TPR, 79 (4) 2008

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The political economy of Coase's lighthouse in history (Part I)

A review of the theories and models of the provision of a public good

As a contribution to policy planning for public goods provision, Part I of this multi-disciplinary article critically reviews the literature and facts for and against the 1974 paper by Ronald Coase on the lighthouse; discusses theoretical issues omitted; and develops a model that characterises an alternative mode of light due collection under different cost and demand conditions. The review and discussion, informed by the precise meanings of key concepts of public goods and a free market, are relevant for a study and application of the economics of planning as well as the changing nature of the lighthouse due to technological advances in shipping.

Policy and theoretical background

A lighthouse appeals to the conservation planner as an archaic yet picturesque and possibly romantic structure worthy of conservation as part of heritage. Why not? It brings back memories of many brave rescue stories, of solitary lighthouse keepers, and it stirs the imagination as a beacon of hope or despair, as a marker of mental arrivals and departures in the dinghy of life. Perhaps for this reason, the Statue of Liberty has been advertised for its history of being a lighthouse. That said, there is a negative side for the conservation planner: a lighthouse is an ecological threat to marine birds (Montevecchi, 2005). This article is not about the preservation of lighthouses either for historical reasons or for their dwindling contribution to global light pollution, but something less sentimental. What follows is important in planning theory, albeit both rather controversial and quite technical.

One of the challenges to a town planner is working out how market failure can be minimised or ideally transformed into positive externalities (Lai and Lorne, 2006; Lai and Hung, 2008). In theorising land use planning, this challenge cannot be properly met without a good understanding of the nature of three types of market failures, namely externalities, public goods, and monopolies, all of which are rampant in the development market.

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Paper submitted October 2007; revised paper received and accepted July 2008.

For this reason, courses on the economics of planning invariably devote great attention to the ideas of Arthur Pigou, Cambridge Professor of Economics and contemporary of John Maynard Keynes. Against Pigou's concepts of externalities and public goods written in *The Economics of Welfare* (Pigou, 1932), 1991 Nobel laureate Ronald Coase, who first met Friedrich A. Hayek in LSE, has written two extremely influential papers, 'The problem of social cost' (Coase, 1960) and 'The lighthouse in economics' (Coase, 1974), which have been respectively taken by many libertarian thinkers as the death knell of interventionist planning against externalities and of public funding for public goods.

In each of these two papers, an example that has become classic in the theorisation of market failure is used. In the 1960 paper, a hypothetical example of cattle escaping from a ranch to a wheat farm is used with a view to demolishing Pigou's theory (Pigou, 1932) of social cost (externalities) as demonstrated by the real-life example of an air-polluting factory. Economics students should not be surprised that this work of Coase is both theoretically and practically more significant to town planners than economists, since the example used basically addresses a matter of land use zoning.

Less well-cited, but no less significant than the cattle–wheat example, is Coase's exposition of the lighthouse in English history. Coase intended this synchronic exposition to critique what he saw to be the erroneous expositions of this maritime example mentioned in a string of late nineteenth- and early to mid twentieth-century works by John Stuart Mill (1965), Henry Sidgwick (1901), Arthur Pigou (1932), and Paul Samuelson (1964). These prominent thinkers thought that direct government provision of the service was essential.

Generally, policy interest in the lighthouse focuses on the role of government in the provision of a service that has problems of non-exclusive use. As we shall see later, however, with respect to the earliest lighthouses this supposition of non-exclusivity is in fact a misunderstanding. Although it can be also used as an example to theorise *externalities*, Coase's example of the lighthouse (1974), reprinted in Cowen (1988) and Coase (1988), has been mainly cited in the literature focussing on the need for and wisdom of government supply of *public goods*. By and large, this specific maritime example has been used by libertarian thinkers as a classic real-life case to rebut standard economic texts which support government interventions in an attempt to correct market failures. These hold the private supply of such goods to be non-viable and thus necessitating government provision. The rebuttal, often with the lighthouse example in conjunction with an empirical analysis of the pollination of apple flowers by honeybees (Cheung, 1973) (both of which were used by Samuelson (1964) as good examples of externalities), seeks to demonstrate the viability (if not the superiority) of private or market supply of such a service. And this is a rejection of the alleged difficulties in metering consumer preferences due to non-exclusive use, complications

in zero marginal cost pricing and problems in enforcing payment (thus free-riding), which have been regarded in the standard economic texts, notably Samuelson (1964), as requiring government intervention for their effective solution.

