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The lightship in economics

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Abstract
What role does government play in the provision of public goods? Economists have used the lighthouse as an empirical example to illustrate the extent to which the private provision of public goods is possible. This inquiry, however, has neglected the private provision of lightships. We investigate the private operation of the world's first modern lightship, established in 1731 on the banks of the Thames estuary going in and out of London. First, we show that the Nore lightship was able to operate profitably and without government enforcement in the collection of payments for lighting services. Second, we show how private efforts to build lightships were crowded out by Trinity House, the public authority responsible for establishing and maintaining lighthouses in England and Wales. By including lightships into the broader lighthouse market, we argue that the provision of lighting services exemplifies not a market failure, but a government failure.

Keywords Government failure · Lighthouse · Lightship · Market failure · Public goods

JEL Classification D72 · H40 · P48

1 Introduction

What role does government play in the provision of public goods? According to the conventional wisdom in economics, when non-rivalrous goods are not excludable, free riding will occur among consumers, discouraging private actors from producing such a good. Therefore, a market failure will exist, requiring government support in the form of taxes and regulations since the private provision of public goods alone will be inefficient. However, the underprovision of any public good can more appropriately be referred to as a "missing market rather than a failing market" (Anderson and Libecap 2014, p. 33).

Theoretical and empirical research have identified a variety of private mechanisms to facilitate exchange by providing excludability to public goods (Allen 2012; Anderson

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and Hill 2004; Benson 1989, 1990; Ellickson 1991; Greif 1989; Leeson 2007a, b, 2008, 2009; Skarbek 2011, 2016; Stringham 2015). Based on that literature, we could hypothesize that government intervention is not necessarily required for the provision of all public goods. It also is possible to hypothesize that government intervention intended to correct a market failure may create the conditions for *a failure of the market to exist in the first place*: correction of an alleged market failure may prevent private entrepreneurs from discovering a market solution to correct such a failure. Studying the provision of a particular public good, namely the provision of coastal lighting services to merchant vessels during the 18th century, provides an important historical example to answer our opening question. Since the time of Coase's publication, "The Lighthouse in Economics" (1974), a debate has ensued as to the role the British government played in the market for coastal lighting services prior to its complete nationalization in 1836. We argue that the provision of such services prior to the nineteenth century illustrates not an example of market failure, but the failure for a lighting market to emerge owing to government failure.

Our main contribution in this article is to address the literature on the evolution of the British lighthouse system that followed Coase's publication of the "The Lighthouse in Economics" (Allen 2012; Barnett and Block 2007, 2009; Bertrand 2006, 2009; Carnis 2013, 2014; Coase 1974; Krause 2015; Lai et al. 2008a, b; Lindberg 2013, 2015; Taylor 2001; Van Zandt 1993). While the emphasis in the literature has been almost exclusively on lighthouses, in particular, we contend that analyzing the political economy of the British lighthouse system, particularly its entry and exit conditions, must be expanded to include coastal lighting services in any form. We do so by expanding the scope of the lighting market to include lightships. Specifically, we utilize novel primary source materials regarding the construction and operation of the world's first modern lightship moored on the Nore River, a shallow area on the Thames estuary going in and out of London from the North Sea. What we show is that the lightship on the Nore was privately constructed, profitable, and, crucial to the present discussion, operated without government enforcement of payments for its services. Combining mechanisms relying on subscriptions (i.e., payments before service) and price-discriminatory payments at ports, the lightship provides an example of a private provision of lighting services.

Moreover, based on evidence gathered specifically from the National Archives of the United Kingdom as well as newspaper sources from the time, we show that monopoly power in the production of coastal lighting is explained by government failure rather than market failure. Privately owned and operated lightships were opposed by Trinity House, the main public lighthouse authority in England and Wales. Rather than facilitating conditions of open entry and exit, Trinity House generated a tendency toward monopoly power in the provision of lighting services by restricting the construction and operation of lightships. Those restrictions, in turn, generated higher prices that later justified the nationalization of the British lighthouse system.

A second contribution of this article is to the literature on public goods. Specifically, our contribution addresses the extent to which the private production of public goods can be efficient (Bergstrom et al. 1986; Boettke and Coyne 2005; Boettke et al. 2011; Brubaker 1975; Cowen 1985, 1988 [1992]; Demsetz 1970; D'Amico 2010; Klein 1990, Klein and Yin 1996; Koyama 2012; Skarbek 2014; Tabarrok 1998). The main objection to the ability of private entrepreneurs to produce public goods is their inability to exclude nonpayers, thereby encouraging free-riding. Without an ability to exclude, individual consumers will not reveal their full willingness to pay for a public good, and therefore no pricing

mechanism can serve to guide the optimal production of a public good (Samuelson 1954, p. 388).[1]

However, the degree to which a good is non-excludable cannot be understood independently of the institutional context within which its being produced (Cowen 1985). For example, Demsetz (1970, p. 306) argued that exclusion of a public good is possible by bundling its consumption with the consumption of another excludable good, therefore creating private incentives for its production. Following Coase, we argue that excludability of lightships was made possible by bundling the services of the Nore lightship with the collection of payments for them at seaports. Our main contribution, however, is to show that such a bundling arrangement also occurred beyond the shadow of state, specifically without any grant of privilege from Trinity House entitling the owners of the Nore lightship, David Avery and Robert Hamblin, to any government enforcement of payment collection or prevention of free-riding by non-paying users. Archival evidence from the Trinity House Corporation as well as the National Archives of the United Kingdom illustrates that, rather than Avery and Hamblin being unable to collect fees for the use of their lightship themselves, it was rent-seeking by Trinity House, specifically to assert what it regarded as its *exclusive* right to charge payment, that prevented Avery and Hamblin from being able operate as a private, for-profit, lightship. In short, Trinity House blocked the possibility of private payment collection.

Brubaker (1975) later hypothesized that while it may be costly to exclude free riders from consuming a public good *after* its production, pre-contractual excludability can be an institutional mechanism by which to elicit demand revelation on the basis of pre-payments made *prior* to the production of a public good. If sufficient pre-payments are not forthcoming, the private producer can exclude non-payers *ex-ante* by threatening not to produce the good at all.[2] Primary source evidence, such as newspaper accounts written by Robert Hamblin, one of the developers of the Nore's lightship, as well as a report by the Attorney General of England, which contested the lightship's operation, show that pre-payments were forthcoming not only for construction of the lightship, but also for future plans to develop lightships in other parts of England. The future development of those additional lightships, however, was suppressed by opposition from Trinity House, which asserted its government prerogative as the sole authority in providing coastal lighting services.

[1] Beginning with the 5th edition of *Economics: An Introductory Analysis*, Samuelson (1961, pp. 192–193) used the lighthouse as an example of pure public good. Even after the publication of Coase (1974), however, Samuelson continued to use the lighthouse as an example of a good that required public provision. The lighthouse still appears as an example of a public good in the 19th edition of his textbook (see Samuelson and Nordhaus 2009, p. 37).

[2] As Brubaker (1975, p. 151) puts it, "An essential and neglected fact is that no matter how costly individual exclusion may be *after* the creation of a collective good, prior to consummation of a contract exclusion of the group, and consequently also of the individual, is always very easily accomplished. The producer simply holds no inventories. He works strictly on the basis of pre-paid orders. Lacking a firm contract with the community there will be no collective good for any of its members". Leeson (2007b) employs a similar self-enforcing mechanism to explain how the extension of credit by producers increased the costs of theft and raised the benefits of trade among middlemen in late precolonial Africa. In terms with which Brubaker might agree, credit is a pre-contractual mechanism of excludability because credit allowed producers to trade with goods that did not yet exist, minimizing the benefits of theft, and incentivizing future repeated dealings. Thus, credit was a pre-contractual mechanism to produce a public good privately, in this case self-governance, namely by eliciting a demand for trade among the middlemen. Analogous to the case being made herein, pre-payments for the construction of lightships allowed its producers to minimize free riding and incentivized payers to reveal their demands for lightship services.

Moreover, Demsetz (1970, p. 302) argued that if non-purchasers of a public good can be excluded, price discrimination can be consistent with a competitive market outcome precisely because a non-rivalrous good can be priced separately by segmenting consumers according to their willingness to pay. Consistent with this theoretical observation, we show that owners of the Nore lightship charged different prices to different vessels according to their tonnages. Such price discrimination not only implies excludability of non-payers, but also the ability of the pricing mechanism truthfully to elicit the demands of individuals. Therefore, the Nore lightship demonstrates that, rather than markets failing to provide coastal lighting services, it was government failure that prevented lightships from being provided privately.

2 The role of the Trinity House system

Since the publication of Ronald Coase's seminal article, "The Lighthouse in Economics" (1974), a debate has emerged over the government's role in operating the British lighthouse system prior to 1836.[3] Before and since Coase, the concept of the lighthouse as a public good (Samuelson 1954) versus a club good (Buchanan 1965) has generated differing conclusions about the government's role in providing non-rivalrous, collectively consumed goods. If a good's consumption is non-rivalrous, yet nonpayers can be excluded from consuming it, then government intervention in the form of regulation, taxes, subsidies, or exclusive franchises (i.e., monopoly) may be considered unnecessary (Stringham 2015). Although economists have retreated from the idea that lighthouse services are solely the prerogative of governments, how much government intervention was necessary to provide lighthouse services still remains an open question. The consensus in the literature has been that private lighthouses operated with state support well above what was provided to private firms producing rivalrous and excludable products.

