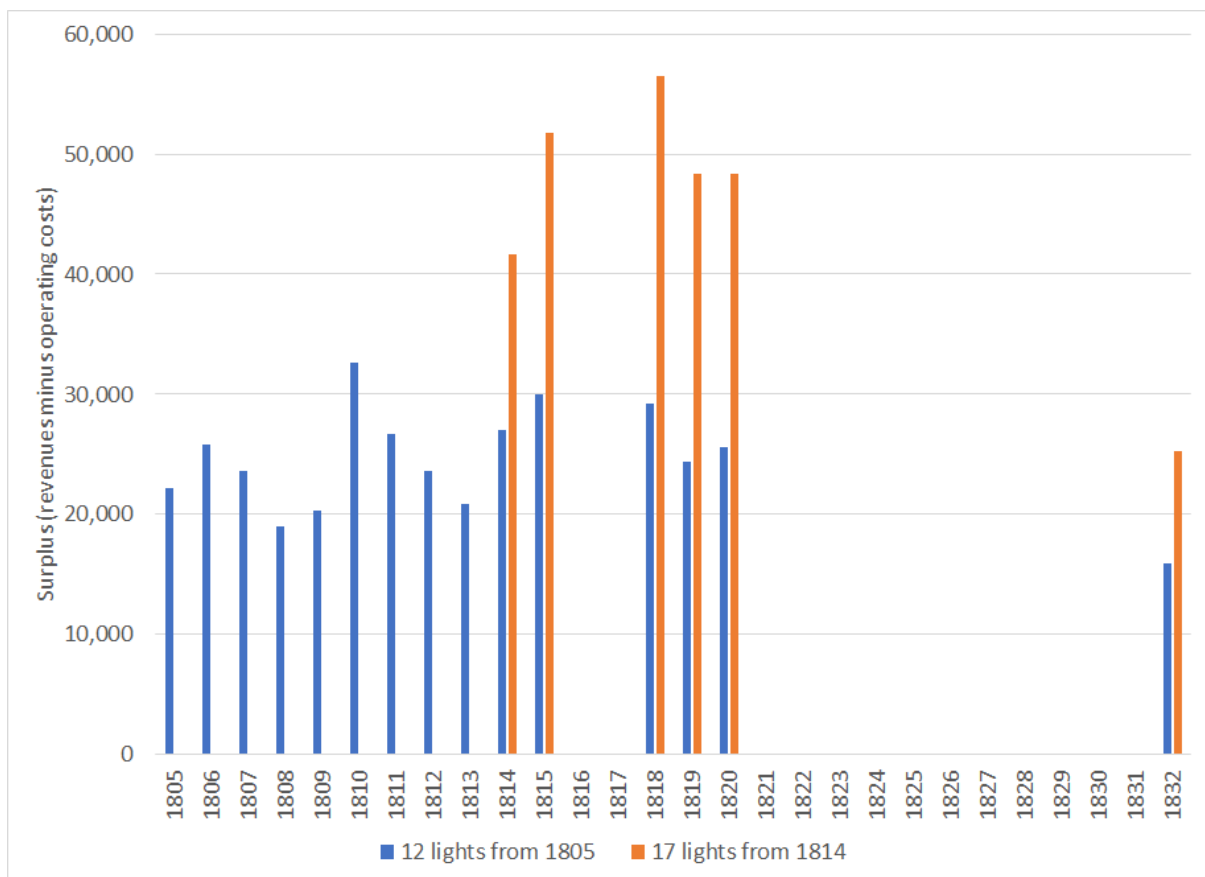
Higher light due rates were one reason for these higher operating margins. The 1822 SC reports that for the 20 Trinity lights, the average light duty rate charged to British vessels was 0.534 pence per ton (ppt) in 1818 to 1820. In 1832, the average rate for the same 20 lights was 0.372 ppt, indicating a significant decline over time. For the top 5 highest grossing lights, the average rate fell from 0.8 to 0.3 ppt from 1820 to 1832.