The relevance of Coase's farming example to planning theory and practice was recently scrutinised, in connection with the Coase Theorem, in this journal (Lai, 2007). With the purpose of bringing about a better understanding of the theory of public goods, this paper scrutinises the lighthouse example of Coase from the point of view of the choice of institutional arrangements under changing technology. Unlike the hypothetical farming example, treatment of the historical lighthouse demands a multi-disciplinary approach, drawing on expertise from policy science, economics, and maritime history. This is essential not only because the recent debate over the lighthouse has been gathering momentum but also because some of the merits and limitations of Coase's 1974 work have not yet been fully appreciated. Interestingly, our critique involves the use of Coase's own earlier (1946) insightful analysis of the efficiency of the monopoly neglected in his lighthouse work.

The focus of this work is to scrutinise the ongoing debate on Coase's work of 1974 on the lighthouse. With the help of an in-depth case study, which will be reported in Part II of this paper, the discussion clarifies various meanings of public goods as understood by economists and planners; and partakes in the debate currently led by Barnett II and Block (2007a, b) by bringing into the limelight salient but omitted price theory issues found in the original documents and those having a maritime technology dimension.

The provision and pricing of public goods is a key consideration in development control as in the instances of imposing planning conditions. It is hoped that economists in town planning will readily see synergies with other public goods with which town planning has more direct involvement.

Public goods, lighthouses and planning research

The concept of public goods is significant in planning research as it is one of the pillars of the Pigovian welfare economic theory of 'market failure', which has been used to justify public intervention by way of regulation, direct provision and taxation (Baumol, 1952). Against the interventionist stance is what we may describe as the neo-institutional or property rights approach adopted by such economists as Tiebout (1956), who argued that residents vote with their feet more effectively than through the ballot box in getting access to local public goods; Coase (1959; 1960; 1974) stresses the role of transaction cost in enforcing payment.

As far as urban planning is concerned, the notion of public goods as a case for government intervention is discussed to different extents in leading planning texts that subscribe to economic theories. Good examples are those by Willis (1980, 39–52),

Table 1 Definitions of public goods in planning research

Topic	Author (Year)	Definitions of public goods (Thesis 1 to 4 + no definition)	Paper of Coase cited
Zoning and development control	Klosterman (1985)	'public goods are defined by two technical characteristics: (1) "jointed" or "nonrivalrous" consumption such that, once produced, they can be enjoyed simultaneously by more than one person; and (2) "nonexcludability" or "nonappropriability" such that it is difficult (in some cases impossible) to assign well-defined property rights or restrict consumer access.' (p. 7) [Theses 1 and 3]	Nil
	Hepworth (1990)	No definition	Nil
	Alexander (1992)	'Some goods, however, are produced by governments and public organisations. They are distributed by means not recognised by the free market model. Public goods, such as defense or public safety, benefit everyone; like rain, they descend upon the just and the unjust alike.' (p. 122) [Thesis 4]	Nil
	Greene (1992)	No definition	Nil
	Nelson (1992)	No definition	Nil
	Richardson et al. (1993)	'the range of public goods (defined in terms of nonrivalry and nonexcludability)' (p. 347) [Theses 1 and 3]	Nil
	Cullingworth (1994)	No definition	Nil
	Gleeson and Memon (1994)	'we defined public good as the set of ethical criteria which defines the best interests of society as a whole for any particular political or social issue' (p. 116) [Thesis 4]	Nil
	Simons (1994)	No definition	Nil
	Eng (1997)	No definition	Nil
	Lai (1997)	'Public goods are those goods or services which the free market is believed to be inherently disinterested in providing an adequate amount, if any at all. The reason is that for certain types of goods, consumption is "joint" and not exclusive. For instance, consumption of a movie is joint among viewers. The marginal cost of showing a movie to one more person is zero (up to the point of capacity seating). In such	Coase (1937; 1959; 1960; 1974; 1988)

Topic	Author (Year)	Definitions of public goods (Thesis 1 to 4 + no definition)	Paper of Coase cited
Zoning and development control (*cont.*)		a situation, efficient resource allocation requires zero pricing and this deters the private sector. Besides, consumers would pretend that they have no demand for the goods in the hope that they could "free ride" on the payment by other consumers. In the case of exclusive consumption, however, consumers will not conceal their real preferences as they would be unable otherwise to obtain the goods.' (pp. 173–76) [Theses 1, 2 and 3]	
	Lai (1998)	'Goods not transacted in the market due to high transaction costs of pricing. They are transacted by the state, which taxes its citizen for payment.' (p. 186) [Thesis 3]	Coase (1937; 1959; 1960; 1974; 1988; 1991)
	Lai (1999)	No definition	Coase (1937; 1959; 1960; 1974; 1988; 1994)
	King and Ma (2000)	'public goods of Samuelson (1954), whose consumption is wholly nonrival' (pp. 207–208) [Thesis 1]	Nil
	Banerjee (2001)	No definition	Nil
	Gunder and Mouat (2002)	No definition	Nil
	Massam (2002)	'the good of the whole' (p. 158) [Thesis 4]	Nil
	Shove (2002)	No definition	Nil
	Lai and Ho (2002)	No definition	Coase (1960)
	Webster (2002)	'Pure public goods are consumed jointly in the sense that all consumers consume the same good. The aggregate quantity of such a good in the economy equals the quantity consumed by an individual, and this is constant for all individuals.' (p. 399) [Thesis 1]	Coase (1937)