Trinity House was the principal lighthouse authority in England and Wales, which Coase (1974, p. 376) refers to as "a private organization with public duties". It was not a government agency, but a private guild with strong backing from the state. First incorporated in 1514 by Henry VIII, Trinity House evolved out of a seaman's guild. Initially, its role was to regulate navigation and provide charity to mariners in the form of relief for the sickly as well as managing old-age pensions (Clarke 2016, p. 28; Hardy 1895, p. 40; Meade 1949, p. 2; Taylor 2001, p. 753). After 1566, it was given the right to establish and regulate seamarks (Clarke 2016, p. 29; Coase 1974, p. 363). Throughout the sixteenth century, Trinity House accumulated additional prerogatives, "including the regulation of pilotage,[4] the provision and regulation of navigational aids on land and at sea, apart from the other corporations. These powers made it the logical body to provide lighthouses, but it largely left this function to private enterprise, and even opposed private construction of lights" (Taylor 2001, p. 753). Despite its growing prerogatives, Trinity House was not the sole producer of seamarks (Bertrand 2006, p. 394, 2009, p. 16). In order to increase revenue, the King also granted patent monopolies to private individuals for the building of

[3] In 1836, an act of Parliament nationalized all remaining privately owned lighthouses in England (Hardy 1895, p. 41); see also Coase (1974).

[4] According to Clarke (2016, p. 32), pilotage refers to "the art of taking a vessel from one place to another in sight of land and providing ships with safe passage onto rivers and harbours or through dangerous waters".

lighthouses (Clarke 2016, p. 29). While it had been granted the exclusive privilege of establishing and maintaining lighthouses, Trinity House fought to assert a monopoly against the entry of private competitors, which it attempted to exclude (Hardy 1895, pp. 30–31; Bertrand 2006, p. 394). Trinity House obtained all of the patents on lighthouse operation from 1679 onward, which it would sometimes license to private operators who would incur all operating costs (Bertrand 2006, pp. 394, 400; Coase 1974, pp. 365–366; Stevenson 1959, p. 367).[5] Throughout the 18th and early 19th centuries, private lighthouses represented a declining share of the market: 22 out of 46 lighthouses in England and Wales in 1820 (Coase 1974, pp. 366–367), as opposed to 14 out of 56 in 1832 (Coase 1974, p. 366).[6] Those who made the case for nationalization in the 1820s and 1830s argued that it would reduce light dues (i.e., duties or fees) as Trinity House's operating costs would be lower than those of private lighthouses (Taylor 2001). As the 1834 Report from the Select Committee on Lighthouses states, "Your Committee, therefore, strongly recommend that the Light Dues should in every case be reduced to the smallest sums requisite to maintain the existing Lighthouses and Floating Lights, or to establish and maintain such new Establishments as shall be required for the benefit of the Commerce and Shipping of the country" (House of Commons 1834, p. iv).

Like other organizational arrangements of pre-20th century Britain, the consensus is that lighthouses could not be considered a fully private good—not unusual given the premodern institutional context within which lighthouses emerged in England and Wales. As Allen (2012, p. 175) states, lighthouse services were "quasi-private affairs in which the Crown was involved to some extent. Like the purchase system in the army in which the Crown regulated prices, approved sales, and generally had an interest in outcomes, premodern governments also took an interest in lighthouses and their dues, operation, and construction".

What has specifically been debated in the literature since Coase is the degree of government involvement in the collection of fees charged by lighthouses, also known as light dues. The consensus is that private, for-profit,[7] lighthouses existed *only* because of state support in collecting light dues (Van Zandt 1993, p. 56). In other words, private lighthouses fell within the state's shadow. As Taylor (2001, p. 752) states, individuals "desirous of constructing a lighthouse would arrange for the dispatch of a petition to the crown from local merchants and shipowners, which had to include a demonstration of willingness to pay light dues to cover the cost of erection and maintenance. If the crown consented to the request, letters patent were granted to the individual nominated in the

[5] Historians argue that since Trinity House was responsible for mariners' pensions, it was reluctant to bear too much risk. As such, its monopoly power allowed it to shift risks to private parties (Lindberg 2013, p. 546).

[6] The 1834 report of the House Select Committee (1834, pp. XXXVII–XXXVIII) reported 55 lighthouses and floating lights operated by Trinity House for 1832 and 14 privately operated lighthouses in England and Wales. Taylor (2001, p. 758) writes that by 1835, the number of private lighthouses had fallen to 10. Ireland and Scotland had their own lighthouse authorities (the Commissioners of Irish Lights and the Commissioners of the Northern Lighthouses), which were separate from Trinity House's operations in England and Wales.

[7] We distinguish between for-profit, private lighthouses and non-profit, private lighthouses specifically to focus our discussion on the former, rather than the latter. Although lighthouses were provided by hermits and religious orders on a voluntary basis, they were operated on a non-profit basis (see Van Zandt 1993, p. 59). Block and Barnett (2009) also argue that purely private production was possible for charitable purposes. Because the main dispute in the literature is on the profitability of lighthouses in the absence of state enforcement of the collection of light dues, we do not focus on non-profit lighthouses.

petition, permitting the levy of light dues to cover construction costs, and the lighthouse could be erected". The time-limited patents were local monopolies because the patents also prohibited the establishment of competing lighthouses within a certain distance (Van Zandt 1993, p. 64).

What is more important, the patents for lighthouse operations contained provisions compelling the payment of light dues at seaports (Meade 1949, pp. 114–115; Nicholson 1983 [1995], p. 13). The "Crown itself not only fixed the dues but also imposed their payment directly on shipowners. The King even helped the lighthouse 'owners' to collect their dues, if necessary with fines or prison sentences immediately imposed on shipowners" (Bertrand 2006, p. 397). Bertrand (2006, p. 397) goes on further to state that it "seems that dues payment had to be made compulsory by constraint for their collection to become effective". The collection of light dues, according to Nicholson (1983 [1995], p. 13), "was overcome by most patentees by entering into an arrangement with the Trinity House agent based on the London Customs House". The Trinity House agent would then employ his own agents to outsource the collection of light dues across different ports, from which the quasi-private agents would be paid a percentage commission for collection, "as much as 20–25 percent in the period up to the mid-19th century" (see also Coase 1974, p. 364; Meade 1949, p. 114). As such, the functioning of the Trinity House system resembled that of modern public-private partnerships. The arrangement allowed the delegation of lighthouse management, which economized on governmental costs (Carnis 2013, p. 53), which were assumed either by private operators or by Trinity House. More often than not, Trinity House also would also license a patent to an entrepreneur who would assume all the risks and expenses. Finally, the existing system of lighthouses (public and private) created the rents needed to sustain political coalitions (Allen 2012, pp. 297–299; Carnis 2014, p. 148; Taylor 2001).

The literature highlights an entanglement of private and government actors (see Wagner 2016), making it hard to assess whether private production was possible beyond the shadow of the state (Carnis 2014, pp. 148–151). Even if lighthouses were privately constructed and operated, the difficulty in collecting light dues on a purely voluntary, profit-making basis would led to free-riding and under-provision of light dues for maintaining lighthouses. While agreeing with Bertrand that Coase failed to appreciate the government's role in coercing payment of light dues, Block and Barnett (2009, p. 3) concede the *theoretical* possibility that lighthouses could have operated privately and without compulsory financing. However, they ultimately conclude, in agreement with Bertrand (2009, p. 17), that the historical evidence shows that "for-profit firms with a minimal role of the State, did not exist" in the context of the British lighthouse system.

Overall, the conventional wisdom in the literature is that beyond the shadow of the state, private lighthouses in Britain and Wales could not possibly operate profitably. However, many other historical examples can be found of the viable private provision of coastal navigation aids, including Argentinian buoys (Krause 2015) and lighthouses in Estonia (Carnis 2014) and Hong Kong (Lai et al. 2008a, b).

In order to assess whether or not we are facing a case of a missing market rather than a market failure, we reframe the existing literature in two ways. First, we focus on coastal lighting services more broadly than the services provided by lighthouses alone. As such, the scope for competition *within the market* for lighting services is expanded to include the entirety of coastal lighting options, including lightships. Second, we reframe the literature in terms of the nature of competition *for the market* for lighting services and ask how much the government encouraged or stifled tendencies toward monopoly. Understood in that way, the debate is not over whether the lighthouse represents a market failure, but whether the

historical context that Coase uncovered and discussed represents an institutional framework that precluded a private coastal lighting market from emerging.[8]

We may assume, for sake of argument, that the marginal costs of adding additional consumers of a non-rivalrous good are zero. But it does not follow that *rivalry in producing such a good does not exist*.[9] Competing producers of non-rivalrous goods can sell their outputs to be partitioned and consumed by different consumers according to their willingness to pay, as was the case not only with lighthouses, but also with the Nore lightship that we discuss in the next section. With non-rivalrous goods such as coastal lighting, competitive production in a geographic area necessarily is mutually exclusive (Demsetz 1970, pp. 298–299).[10] Within a particular geographic market area, then, a lighthouse may have a "monopoly" in providing services within the radius of its light emissions. But while the conditions of a non-rivalrous good may imply nonrivalry of production *within* a particular market, it does not necessarily imply nonrivalry *for the market itself* (Demsetz 1968, p. 57, fn. 7). Therefore, when governments promote or stifle the conditions of entry into and exit from a market for non-rivalrous goods, including pure public goods, it will affect whether contestability or competition for the production of those non-rivalrous goods will manifest itself as a market failure or a government failure.

To summarize, the literature cites two market failures associated with lighthouses under the Trinity House system: (1) monopoly power in the pricing of light dues, which inhibited maritime commerce (see Taylor 2001, p. 756), and (2) public goods, requiring government exclusion to compel payment of light dues. By defining the lighthouse market more broadly to include lightships, we illustrate that the Nore lightship was a private entrepreneurial response to high light dues, whose collection was in fact voluntary.