The high rates and operating margins for Trinity's lights seemed to catch the attention of government officials. In 1816, the House of Commons published an account of the 'profits of lighthouses', distinguishing each from the total from 1805 to 1815.³¹ Upon inspection, the profits listed are what later reports would call the surpluses, or gross revenues minus

³¹ House of Commons, *Accounts Relating to the Trinity-House of Deptford-Strond; 1805—1815*, (London, 1816).

operating costs. We have linked surpluses for Trinity lights in the 1816 account to the 1822 and 1834 SC reports. In figure 2, we chart the total surplus for 12 Trinity lights from 1805 to 1832. We added five lights to this group in order to chart surpluses for 17 Trinity lights from 1814 to 1832. The 12 Trinity lights that had the highest surpluses from 1810 to 1820 and the end of the Napoleonic Wars in 1815, seem to have put them at a consistently higher level. The 17 lights may have also had higher surpluses after the War, although there are fewer observations to confirm that. Overall, the high surpluses and upward trend in the 1810s give some hints as to why governments began to investigate Trinity’s affairs in the late 1810s, and eventually to intervene. Note that the literature has highlighted government intervention in the 1830s and mainly towards private providers, so this is all the more enlightening as it shows that Trinity was not beyond reproach when it came to its finances before this time.

Figure 2: Financial surpluses for Trinity lights, 1805 to 1832



Source: House of Commons 1816, SC 1822, and SC 1834.

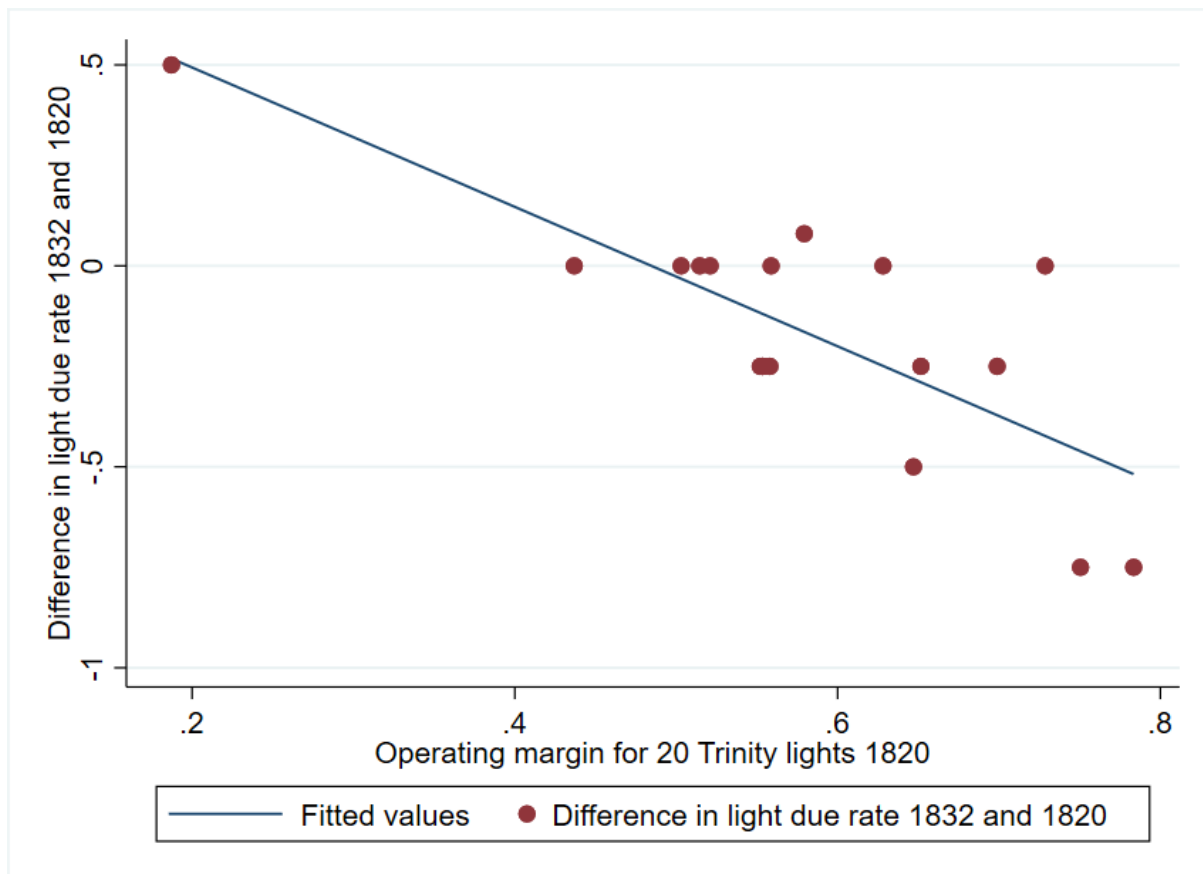
The text of the 1822 SC report gives a more direct insight into the government's concerns. 400 pages of evidence were gathered from witnesses to work out what was going on with charging and profit in the complex system of mixed ownership. It states that commerce and shipping should be free of taxation and regulation as far as possible. Trinity attracted strong 'disapprobation' about high charges - mixed but primarily from its light duties leading to unjustifiable high profits (SC 1822, 14). Light duties were stated as intended specifically to pay for building and upkeep of lights.