Topic	Author (Year)	Definitions of public goods (Thesis 1 to 4 + no definition)	Paper of Coase cited
Zoning and development control (*cont.*)	Fischel (2003)	'Public goods are non-exclusive and non-rival in their consumption.' (p. 344) [Theses 1 and 3]	Coase (1974)
	Deng (2003)	'most public goods are actually territorial collective goods, only available within some bounded area' (p. 135) [Thesis 1]	Coase (1974; 1991)
	Nelson, Burby, Feser and Dawkins (2004)	No definition	Nil
	Nelson, Dawkins and Sanchez (2004)	No definition	Nil
	Lai (2005)	No definition	Coase (1937; 1959; 1960)
	Sanyal (2005)	No definition	Nil
	Stamps III, Nasar and Hanyu (2005)	No definition	Nil
	Webster (2005)	No definition	Coase (1960)
	Abramson (2006)	No definition	Nil
	Nelson (2006)	No definition	Nil
	Willis (2006)	'A public good in economic terms is a good that is non-excludable and non-rival in consumption' (p. 485) [Theses 1 and 3]	Nil
	Maruani and Amit-Cohen (2007)	'public goods are defined by Vining and Weimer (1992) as non-excludable in use and non-rivalrous in consumption' (p. 3) [Theses 1 and 3]	Nil
	Webster (2007)	'public goods are non excludable and consumed without rivalry' (p. 83) [Theses 1 and 3]	Nil

Topic	Author (Year)	Definitions of public goods (Thesis 1 to 4 + no definition)	Paper of Coase cited
Communicative planning and public participation	Beatley, Brower and Lucy (1994)	No definition	Nil
	Wilson (1997)	'Public goods are those whose value can be maintained only through co-operation and trust, and whose value is lost through the pursuit of individual self-interest.' (p. 747) [Thesis 4]	Nil
	Bengtsson (1998)	'The theoretical characteristics of such goods, that may be tangible or intangible, are "non-excludability" and "jointness of supply"' (p. 101) [Theses 1 and 3]	Nil
	Hillier (2000)	No definition	Nil
	Huxley and Yiftachel (2000)	No definition	Nil
	Roy (2001)	No definition	Nil
	Hall et al. (2004)	'Public goods have specific consumption attributes of non-rivalness and non-excludability that can validate government involvement in their supply' p. 211) [Theses 1 and 3]	Nil
	Avritzer (2006)	No definition	Nil
	Sager (2006)	No definition	Nil
	Morano (2006)	No definition	Nil
	Sager (2007)	No definition	Nil
Sustainable development	Campbell (1996)	No definition	Nil
	McGranahan, Leitman and Surjadi (1998)	'A public good cannot be sold because it can only be supplied simultaneously to large numbers of beneficiaries; provision cannot be restricted to those who pay' (p. 510) [Theses 1 and 3]	Nil
	Lekakis (2000)	'public good whose demand appears in the form of public pressure to the government to secure the good for everyone' (pp. 140–41) [Thesis 4]	Nil

Topic	Author (Year)	Definitions of public goods (Thesis 1 to 4 + no definition)	Paper of Coase cited
Sustainable development	Lovett (2001)	No definition	Coase (1960)
	Lindsey (2003)	No definition	Nil
	Godschalk (2004)	No definition	Nil
	Staley (2006)	No definition	Nil
Valuation	Aadland and Caplan (1999)	No definition	Nil
	Byrnes, Jones and Goodman (1999)	No definition	Nil
	Christie (1999)	'display the public good attributes of non-excludability and non-rivalry' (p. 551) [Theses 1 and 3]	Nil
	Lindsey and Knaap (1999)	No definition	Nil
	Burgess, Clark and Harrison (2000)	No definition	Nil
	Getzner (2000)	No definition	Nil
	Gret-Regamey, Bishop and Bebi (2007)	No definition	

Notes:
Thesis 1: Joint consumption or non-exclusive use (non-exclusiveness).
Thesis 2: Zero marginal cost.
Thesis 3: Free-riding or non-excludability.
Thesis 4: Generating positive externalities or some perceived public interest or benefit.