3 The Nore lightship

According to historical record, the Nore lightship was the first modern lightship developed by two entrepreneurs, David Avery and Robert Hamblin, first launched in 1731 at the entrance to England's Thames River (Clarke 2016, p. 14; Hardy 1895, p. 33; Putnam 1917, p. 200).[11] Lightships, also known as "floating lights" or "swimming lights", are manned[12] seamarks anchored in a river at a specific point, generally a shallow one, such as shoals and sand banks, for the purpose of avoiding shipwrecks.[13] Fixed in place by a

[8] Our argument also builds on a theme that Coase already had developed in his 1961 paper, "The British Post Office and the Messenger Companies," which illustrates how, in an attempt to preserve its monopoly, the Post Office tried to obstruct the entry of private entrepreneurs into the provision of postal services.

[9] We use the term "rivalry" here to mean mutual exclusivity of consumption and/or production; we do not use it interchangeably with "competition" or "contestability".

[10] In any case, patents for lighthouse operation came with a radius of exclusive operation within which no competitor could install itself.

[11] In navigational distance, the Nore lightship was 48 miles away from London (Chandler, Diston and Adams 1788, p. 113). The route between the Nore and the Port of London took roughly three hours (House of Commons 1796, p. 46).

[12] Modern lightships under the Trinity House system are no longer manned. According to Clarke (2016, p. 150), the majority of manned lightships was decommissioned in the 1970s and 1980s. The last manned lightship in England, the *Inner Dowsing*, was decommissioned in 1991.

[13] Clarke (2016, p. 38) reports that the origins of modern lightships can be traced back to ancient Roman galleys, known as *liburnae*, used by the Roman navy for raids, but also provided lighted beacons to deter pirates. As he states further, the "vessels carried on their mastheads iron baskets in which fire was built serving as a signal when a friendly vessel was sighted". However, their functions as lightships were limited

mushroom-shaped anchor, the small lightships would use large lanterns affixed atop the main mast. Hamblin himself advertises the Nore lightship as "a complete vessel of about 100 tons" (*Universal Spectator*, October 16). It had two oil lanterns mounted 12 feet apart at the top of the ship's masthead (Stevenson 1959, p. 139), but after 1825 the ship was reduced to single light (Clarke 2016, p. 42).

The main advantage of lightships is that they could be placed in areas where it was impossible for lighthouses to act as efficient seamarks; however, for the early ones, turbulent waters could shift the anchor and thus the ship's positioning (Talbot 1913, pp. 241–242).[14] In the worst-case scenario, the chains could snap, leaving the ship in dire straits. By the early 19th century, though, numerous lighting inventions (Clarke 2016, pp. 14, 42), as well as mooring technologies using iron, could anchor a vessel 12 to 14 times the tonnage of the largest lightship (Clarke 2016, pp. 50–56), making lightships more reliable over time.

While ubiquitous to seafarers, their offshore positions meant that lightships were out of eyesight of most people, which explains why they were overlooked, even by most economists and historians—including Coase,[15] who studied coastal lighting services. Yet, lightships featured prominently in Britain's frequently cited 1834 Report from the Select Committee on Lighthouses. In fact, of the 55 lights operated by Trinity House in England and Wales, 13 were provided by "floating lights" (House of Commons 1834, p. VI).[16] By then, lightships had become important contributors of lighting services as a result of the entrepreneurial efforts (less than a century before) of Avery and Hamblin.

How did Avery and Hamblin come upon the idea of developing a lightship?[17] Avery, who was regarded as "a man whose brain was full of grand projects, but who was cruelly hampered by poverty" (Adams 1870, p. 254), had developed the idea of using ships as the basis for a floating lighthouse in areas where ordinary lighthouses could not be built. Hamblin, although trained as a barber, had married the daughter of a shipowner, and would later operate a collier, a large type of ship carrying coal to London. Overtime, Hamblin "gained a reputation from port owners and seafarers as to his ability as a Master of a vessel with knowledge of the dangers of the east coast" (Clarke 2016, p. 41). From his sailing experiences, Hamblin was able to observe the danger of sailing up the Nore bank, at the confluence of the Thames and Medway rivers and the inadequacy with which lighthouses marked the shallowness of that entrance into the Port of London. Although Trinity House had placed a buoy at the Nore, it served little purpose in darkness and in bad weather (Adams 1870, p. 254; Clarke 2016, p. 39). Moreover, as sand banks change position from year to year, navigation charts proved unreliable to sailors (Fautley and Garon 2005, p. 208). As a

Footnote 13 (continued)

because ancient sailors tried not to sail at night. It is unclear whether Avery or Hamblin were aware of their historical provenance.

[14] Lightships were very popular for the navigation of Canada's Saint Lawrence seaway (Cloutier and Charest 2016) and the American eastern coastline (Webster 2000). This is a telling element given that frontier economies like Canada and the United States would be have been blank slates in terms of technologies available to adopt, which may explain their greater relative popularity in North America.

[15] Coase (1974, p. 366) excluded "floating lights" from his presentation of the numbers.

[16] By 1834, all 13 lightships were owned by Trinity House (House of Commons 1834, p. 344).

[17] Most of the secondary sources that discuss the event rely nearly exclusively on the information provided by John Whormby (1746 [1861]). Whormby was the clerk of Trinity House who wrote a history of the Corporation in which he gave his retelling of the Nore lightship episode as he lived it. Most of it is condescending towards Hamblin and Avery.

result, as maritime commerce began to grow during the 1700s, the cost to shipowners in terms of time and lost revenue rose, because it often was the case that ships sailing into the estuary at night would anchor until daylight to avoid shipwreck.

The particular importance of the Nore lightship was that it was introduced, with the vocal opposition of Trinity House, precisely at a time when traffic at the Port of London was increasing rapidly. In 1702, the international trade entering the Port of London stood at 157,035 tons. By 1751, it had risen to 234,639 tons and, by 1794, it had reached 620,845 tons (House of Commons 1796, p. V). To that growth had to be added the river and coastal trade, which included larger numbers of smaller ships making numerous trips each year (House of Commons 1796, pp. V–VI; Usher 1928). The expansion of traffic occurred at a time when the Port of London could hold fewer than 900 ships in its pool (Colquhoun 1800, p. 23), which implies that navigational issues grew dramatically for merchants. To meet the rising demand for safety as well to reduce the costs of trade, on July 4th, 1730, Avery and Hamblin finally secured a 14-year patent for their invention (Anonymous 1865, p. 624). The *Daily Courant* and the *Daily Post* published the first advertisements of its imminent launching on September 15, 1731. By October 10th 1731, the ship was in active service (*Daily Courant*, October 12th 1731). [18]

The just-mentioned facts of time and place reveal that the nature of any economic good, including lightships, is endogenous to its institutional context. Moreover, whether or not a good is regarded as private or public is a matter of degree, not of kind (Cowen 1985). That was no less the case for lighthouses and lightships in two respects. First, given that the mounting traffic along the Thames River into the Port of London increased the demand for a lightship, particularly at the shallow mouth of the Thames River, where the risk of shipwreck was highest, implies that suppliers of lighting services faced *positive* marginal costs in providing additional light to its consumers. The willingness of entrepreneurs, such Avery and Hamblin, to supply a lightship emerged only when the profitability of accommodating additional commercial ships rose. Therefore, the consumption of lighting services grew more rivalrous as commerce increased. Secondly, light emitted from a lightship may be non-rivalrous to a certain extent, but the fact that the use of such light by commercial ships is bundled and tied to the use of seaports means that the lightships also are excludable. Therefore, although lighthouses generated positive externalities, the benefits to commercial vessels were internalized by the agents of lighthouse owners, including the

[18] Some secondary sources mention 1732 (e.g., Adams 1870, p. 254; Gattie 1890, p. 156) and some even place it in 1733 (Cotton 1818, p. 77), while others are vague about the date (Adams and Woodman 2013, p. 87). But the advertisements published in the *Daily Courant* (October 12, 1731), the *Universal Spectator and Weekly Journal* (October 16, 1731), the *Daily Post* (October 12, 1731), and the *London Journal* (September 18, 1731; October 16, 1731) all make it clear that the ship became operational in 1731. Hamblin mentions in an ad submitted on October 10 that he had "this morning moor[e]d a complete ve[ss]el of about 100 tons" (*London Journal,* October 16, 1731). The only secondary source that gives 1731 as the starting date is Stevenson (1959, p. 139) for whom we have confirmed every assertion. A July 22nd, 1731, article in the *Grubb Street Journal* mentions a ship placed at the buoy at the Nore on order of Trinity House (this is echoed in the *Caledonian Mercury* of July 26, 1731). However, the article is unclear about what was occurring, but we know that, given its virulent reaction (see next section) to the Nore lightship, Trinity House could not have ordered the placing of the first 19-ton lightship. The possibility exists of a journalistic error. However, it is true that notice of a first ship was placed by Hamblin for advertising purposes. Secondary sources confirm it. Robert Peirce Cruden (1843, p. 412) pointed out that on the August 9th 1731 (a date that contradicts the July *Grubb Street Journal* ad), Hamblin moored a 19-ton vessel at the Nore (called the *Experiment*), which he had replaced by an additional ship (called the *Good Intention*) of 100 tons on October 10th 1731. The mooring of the *Experiment* apears to have been meant as a marketing ploy. The elements contained in Cruden's account are confirmed by the September and October ads placed in the *Daily Post, Daily Courant, Universal Spectator* and *Grubb Street Journal.* As such, the 19-ton *Experiment* operated from either late July 1731 to early October 1731 or from early August 1731 to early October 1731.