The 1822 SC noted how Trinity's income varied by light, but that in the main, its duties had grown out of proportion to the amount required to manage each lighthouse and build new ones. They noted the problem of growing shipping tonnage that had raised fixed rates of income far beyond this originally defined purpose, and how this was particularly problematic for older lights, whose rates were set at a time when fewer ships paid light duties. Importantly, the 1822 SC recommended that Trinity's rates should be reduced. The committee recommended primarily that Trinity should reduce its spending on pensions, by far its largest single expense, to better enable reduction in its tolls, invest in its own lighting stock, whilst taking over lights it had leased to private individuals whom the committee desired to phase out of the system mainly due to their high light due rates (SC 1822, 18-19).

The recommendations of the 1822 SC seem to have led to a change in Trinity's internal policies. As noted above, Trinity's average light due rates fell from 1820 to 1832. Upon closer inspection, we find some lights had their light dues maintained, and two even had them increased. We don't have direct evidence on why decisions differed across lights, but it appears related to the high operating margins in 1820. Figure 3 plots the operating margin for 20 lights in 1820 against the difference in the light due rate between 1832 and

1820. There is a clear negative relationship, suggesting Trinity responded to the government's criticism by reducing rates on lights with the highest margins. In one case, rates were substantially increased; this light had the lowest operating margin in 1820 around 0.2.

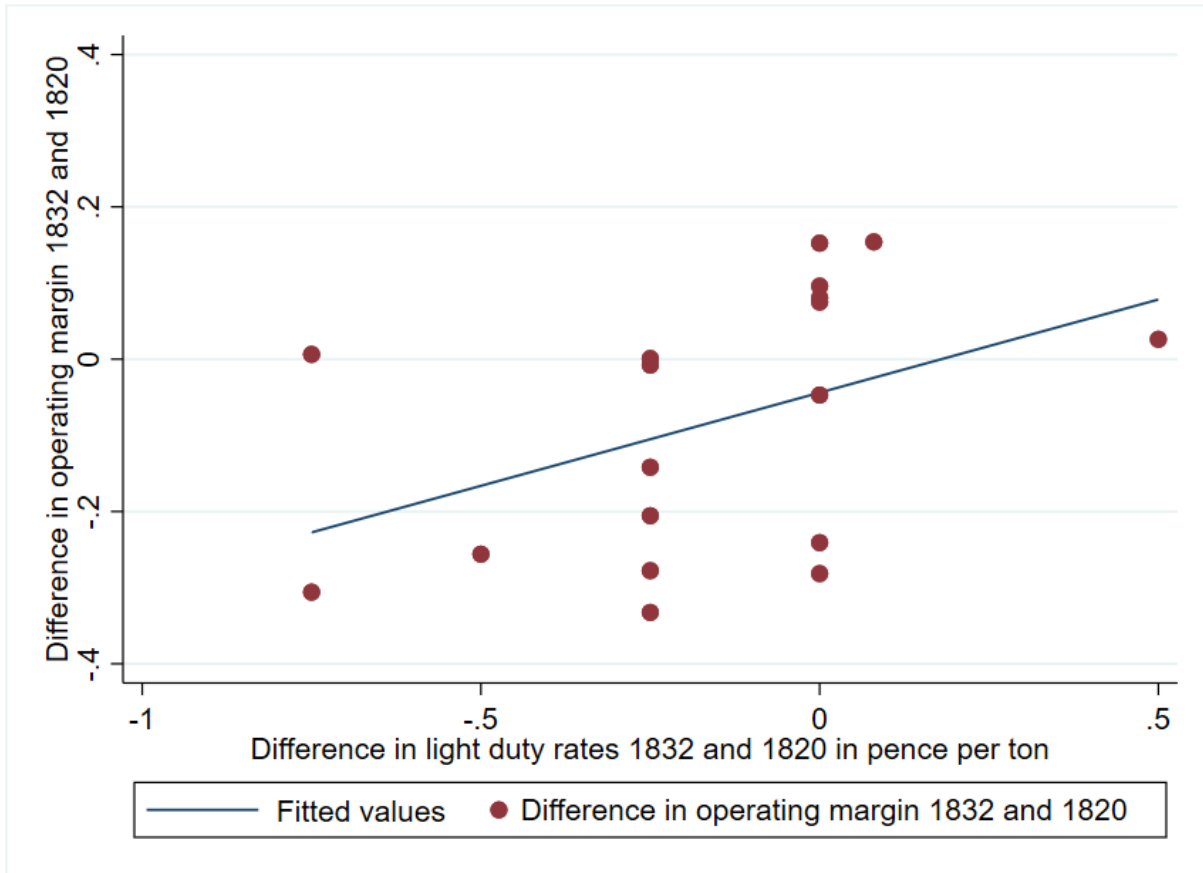
Figure 3: The relationship between operating margins and light due rate changes for 20 Trinity lights from 1820 to 1832