Nore lightship, in enforcing the collection of light dues. As Meade (1949, p. 114; emphasis added) explains,

> It has frequently been asked how the lighthouses and the various systems of light-vessels, buoys and beacons were paid for.… In the early days, when the business was in many places in *private* hands, the means of collecting dues had of course to be carried out by an agent at a seaport. One could not expect the lighthouse-keepers to go out in a boat and collect a toll as in the case of a turnpike road on land. It meant that the owners of lighthouses would have the additional expense of paying their agents, which naturally ultimately fell upon the shipman.

Meade (1949, pp. 114–115) goes on to write that "[p]rivate individuals under patents or leases from the Crown paid rent for them and had the right to collect tolls", but that was *not* the case for the owners of the Nore lightship. The most important feature of their invention is that it was *outside* the conventional patent system. As we stated in Sect. 2, individuals petitioning to the King for permission to construct a lighthouse would be granted a patent providing lighthouse owners with the Crown's enforcement of light dues' collection. However, the patent for which Avery and Hamblin petitioned, issued on July 4th, 1730, was only for the invention, *not* for the collection of fees by Trinity House customs agents acting on the behalf of Avery and Hamblin (National Archives 1730, SP 36/17/81). Avery and Hamblin stipulated in their petition that their invention was meant to provide a method of distinguishing one lighthouse from another, thus allowing their service to be discernable from others. In their petition to the King, they say nothing about competing with other lighthouses. However, their long-term plan was to "fix floating lights at short distances from the shore, in such positions as would render the existing lighthouses absolutely useless" (Hardy 1895, p. 72).[19] Soon after they opened the Nore lightship, secondary sources point to their announcement of the launching of a second lightship at the Scilly Isles (Renard 1867, p. 194; Adams 1870, p. 254). In fact, primary sources point to more announced launchings that Hamblin "hath projected another light at the Scilly and proposed another at a place called the Well and other places" (National Archives 1732a, PC 1/5/4, 4/3-4/4).[20] The sources that relate the event all point to the popularity among merchants of Hamblin and Avery's enterprise (Adams 1870, p. 294), suggesting that they had tapped into customers' dissatisfaction with Trinity House.[21]

In the absence of a patent supporting mandatory collection of dues, Hamblin and Avery operated in a *voluntary* contribution system in order to compete with existing lighthouses.[22] A combination of factors allowed them to overcome free riding. First, operating costs were

[19] This is confirmed by the clerk of Trinity House, John Whormby, in his 1746 history of the corporation. He pointed out that Trinity House apprehended, "very justly" in in his opinion, that Avery would go "round the kingdom with lights of that kind, to the danger and confusion of navigation, as well as *to the prejudice of fixed lights*" (Whormby 1746 [1861], pp. 135–146; emphasis added).

[20] The Well refers to Dudgeon Shoals off the coast from Cromer in East Anglia where a lighthouse already existed (Stevenson 1959, p. 136).

[21] Few sources provide details about how that was the case. The one exception is a laudatory article in the *Newcastle Courant* on August 21, 1731. The article refers clearly to the first, smaller, lightship as a "great advantage to Navigation in general, as well a Means to preserve the Lives and Fortune of his Majesty's Trading and Maritime Subjects from the Dangers of the Nore Sand". However, that article was a copy of the August 11, 1731 article published in London's *Daily Courant.*

[22] The voluntary payment component of the lightship at the Nore often is noted in passing (Cruden 1843, p. 412; Pask 1884, pp. 604–605). In fact, Trinity House complained explicitly about the voluntary nature of payments through subscription books.

low, which facilitated turning a profit (see Table 1). Second, they charged rates below those of other lighthouses, which endeared them to merchants and, unlike Trinity House, they engaged in price discrimination to limit the extent of free-riding (see Table 2). Third, and what is most important, they relied on subscriptions by sailors and merchants in order to finance initial investment and operation of the lightship; for the rest, they collected dues at ports.

In terms of operating costs, it is hard to compare the Nore with other lighthouses because only one estimate is available: the estimate of £2,000 for "fitting out" (Stevenson 1959, p. 140) that Avery provided to Trinity House when he negotiated for a patent to operate the lightship on its behalf. That estimate is probably high as it was used in a negotiation by a party seeking some form of compensation for the troubles caused by Trinity House (see more in the next section). It also is uncertain as to whether or not the estimate includes the cost of operation along with the cost of construction, which hinders comparability.[23]

We also do not know if Avery included the legal costs he and Hamblin incurred in acquiring the patent. In the Appendix to this paper, we use a wide array of upwardly biased operating cost estimates to net out construction costs and arrive at annual operating costs measures: from £298.1 to £345.0 per year (in 1832 pounds). The costs are less than those reported for lightships and lighthouses built later by Trinity House (see Table 1). This stands in contrast to the Report from the Select Committee of 1834, at which point all lightships were owned by Trinity House (as of 1832), indicated that lighthouses were cheaper per year to operate than lightships: £511 as opposed to £1,334 (House of Commons 1834, p. 345).[24] The estimates we generate also fall below those of the Nore lightship when it was operated by Trinity House: £681, £950 and £605 (inclusive of collection costs) in 1832, 1820 and 1805–1815, respectively (expressed in 1832 currency, see Appendix Fig. 1).

The figures produced by Avery are well below Table 1's numbers; plausible estimates of costs (see Appendix) point in the same direction. Their relatively low costs made it easy for Avery and Hamblin to offer relatively lower rates for lighting services. When Hamblin advertised in the September 15 issue of the *Daily Courant,* he stated that merchants would "pay the following Prices for each Voyage *viz.* for all Ships or Ve[ss]els under 100 Tons, to pay 6 *d.* [pence] each, for all Ditto, from 100 to 200 tons, 1 *s.* [shilling] each; and for all Ditto, above 200 Tons, 1 *s.* 6 *d.* each". At the time, the dues were low: between 0.045 and 0.12 pence per ton.The fees could be paid at the Customs House (*Daily Courant*, October 12, 1731). In Table 2, we compare the lightship's dues to those of other lighthouse services: the range of light dues, which includes the 1830s estimates reported by Coase (1974, p. 365), is well above the dues charged by the Nore lightship.

At those rates, we calculate (see Appendix) downwardly biased[25] potential revenues (expressed in 1832 pounds) at £675.4 per year. Given the upwardly biased operating costs

[23] The official historians of Trinity House refer vaguely to expenses of £2,000 on the "project" (Adams and Woodman 2013, p. 87). Many sources mention "fitting out", but they all represent secondary sources. As we document in Appendix, it is likely that the estimates combine operating costs (i.e., variable costs) and fixed (i.e.,construction) costs. If the secondary sources are correct that the figure of £2,000 concerns only the construction and fitting-out of the *Experiment* and *Good Intention*, then the operating cost estimate derived using the number of workers and gallons of fuel consumed is the most accurate (see Appendix).

[24] They also were more expensive to build: *Chambers's Encyclopaedia* (1891, p. 623) placed the construction cost of a lighthouse between £5,000 and £10,000, while a lightship cost £9,000 during the late 19th century.

[25] Revenues from smaller ships are omitted. Moreover, we do not include revenues from the public subscriptions, which were collected ex ante.

Table 1 Construction and operating costs

Item	Type	Nominal cost	Real cost (1832 prices)
Lightship at the Nore, 1730 to *circa* 1733[a]	Uncertain	£2,000 total	£3,491 total
Lightship at the Nore, 1731 to 1733[b]	Operation	–	£298 to £345 annually
Ligthship at the Nore, 1805-1815[c]	Operation	£759 (inclusive of collection costs)	£605 (inclusive of collection costs)
Lightship at the Nore, 1832[d]	Operation	£681 annually (inclusive of collection costs)	£681 annually (inclusive of collection costs)
Lightship at the Nore, 1820[e]	Operation	£1,104 annually (inclusive of collection costs)	£950 annually (inclusive of collection costs)
Lighthouse at the Skerries, 1717[f]	Construction	£3,000 total	£4,911 total
Lighthouse at the Lizard, 1752[g]	Construction	£3,000 total	£4,819 total
Goodwin Sands Lightship, 1795[h]	Construction	£5,587 total	£6,213 total
Galloper, Gull Stream, and Bembridge, 1790s[i]	Construction	£1,000–£1,800 total	£1,179–£2,122 total
Lighthouses at the Farne and Longstone Rocks, 1810[j]	Construction	£4,250 total for each	£3,246 total
Average of 36 lighthouses, 1832[k]	Operation	£510.85 annually	£510.85 annually
Average of 13 lightships, 1832[k]	Operation	£1,333.58 annually	£1,333.58 annually

Source for price index: (Clark 2018) available online at http://www.measuringworth.com/ukearncpi/

[a]Anonymous (1865, p. 624); [b]see Appendix; [c]Cotton (1818, pp. 186,196); [d]House of Commons (1834, p. 333); [e]House of Commons (1834, p. 412); [f]Stevenson (1959, p. 135); [g]Stevenson (1959, p. 141); [h]Gattie (1890, p. 157); [i]Clarke (2005, p. 45); [j]Stevenson (1959, p. 142); [k]House of Commons (1834, p. 341)

Table 2 Light dues charged

Item with year of patent approval	Nominal price	Real price (1832 pence)
Lightship at the Nore, 1731[a]	0.045 to 0.12 pence per ton*	0.08 to 0.21 pence
Lighthouse at the Lizard, 1623[b]	0.50 pence per ton	0.99 pence per ton
Lighthouse at Spurn Point, 1676[c]	0.25 pence per ton	0.46 pence per ton
Lighthouse at the Scilly Isles, 1689[d]	0.50 pence per domestic ton; 1.00 pence per foreign ton	0.98 pence per domestic ton; 1.95 pence per foreign ton
Lighthouse at Milford Haven, 1713[e]	1.00 pence per domestic ton; 2.00 pence per foreign ton	1.60 pence per domestic ton, 3.21 pence per foreign ton
Lighthouse in the Skerries, 1714[f]	1.00 to 2.00 pence per ton	1.56 pence per domestic ton; 3.11 pence per foreign ton
Lighthouse in Portland, 1716[g]	0.25 pence per ton	0.40 pence per ton
Lighthouse in Cromer, 1719[h]	0.25 pence per ton	0.43 pence per ton
Lighthouses in Kent, 1720[i]	1.00 pence per domestic ton; 2.00 pence per foreign ton	1.61 pence per domestic ton; 3.22 pence per foreign ton
Lighthouse in Casquets, 1723[j]	0.50 pence per ton	0.84 pence per ton
Lighthouses across Britain, *circa* 1768[k]	0.25 to 1.00 pence per ton	0.36 to 1.43 pence per ton
Lighthouses across Britain, *circa* 1818[l]	0.25 to 1.00 pence per ton**	0.20 to 0.79 pence per ton
Lighthouses across Britain, 1821–1822[m]	0.5 to 1.00 pence per domestic ton; 1.00 to 2.00 pence per foreign ton	0.49 to 0.98 pence per domestic ton; 0.98 to 1.96 pence per foreign ton
Lighthouse across Britain, 1832[n]	0.25 to 1.00 pence per ton***	0.25 to 1.00 pence per ton

Source for price index: (Clark 2018) available online at http://www.measuringworth.com/ukearncpi/

[a]*Daily Courant* (Sept. 15, 1731); [b]Stevenson (1959, p. 101); [c]Stevenson (1959, p. 106); [d]House of Commons (1802, p. 219); [e]Stevenson (1959, p. 133); [f]Stevenson (1959, p. 135); [g]Stevenson (1959, p. 134), [h]Stevenson (1959, p. 136); [r]Treasury Department (1889, pp. 8–9); [j]Stevenson (1959, p. 137); [k]Anonymous (1768, p. 22—24); [l]Cotton (1818, p. 77); [m]Taylor (2001, p. 756); [n]House of Commons (1834, p. 341), also found in Coase (1974, p. 365)

*Avery and Hamblin charged by tonnage category (below 100 tons; 100 to 200 tons; 200 tons and above) per voyage passing across the lightship, but to compare their report with the other lights which quoted rates per ton, we had to convert on the basis of tonnage. For any ships between 50 and 100 tons, the Nore rate would vary between 0.06 and 0.12 pence per ton, with the smaller ships being closer to 0.12 pence. For any ships between 100 and 200 tons, the rate would fall in the same range, with smaller ships being closer to 0.12 pence. Beyond 200 tons, the rate would start at 0.09 pence per ton and then decline so that a 400-ton ship would pay 0.045 pence per ton

**Cotton reports one toll at 16 pence per 100 tons and one without toll at the Galloper and Gull Streams which was provided as a result of a special arrangement with the Royal Navy, which paid for it (Cotton 1818, p. 151; Clarke 2016, p. 44)

***Coase did not report a date nor a source for the prices, but we can assume that he was referring to the Report from the Select Committee of 1834

mentioned above, Avery and Hamblin needed only to be able to collect between 44.1% and 51.1% of potential revenues to earn a profit.

The rate schedule proposed by Avery and Hamblin also is of relevance. When a patent was obtained for operating a lightship, it came with fixed rates that could not be changed. In 1768, out of 40 lighthouses and lightships reporting (Anonymous 1768, pp. 17–18), only three rate schedules discriminated by tonnage categories (Anonymous 1768, pp. 22–24),[26] while the others charged flat rates per ton or per ship (the only exceptions were foreign ships which were charged doubled rates). Generally, those rates discriminated only on the basis of foreign ownership rather than tonnage. Exempt from the foreign ship overcharge, Avery and Hamblin discriminated on the basis of tonnage. That pricing strategy allowed them to cater to each shipowner category, which permitted greater social surplus to be generated.[27] Coasters and international ships (the only categories that provide us with tonnage breakdowns–see Appendix)[28] suggest that revenues without price discrimination from those ship categories would have been lower by between 12.6 and 6.7%.[29]

In addition to collecting light dues at ports, several primary sources indicate that Avery and Hamblin also solicited investors to generate the initial revenue required to build the Nore lightship, namely by leaving "Parchments as he calls them (not books) for publick Subscription at several places mentioned in the publick papers and hath drawn in several unwary persons to become Subscribers therein to contribute towards the Support & maintenance of his projected Lights" (National Archives 1732a, PC 1/5/4, 4/4).[30] The clerk of Trinity House, John Whormby (1746 [1861], p. 135), also points out that Avery used the subscriptions to solicit funds, issuing bonds to colliers for the financing of the third lightship at the Well. As Whormby (1746 [1861], p. 135) states, "Avery published several puffs about this in the newspapers. He also took it upon him to collect money for it, and promoted various papers amongst the traders, to engage them to subscribe and pay thereto,

[26] Including the lightship at the Nore, which had, by that time, passed into the hands of Trinity House. The rate schedules probably were vestiges of Avery and Hamblin's experiment because the schedules were taken from the last establishment that practiced price discrimination in 1832 (House of Commons 1834, p. 341). The other lighthouses were the Castor and Lowestoft lighthouses (which charged a flat fee of four pence for all ships and then an additional 16 pence for every 100 tons) and the Winterton lighthouse (which charged 6 pence for ships under 100 tons and 12 pence for all ships above 100 tons) (Anonymous 1768, p. 21–22). All other lights had a flat rate per ton or per ship.

[27] Lai et al. (2008a, b) are the only contributors to the lighthouse literature who emphasize the importance of the point regarding price discrimination, arguing that it makes private provision more viable–an argument that has not been made elsewhere. However, Koyama (2012) advanced the same argument for the same period of British history, but for prosecution associations (private conflict adjudicators) because it elicited greater participation by poorer individuals. What is more important, is that it is worth emphasizing that free riding can be endogenous. If free riding was to drive the enterprise into losses, the marginal user might free ride less so as to keep the operation afloat. A system of price discrimination would have been able to cater to that marginal user and thus permit sustainable production (we are thankful to Robert Whaples for this insight).

[28] Omitting colliers, which were major sources of potential revenues.

[29] The secondary sources tend to mention that the patent specified ships' ability to distinguish light sources based on their colors. That is not the case. Hamblin's petition makes no clear mention of color (National Archives 1730, SP 36/17/81). It merely speaks of the ability to distinguish one light from another. However, the lightship–being a novelty–would have distinguished itself from lighthouses, making it easier for Avery and Hamblin to differentiate their product and collect fees from users. Moreover, the vague wording of the petition, by not mentioning the lightship, meant that the innovation could be copied by others. Patents define products, not markets.

[30] From the Attorney General's report to the King regarding the petition made by Trinity House to revoke the patent.

which some coasters did". In its complaint to the Privy Council, Trinity House made much of the "publick Subscriptions", arguing that they constituted, along with the contention that the invention was not new, a breach of the patent that should considered null and void (National Archives 1731, PC 1/5/3, 3/1).[31] Avery's parchments, according to newspaper advertisements of the time, were left at "Sam's and Holland's Coffee-houses, at the Customhouse,[32] Jack's Coffee-house at Bear-Key, Salvation, Swan, Dog, and Goa Taverns at Billingsgate, Lloyd's, Jerusalem, Jamaica, Virginia and Maryland, Marine, Sword-Blade, Pennsylvania, Portugal, New England, and the Coffee-houses near the Royal Exchange, and at Mr. Fayram's bookseller under the South Entrance of the Royal Exchange for Owners and Commanders to sign at Leisure their Approbation and Consent to pay the following Prices" (*Daily Post*, September 15th 1731). Such prepayment provided an additional exclusionary mechanism to limit free riding and elicit demand revelation for the lightship among those who would benefit most from the rise of commercial traffic that followed from its provision, particularly coastal shipowners (coasters) (see Whormby 1746 [1861], p. 135; Brubaker 1975).[33] The newspaper announcements, because of the mention of a ship "to be moored" at the Nore, made it clear that subscriptions served as another ex-ante exclusionary mechanism.[34]

As we have seen, the costs and revenues of the lightship also would have allowed Avery and Hamblin to tolerate some free riding and still earn a profit. What is more important, the combination of subscriptions and collection of light dues at ports, *without paying Trinity House agents*, would have permitted key collection-cost savings as they relied on voluntary mechanisms. That much is clear, as even Whormby (1746 [1861], p. 136), writing dismissively of Avery and Hamblin, points out that they were able to collect fees in London

[31] More details on the legal technicalities raised could not be found. However, by virtue of the petition of Trinity House (National Archives 1731, PC 1/5/3), combined with the report of the Attorney General and Solicitor General (National Archives 1732a, PC 1/5/4), we can see that revocation was argued on two bases. The first was that the invention was not new, the second that public subscriptions with more than five individuals was not permissible under the patent. The former seems to have been the basis that the special committee of the Privy Council (National Archives 1732b, PC 1/5/5) used to justify the revocation. It made no mention of the latter point to justify revocation.

[32] The presence of the Customhouse appears strange, as it invokes the possibility that Customs officials collected the revenue. However, in an advertisement in the October 12th edition of the *Daily Post,* Hamblin specified that payments could be collected in the Long Room of the Customs House. The Long Room was open to the public and merchants frequently would interact on the premises. As such, it acted as a meeting place and was not an indication of state support. The revocation of the patent by the King in May 1732 and the continued existence of the lightship at the Nore thereafter militate against that contention. Why would the King provide his support to collect revenues for the lightship after the patent was revoked?