Source: see text.

What was the impact of the changing rates on operating margins after 1820? Figure 4 shows that lights which had their rates decrease the most between 1820 and 1832 generally had greater declines in operating margins between 1820 and 1832. The statistical relationship is noisy, but on the whole it suggests Trinity achieved lower operating margins by 1832 in part because of a policy change designed to lower its light dues.

Figure 4: The relationship between light due rate changes and operating margin changes for 20 Trinity lights from 1820 to 1832



source: see text.

6. CONCLUSIONS

We have used a new dataset, LAN, to reveal the full extent of coastal lighting in England and Wales in 1831. This data is linked with parliamentary papers to determine ownership and finances for many lights in 1832. Pricing, costs, and service levels are then compared for the mix of private providers. One of our aims is to examine the economic reasons behind a major reform in lighthouses, which has led to the present structure in the UK. Another aim is more general and speaks to the potential advantages of organizational scale and bundling.

In this historical context, there was mounting pressure to reduce taxes and eliminate corruption in government services. Select committees (SCs) began to scrutinize Trinity, which was becoming a major player in lighthouses and earning greater surpluses. Trinity was formally admonished by an 1822 SC, and as we show it responded by reducing its light dues substantially over the following 12 years. The progress made by Trinity was noted by the 1834 SC, who recommended more centralization in Trinity. Several private lighthouse owners, some descended from private lights starting in the 1600s, were seen as too costly to the nation's maritime commerce. Greater centralization was implemented by the Act of 1836.

Our analysis strongly suggests that economic factors were one reason for the reform. We show that privates had higher light due collection costs than Trinity in 1831. Underlying this difference were the higher commission rates charged by agents working for private lights. Private agents charged higher commission rates even at the same ports served by Trinity's agents, eliminating any potential for locational explanations. Trinity's advantage in collection costs was related to its larger scale. Its agents collected dues for many lights, while agents working for privates collected dues for a single light. As there was some fixed cost to hiring an agent, then the fragmented private system was inefficient.

We also show Trinity charged much lower light due rates than privates in 1831, and it had lower gross revenues and operating margins. These differences are found even after controlling for differences in lighthouse location and characteristics. Lower light due rates were a product of Trinity's efforts, starting in the 1820s, to make itself look like the low-price industry leader. Ultimately, Trinity was chosen to be the answer to the question of how to eliminate undesirable profits that led to overcharging for critical lighthouse services. It is tempting to conclude that this government intervention was crucial in addressing the inefficiencies present in 1831. But this requires a further chapter of the story of British lighthouse provision evaluating the period after 1836. This story remains for a future article.

Our analysis of harbor authorities points to another part of this story and one which also provides general lessons. The consolidation of national management in Trinity was coupled with a laissez faire policy towards harbor authority lighting services, which started building lights in the mid 1700s and continued deep into the 1800s. Harbor authorities are largely ignored in the literature, but as we show, they had lower light maintenance costs than privates or Trinity. This difference holds even after accounting for their location and technical characteristics of lights, and after matching based on observables. Some of their cost advantage is likely attributed to bundling of lighting services with the provision of other harbor infrastructure, like docks and piers. The intriguing success of harbor authorities suggests more research is needed to understand the gains from bundling in public services.

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