[33] This supports a point made by Mancur Olson (1965 [1971, p. 33, emphasis in original) in *The Logic of Collective Action*, that "*if at any level of purchase of the collective good, the gain to the group exceeds the gain to any individual, then there is a presumption that the collective good will be provided, for then the gain to the individual exceeds the total cost of providing the collective good to the group*".

[34] A similar mechanism existed in the United States, where lotteries financed some of the lighthouses of the colonial era (Dolin 2016, p. 60) even if few private lighthouses existed at the beginning of the Republic. Moreover, given that the subscriptions were solicited at coffeehouses, it also worth pointing out that, according to Stringham (2015) and Kingston (2007, 2014), coffeehouses often used ostracism and social norms to enforce complex contractual arrangements that otherwise may have given room for opportunistic behavior. Members who did not honor their arrangements would be blacklisted and, through multilateral punishments, other club members would shun relations with them. Most of the coffeehouses mentioned by Hamblin in his advertisement were merchant houses that could have acted to ostracize non-payers. They also could offer a reputational premium through the discipline of continuous dealings. For example, Lloyds coffeehouse, where individuals involved in the insurance market met, was known for being "a hub for information about… the reputations of market participants" (Kingston 2007, p. 380; see also Kingston 2014).

even if they did not possess a patent to do so. Collection costs were not negligible: according to the 1834 report of the House of Commons (1834, p. 412), collection fees represented 17.4% of all expenses in 1820 and 25.4% in 1832. Economizing on costs in those proportions reduced expenses significantly, providing an incentive to develop a cheaper and more reliable collection procedure.[35]

Those mechanisms appear to have been sufficient for the needs of Avery and Hamblin. Moreover, it seems that the patent for the invention was not required for the profitable operation of the lightship at all. When Trinity House revoked their patent (see next section) in April 1732, Avery and Hamblin kept operating. On December 12, 1732, the *Daily Courant* reported that the floating light at the Nore had parted from its moorings, which forced Avery to hire smaller boats to help place the lightship back in its proper spot despite the fact that the invention's patent had been cancelled in the previous May.[36] The Nore lightship evidently continued to operate even after its patent had been revoked.

The story of the Nore lightship, which was privately introduced into operation and seemingly able to charge lower prices than the existing lighthouse to make a profit, shows that attention has been too heavily centered on the lighthouse itself rather than coastal lighting services in general. Although a debate is still ongoing over whether government intervention was necessary to provide lighthouse services, even those who have disputed Coase's narrative also have agreed with his claim that Trinity House exacerbated a market failure in lighting services by trying to exclude private entrepreneurs from entering the market (Bertrand 2006, p. 394). As such, the introduction of the lightship was filling a missing market opportunity that Trinity House failed to provide and offered a market solution to what later became political justification for nationalizing all British lighthouses, namely that light dues were too high. Therefore, without including lightships, not only have critics defined the market too narrowly, but also, with the exception of Carnis (2013, 2014), they have underestimated how much political competition narrowed the extent of the market for coastal lighting services, expanded the scope for rent seeking by existing patent holders of lighthouses (Van Zandt 1993, pp. 56–57, fn. 31), and caused light dues to be higher than they would have been under conditions of free entry. The historical record indicates that a market for private, for-profit lightships existed and that the collection of light dues was carried out at ports privately and voluntarily without government enforcement. Those institutions later disappeared because of government opposition.

4 Government failure by Trinity House: opposition to the nore lightship

Why did Trinity House petition to have Avery and Hamblin's patent for their lightship invention revoked? Throughout the literature on lighthouses, it is recognized that Trinity House deliberately obstructed private individuals from constructing lighthouses in an attempt to assert what it regarded as its monopoly privilege. In addition, it had obstructed previous attempts to establish a lightship at the Nore. To accommodate merchants, in 1679 and 1724, Sir John Clayton and Captain John Waggett, respectively, also had proposed

[35] As we document in Appendix, with such economies and with the relaxing of some of upwardly biased operating costs estimates, it is impossible for potential revenues to have been less than costs.

[36] The article identified Avery as the proprietor.

installing floating lights on the Nore's bank (Clarke 2016, p. 39; Stevenson 1959, p. 138) as a way of protecting vessels entering and exiting London.[37] Sir John Clayton's attempt to establish a lightship at the Nore was opposed vehemently by Trinity House; he faced additional opposition from private lighthouse operators, who feared competition from his scheme (Clarke 2016, pp. 38–39).

In anticipating such opposition from Trinity House, Avery and Hamblin applied for a patent that was worded vaguely so as not to appear in direct competition with coastal lighthouses, even if that was their intention (National Archives 1730, SP 36/17/81; Hardy 1895, p. 72; Stevenson 1959, p. 139). The petition for a patent was drawn in terms of a new invention that not only would distinguish coastal lighthouses from one another (Stevenson 1959, p. 139), but also would aid merchant vessels in navigating the sands and shoals that extended miles seaward, unseen during high tides (Adams 1870, p. 339). "None could guess," however, "from the terms of the patent that it concerned lightships and that he intended to moor them round the coast" (Stevenson 1959, p. 139) and at such short distances from the shore that they would compete directly with lighthouses (see also Hardy 1895, p. 72).[38] Therefore, Avery and Hamblin were attempting to evade opposition from Trinity House by appearing to be complementing the lighthouse system, rather than substituting for existing lighthouses.[39] They obtained a patent for the invention of the lightship, not for its operation within the existing system of forcible collection of dues and monopoly rights to patentholders.[40]

Once Trinity House understood that Avery and Hamblin had used subterfuge to create a competitor, its reaction was immediate and virulent.[41] On November 29th 1731, two months after the publication of the first advertisement for the lightship, Trinity House petitioned the Crown to revoke the patent, arguing that the lightship constituted a breach of its own privileges and that Avery and Hamblin had misrepresented themselves in their petition (Stevenson 1959, pp. 139–40; National Archives 1731, PC 1/5/3). Private lighthouse operators joined Trinity House's appeal (Hardy 1895, p. 74), but the Admiralty refused to take part, believing the scheme beneficial to its interests (Stevenson 1959, p. 139). Trinity House even engaged in a slander campaign questioning Hamblin and Avery's seafaring abilities and alleged that Hamblin once dabbled in smuggling (Clarke 2016, p. 41).

[37] Hardy (1895, p. 32) argues that there were similar proposals as early as 1623, but he provides few details on these proposals.

[38] Later, the Attorney General said that he thought that Hamblin and Avery merely intended to diversiy the colors of the lights by making them burn blue or green (Adams and Woodsman 2013, p. 87).

[39] Coyne and Leeson (2004, p. 237) have coined the term "evasive entrepreneurship" to describe such activity. Avery and Hamblin, while engaging in productive entrepreneurship, also were expending effort and resources to evade being excluded from the coastal lighting market by Trinity House.

[40] Stevenson (1959, p. 139) makes it clear that the patent they obtained was unusual. The normal patent empowered its holder to collect dues for a term of years from every vessel. The type of patent received by Avery and Hamblin "allowed an individual to exploit an invention for 14 years" (ibid.). One secondary source asserts that once they had obtained their patent, Avery and Hamblin petitioned for the "power of levying payment" (Anonymous 1865, p. 624). However, no other source mentions that aspect of the petition. In fact, other sources highlight the "voluntary" nature of the payment system (Cruden 1843, p. 412; Pask 1884, pp. 604–605). Moreover, one of the key complaints of Trinity House in its November 1731 petition is the system of public subscriptions upon which the financing of the Nore lightship rested (National Archives. PC 1/5/3 1731).

[41] The accounts of the reactions can be found in multiple sources. They all offer the same timeline and storyline with varying degrees of detail (see Anonymous 1865, p. 624; Renard 1867, pp. 193–195; Adams 1870, p. 254; Gattie 1890, pp. 156–159; Hardy 1895, pp. 72–75; Stevenson 1959, pp. 138–140).

In their petition against Avery and Hamblin, Trinity House claimed specifically that Avery and Hamblin had no right to collect any payments, a prerogative that it regarded as its own. That assertion implies that the private collection of light dues not only was contemplated, but was to be relied on to such an extent that Trinity House was compelled to expend time and resources petitioning against Avery and Hamblin's patent specifically on that basis. In the petition filed by Trinity House, dated November 29, 1731, the grounds on which the revocation of the patent was justified was that Avery and Hamblin were not issued a patent for collecting light dues. The petition filed by Trinity House refers clearly to what was regarded as its monopoly privilege in the collection of dues:

> [T]he Invention described in the said Letters Patent & description aforesaid is expressly confined as a new method of distinguishing fixed Lights for the guidance of Shipping by night whereby one Light may be perfectly known from another which your Petitioners humbly apprehend Import such Lights as were in being at the time of making the Grant or might afterwards be set up by lawful authority but your Petitioners humbly conceive that Mr. Hamblin hath no colour of right or power either by the Letter or Invention of his Grant to erect Lights or Sea Marks either upon Land or in the water *or to receive any Duties or Contributions for the same he having no Grant or Authority for that purpose*, for the right of Erecting Lights and Sea Marks both by Land and Sea was anciently Granted to your Petitioners & Confirmed to them by Act of Parliament. (National Archives 1731, PC 1/5/3; emphasis added)

Once the crown cancelled the patent in an unprecedented act (Stevenson 1959, p. 139), Avery bought out Hamblin and attempted to negotiate with Trinity House to continue to operate the lightship.[42] Eventually, in exchange for £100 per year, Trinity House agreed to let him continue to operate the lightship at the Nore for 61 years (Clarke 2016, p. 45; Stevenson 1959, p. 139). That lease was granted in the form of a new patent, which was reported in newspapers of the time: "On Tue[s]day, [October 27, 1733] a patent pa[ss]ed the great seal for the e[s]tablishment of Mr. David Avery, of Broad-[S]treet, merchant, his floating light at the Nore" (*Grubb Street Journal,* November 1, 1733).

It cannot be denied that private lighthouse owners gained monopoly rents from the restrictions on competition that came from owning a patent. Patents restricted the construction of nearby lighthouses as well as the right to use the state's official seal to collect their dues. Private lighthouse owners also gained from allying themselves with Trinity House to block future entry–which is what they did upon facing the threat of the Nore lightship.[43] But such monopoly rents presented entrepreneurial profit opportunities for potential competitors to capture shares of the market for coastal lighting services, eroding monopoly rents by introducing lightships as substitutes for lighthouses.[44] In the case of the Nore lightship, forcing Hamblin to bow and co-opting Avery eliminated the potential competition, even within the patent framework, that would have brought prices (i.e., light

[42] Adams and Woodman (2013, p. 87) mention that Hamblin attempted to open another lightship (date undisclosed) with a Yarmouth pilot at the Cockle Gat, but that Trinity House turned them down, preferring the existing lighthouse.

[43] This line of reasoning explains why Avery's negotiation of a license with Trinity House to keep the lightship operating resulted in private operators of lighthouses joining hands with Trinity House to protest the lightship's patent.

[44] Krause (2015) provides an example lighting provision with buoys in the case of a present-day suburb of Buenos Aires. While we have focused on the case of the lightship as an example, buoys and other seamarks should enter future studies as well.

dues) down and created social wealth. The attempt was snuffed out by Trinity House's rent seeking, but also by existing lighthouse owners, which prevented a broader coastal lighting market from emerging.

As a result, instead of spending time and resources to obtain profits and grab market share for lighting services by lowering light dues for consumers, prices were prevented from falling. Resources were expended to preserve monopoly rents acquired by other holders of patents for providing lighting services, including Trinity House (Taylor 2001, p. 57, fn. 31). As Carnis (2013, p. 54) argues, "this close relationship between entrepreneurs and the government resulted in a de facto political alliance to maintain the benefits provided by a mutually advantageous situation". Therefore, rather than the private provision of lighting services resulting in market failure and requiring centralization, as Bertrand suggests (2006, p. 401), it was the dynamics of interest group politics[45] that concentrated benefits on a small number of existing patent holders and dispersed the costs of rent seeking among the larger population of consumers, that generated political competition ending in government failure. With freer entry and exit, the high prices of lighting services created by patents would have incentivized private entrepreneurs, such as Avery and Hamblin, to enter the market, driving prices down, not vice versa. In the end, however, the final public purchases of all lightships and lighthouses in 1836 followed predictably from previous government intervention by Trinity House, which had stifled an endogenous market solution that would have delivered lower light dues and the private collection of them.

5 Conclusion

Were lighthouses a case of missing markets or failing markets? Ronald Coase answered by showing that private involvement could and did exist as a viable alternative to public provision of coastal lighting services financed by general revenues. However, the extent of the viability of private-sector involvement has been debated. As a result of the powers granted to Trinity House to establish and regulate the market for lighting services, we argue that the viability of a private alternative in the form of lightships was curtailed by government failure rather that market failure.

Our conclusion has three implications for the role of government in the production of public goods, specifically coastal lighting services and one implication for future research. First, in the face of a missing market in lighting services, the Nore lightship illustrates that private provision of lighting services was in fact possible *in spite of* the fact that it was opposed by the British government. Second, if Trinity House had an interest in fostering the conditions necessary for a lighting market to emerge, it would not have excluded potential entry by private entrepreneurs seeking to provide lighting services. That the justification for nationalizing all private lighthouses in 1836 and abandoning the Trinity House system was to reduce the light dues paid by shipowners, even though a cheaper private alternative had been developing in the form of lightships, shows that monopoly power in lighting services was a consequence of government failure, not a market failure. Third, given that past research generally has overlooked lightships in the broader market for *coastal lighting services*, the degree of government failure has been underappreciated, while the existence of market failure has been overemphasized. Since the entry of lightships would have eroded Trinity House's rents significantly, namely royalties

[45] Bertrand's argument also aligns with the broader portrait of rent seeking between different interest groups that were competing for the rents from the British Crown (see Zahedieh 2010). As such, lighthouse operators can be seen as one of the many groups participating in that wider historical struggle.

from the patents on lighthouses it licensed to private individuals or from the revenues of the lighthouses it operated directly, Trinity House exercised its regulatory authority by prohibiting market entry on the part of private entrepreneurs. Finally, we confirmed that private production of coastal lighting services was possible beyond the shadow of the state. By doing so, we open an opportunity for future research studying the private collection of fees, not only by privately owned lighthouses, but also by private lightship operators. The place most likely to provide deeper answers on that front is the Port of London, where privately owned riverfront wharves and docks supply good examples of club governance in the provision of docking services.

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Appendix: Estimating the costs and revenues of the lightship at the Nore

In order to properly assess the potential profitability of the lightship and the extent of free riding that its operators could tolerate, it is necessary to estimate operating costs and potential revenues. In the present appendix, we prudently use an array of sources providing different nominal values at different points in time. In order to maintain comparability, we deflated prices. Unless stated otherwise, the prices are reported in 1832 terms. The resulting estimates of profitability are meant to present a conservative scenario as we believe our estimates of potential revenues to be understated while operating costs are overstated.

Costs

The best starting point for operating costs is the 1834 report to the House of Commons. In that report, the lightship at the Nore reported expenditures of £681 for the year 1832 (House of Commons 1834, p.412).[46] In 1820, that figure stood at £949.8 (House of Commons 1834, p. 412). Joseph Cotton (1818, pp. 186, 196)[47] provides revenues and net produce of the lightship at the Nore for the period between 1805 and 1815, which allows us to generate expenses of £605.2.[48] As discussed in the text, Avery and Hamblin relied on voluntary payment mechanisms rather than the mandatory dues collection system of Trinity House, whose agents would collect the fees and keep a share of those fees. In 1820 and 1832, collection costs represent 17.4 and 25.4%, respectively, of all expenditures. If we

[46] Of that amount, £11.25 came from superannuated pensions to seamen–an expense that Avery and Hamblin would not have needed to cover (House of Commons 1834, p. 346). To remain conservative, we did not adjust for this minor issue.

[47] The same numbers were reported in a House of Commons document (House of Commons 1816, Vol XIX, pp. 149–173). That probably is the source of Cotton's numbers.

[48] The lowest level of expenses was in 1813, at £479.8 and the highest was in in 1808, at £840.6.

deduct collection costs (which Avery and Hamblin would have avoided) and apply those proportions to the 1805-1815 estimates, we can arrive at an estimate of operating costs for the lightship at the Nore. In 1820 and 1832, operating costs would have been equal to £784.6 and £508.1. Between 1805 and 1815, those costs would have been between £451.5 and £499.9.[49] How well do these figures relate to 1731, given that they relate to estimates more than a century later?

One way to answer the question is to consider the cost reported by Avery in 1733 for "fitting out" the lightship. When Avery reported costs incurred at £2,000 (£3,491 in 1832 terms), some sources mention that the expenses were for "fitting out" (Stevenson 195, p. 140). However, other scholars seem to think that Avery's £2,000 encompasses both operating and building costs (i.e., variable and fixed or sunk costs) because he referred to expenses on the "project" (Adams and Woodman 2013, p. 87). However, it is plausible that Avery meant construction costs only, given the numbers available for the building of later lightships. For example, the Owers Lightship was built in 1788 at a cost of £6,112 (Adams and Woodman 2013, p. 88)–close to twice the figure reported for the lightship at the Nore. In the 1740s, a fully fitted-out ship cost £23.7 per ton (Price 1976, p. 720).[50] Another estimate from the 1770s, augmented by fitting-out costs, brings the total to £23.6 per ton (Craig 1971, p. 129).[51] Relying on those estimates, the cost of fitting out the two ships[52] launched by Avery and Hamblin stands between £2808.4 and £2820.3. Given that the first lightship (the 19-ton *Experiment*) was launched in late July 1731 and replaced by the larger 100-ton *Good Intention* in October 1731, which operated outside of Trinity House's purview until November 1733, the annual operating costs would be between £298.1 and £303.4. Those estimates are biased upward because they include the legal fees Avery and Hamblin incurred to acquire their patent and to fight Trinity House's petition to revoke it. We also assume that the lightship was just an ordinary vessel with no special fixtures (like the mushroom anchor and the lanterns) that would have increased fitting-out costs (and thus reduced our estimate of operating costs).

Another way to determine costs would be to estimate operating costs directly. In 1832, the lightship at the Nore consumed 199 gallons of oil and hired three seamen, one mate and one master (House of Commons 1834, p. 332).[53] If we assume the same oil consumption for 1731[54] and also assume 365 days of wages being paid for the same crew size, we can

[49] The lowest level of expenses after removing collection costs was in 1813, at £357.9 and the highest was in in 1808, at £694.3.

[50] These numbers refer to large vessels. Willan (1934 [1964], pp. 103–105) points to lower costs, but the numbers therein apply to barges, lighters and trows.

[51] Ralph Davis (1962, pp. 373, 378) reports a wide array of prices–few of which include the cost of fitting-out ships with masts, spars, ropes and the critical pieces of equipment for lightships, such as anchors and lanterns. He reports only construction costs. Armstrong (1991, p. 80) argues that fitting out a ship inflated total costs by somewhere between 50% and 100%. Those percentages probably are too low for a lightship, given the special equipment it requires. The lanterns were not inexpensive and the anchors were specifically designed (mushroom anchors) to limit drifting. As such, we used the high bound of the fitting-out cost when using Craig's (1971, p. 129) estimate.

[52] The first sailed at 19 tons and acted as an experiment (the ship was christened *Experiment*), while the latter weighed at 100 tons (Cruden 1843, p. 412; *Grubb Street Journal* July 22nd 1731).

[53] On another page of the House report (1834, p. 340), oil consumption is given at 193 gallons rather than 199 gallons. The difference would reduce operating costs by £2.4.

[54] The quantity of oil to be burned would be roughly constant.

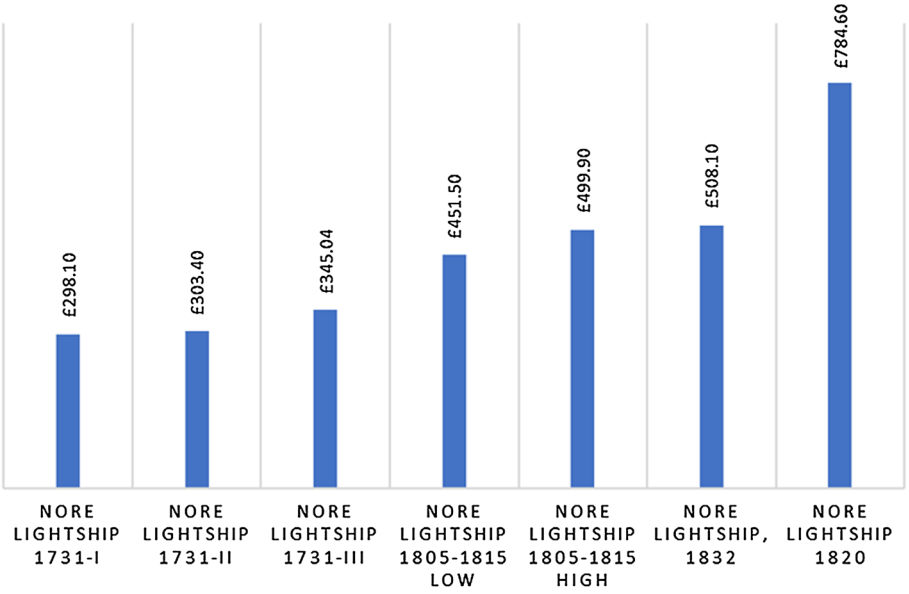

Fig. 1 Estimates of operating costs (Expressed in 1832£) for the Nore lightship

use Clark's (2005) wage and price data to estimate operating costs.[55] Doing so, we arrive at £345.04 per year in operating costs. We also believe this cost estimate to overstate costs as there is an emerging literature in economic history that asserts that English daily wage rates tend to be overstated. On the one hand, new archival evidence has shown wages to be inferior than previously (Stephenson 2018). Simply shifting from the wage rates reported for unskilled building laborers to wage rates for unskilled farm workers reduces the annual operating cost by £14.8. On the other hand, daily wage rates are not the most ideal measure as pre-19th century workers tended to sacrifice large shares of the going day-labour wage rate if they could obtain steady employment (Broadberry et al. 2015: 265–266; Humphries and Weisdorf 2015, 2017). Given that the workers on the lightship would have been employed year long, the cost of their labor to the operator was probably inferior to what we estimated. Nevertheless, we believe that this estimate is probably the most accurate of the three we generated here.

As such, as can be seen in Fig. 1, most of the estimates come in below or equal to £500 per year, with the exception of 1820.

Revenues

The estimation of revenues must be understood as a measure of "potential revenues". Those potential revenues would have been the same regardless of whether or not collection

[55] Seamen were paid the same wages as construction laborers; the mate was paid the wage of a skilled craftsmen, while the master was paid twice the wage of a skilled craftsmen. Converted to 1832 pounds, those wages are higher than the ones reported by the House of Commons in 1834. As such, we believe that our estimate is upwardly biased. We also should not assume size of the crew in 1832 was the same as in 1731. Hiring only a master and two seamen brings the cost to £256.48.

was voluntary. For our purposes, the goal is to see what share of this potential the Nore lightship had to tap to be profitable, and we interpret this as the room available to tolerate free riders.

The largest complication regarding the calculation of revenues relates to entrances and clearances into the Port of London. From some of the advertisements in 1731, we see mention that the fees are per "voyage". Based on those advertisements, we do not know if they applied round-trip of for each passage. Navigation dictionaries define a voyage as "a journey by sea out and home" (Russell 1883, p. 156). However, from a later advertisement–when Avery secured his deal with Trinity House–we know that the rates applied to ships "passing and repassing" the Nore lightship (*Grubb Street Journal* November 1st 1733), meaning that each voyage meant two payments. For larger vessels engaged in transatlantic trade, no problem is posed as such ships did not make large numbers of voyages per year. However, for the Baltic, Mediterranean and coastal trade, ships made numerous visits to the Port of London. That frequency raises questions about how to estimate potential revenues. We base our fees on "voyage", knowing full well that if dues were assessed on each leg of a trip, our case is only made stronger as potential revenues will be larger.

Using the breakdowns of ship classes provided by Colquhoun (1800, pp. 11–13) and the entries into the Port of London provided by Usher (1928, p. 471), we can arrive at estimates of coastal and foreign trade entries into London. For 1728, Usher (1928, p. 471) estimates that 2,152 British and foreign vessels engaged in foreign trade entered the Port of London. Applying the advertised rates to the categories of ships homeported in London for 1732 provided by Colquhoun (1800, p. 9), we arrive at revenues of £204.7 from international vessels.

For the coastal trade, we interpolated the values provided by Usher (1928, p. 471) for 1700 and 1750 to arrive at 6,079 coastal ships in 1731. The coastal trade includes smaller coasters and larger colliers (i.e., ships engaged in the coal trade, largely out of Newcastle). According to Colquhoun (1800, p. 13), the average coaster weighed 73.1 tons in 1798, while the average collier was much larger at 228 tons. Unfortunately, Colquhoun (1800, p. 13) provides breakdowns only for the smaller coasters (of which 86% were less than 100 tons). Assuming that the breakdown of the coastal trade fleet was the same in 1731 as it was in 1798, and that colliers exceeded on average 200 tons (Hausman 1991, p. 593), we arrive at a conservative revenue estimate, namely that Avery and Hamblin collected revenues of £208.3 from coasters and £262.5 from colliers. The total income from those sources, amounting to £675.4, would have constituted the bulk of potential revenues for the lightship at the Nore.

However, less important revenue sources are harder to estimate. Colquhoun (1800, pp. 14–15) pointed out that in the late 18th century, an additional 2,288 lighters, barges and punts circulated on the River Lea and the upper and lower Thames, plus some 3,000 wherries (small ships of 10–12 tons) and a little more than 300 bumboats, sloops, cutters, hoys and fishing peter boats. Alone, the barges, lighters, punts, boats, sloops, cutters and hoys (with an average weight of 32.2 tons per ship)[56] "in active service in the Port of London" numbered 3,419 in 1796 (Colquhoun 1800, p. 15), representing 23.1% of the ships entering the port at the time. Converted to 1731 proportions, tat percentage translates into an additional 1,901 ships. As such, those smaller vessels potentially added £47.5, bringing total

[56] Wherries are excluded.

revenues to £723. Readers should bear in mind that the smaller vessels would have made numerous trips down the Thames and that our estimate assumes that they made only *one* voyage. Adding the other small ships also would raise the pool of potential earnings. However, we prefer not to include them in the estimates because we know that some smaller ships (less than 20 tons) tended not to be subject to light dues at all. Finally, all our estimates of revenues exclude proceeds that would have come from the subscription period (pre-payments). Taken together, those considerations imply that our estimates of potential lightship revenues are biased downward.

By way of comparison, the lightship at the Nore collected £2553.6 in revenues in 1832 (House of Commons 1834, p. 333). By that time, rates had doubled for all ship categories below 200 tons, with an additional shilling to pay per 100 tons. Given the larger volume of entry into the Port of London (Usher 1928, p. 471), our estimation appears to be reasonable.

Profits and plausibility

Given the cost and the conservative revenue estimates, the surplus of potential income over operating costs varies from £330.4 and £377.3 per year. Stated differently, Avery and Hamblin needed to collect somewhere between at worst 51.1% of our downwardly biased estimate of potential revenues to earn a profit. Using the estimates relating to 1805-1815 and 1832, the lightship kept well within the range of profitability: between £167.3 and £223.9. Only 1820 shows a loss of £109.2. How plausible are those estimates?

To answer that question, it is necessary to consider the deal that Avery reached with Trinity House. To continue operating the lightship at the Nore, Avery agreed to pay £100 per year to Trinity House. For him to have accepted such a deal, his profits must have been greater than that sum. Not only that, but he would have had to pay Trinity House for the right to collect light dues, sums ranging between 17.4 and 25.4% of operating costs in 1820 and 1832. Our estimates suggest that he plausibly could have agreed to bear the extra cost burden (collection costs and lease payments) while continuing to earn a hefty profit.

The foregoing discussion lends credence to our calculations and lead to the conclusion that the operation of the lightship was profitable even if our estimates of operating costs are biased upwardly and our revenue estimates are biased downwardly. Additionally, it is worth pointing out that Avery and Hamblin were about to open two more lightships–at the Scilly Isles off the Cornish coast and at the Well. Avery and Hamblin would not have contemplated expanding their coastal lighting services had they been losing money. Nonetheless, we urge caution and suggest that further efforts be devoted to estimating the profitability of lightships.

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