Fischel (1985; 1987, 294–96), Alexander (1992; 1993, 122), Lai (1996; 1998, 3, 29–32), Heikkila (2000, 103–26), Pennington (2000, 5), Sager (2002, 323), Webster and Lai (2003, 110–41). Of these, Willis' discussion was the most heavily persuaded by Coase's 1974 paper on the lighthouse. The textbooks by Fischel (1985; 1987) and Webster and Lai (2003) were more influenced by the idea of Tiebout (1956). Pennington (2000) and Sager (2002) provided detailed definitions of public goods which we shall revisit later.

As far as the specialist planning research literature is concerned, the role of public goods is significant. Table 1 presents examples in which the concept of public goods was invoked by planning researchers in various branches of knowledge in the planning arena. Not all authors provide definitions or make reference to any work by Coase. Those definitions provided generally fell into four categories (Theses 1, 2, 3 and 4). The first three theses – namely non-exclusive (joint) consumption, zero marginal cost, and non-excludability (free-riding) – unlike the amorphous Thesis 4, are relevant for a discussion of Coase's lighthouse article. The aggregate demand curve for a joint consumption (Thesis 1) good can be represented by the vertical summation of individual demand curves.[1] A joint consumption good has the problem of allocation since there is no single price that can efficiently allocate the good to consumers, who can easily conceal their true preferences/valuation. For a zero marginal cost (Thesis 2) good, the efficient price should be zero. To economists like Samuelson, this means that the investment cost of producing the good cannot be recovered. For a non-excludable (Thesis 3) good subject to free-riding, the transaction costs of enforcing payments far exceeds any revenue collected, rendering the project a commercial no-go. Free-riding is a common problem to Theses 1 and 3 public goods.

In the research on zoning and development control, the concept, with definitions, can be found in the works by Klosterman (1985), Alexander (1992), Richardson et al. (1993), Gleeson and Memon (1994), Lai (1997; 1998), King and Ma (2000), Massam (2002), Webster (2002), Fischel (2003), Deng (2003), and Willis (2006).

In the field of communicative planning and public participation, definitions of the concept feature, for instance, in the works by Wilson (1997), Bengtsson (1998) and Hall et al. (2004). In sustainability discourse, definitions of public goods can be found in McGranahan et al. (1998) and Lekakis (2000). In valuation studies, definitions of public goods appeared in Christie (1999).

1 Note, however, that this formulation depends crucially on how the x-axis is labelled. The vertical demand summation methodology can be applied if the x-axis is interpreted as use intensity. However, if the x-axis is interpreted as the number of users of the goods, further distinction on the marginal cost concept needs to be made, as the latter part of this article will elaborate.

The lighthouse as a public good: the Musgrave–Samuelson Proposition and Coase's critique

Due to Paul Samuelson's reputation as an economist, the lighthouse has been a popular academic example of a public good characterised by features of non-exclusive consumption, zero marginal cost and free-riding. Samuelson's idea of the lighthouse as a typical example for public finance of a public good, following in the footsteps of John S. Mill (1965) and Henry Sidgwick (1901), was influenced heavily by near contemporary economists Arthur Pigou (1932) and Richard Musgrave (1959). The foci of attention of Samuelson were Theses 2 and 3, zero marginal cost and free-riding. Arguably, Thesis 1 is covered by 3.

> in the lighthouse example one thing should be noticed: The fact that the lighthouse operates cannot appropriate in the form of a purchase price a fee from those it benefits certainly helps to make it a suitable social or public good. But *even if the operators were able – say, by radar reconnaissance – to claim a toll from every nearby user* [Thesis 3], that fact would not necessarily make it socially optimal for this service to be provided like a private good at a market-determined individual price. *Why not? Because it costs society zero extra cost to let one extra ship use the service* [Thesis 2]; hence any ships discouraged from those waters by the requirement to pay a positive price will represent a social economic loss – even if the price charged to all is no more than enough to pay the long-run expenses of the lighthouse. (Samuelson 1964, 151, as quoted in Coase 1974: 359, italics and square brackets authors')

From this followed what may be called the Samuelson Proposition, as explained in detail below. This proposition generally holds that a public good must be provided by the state out of general revenue.

Public economist Richard Musgrave, highly regarded and cited by Samuelson (1964), identified four categories of the production of goods and services, both government and private, paid for by direct and/or indirect charges.

1. Goods and services provided free of direct charge and produced by the government (Category 1).
2. Goods and services provided free of direct charge and produced by private firms (Category 2).
3. Goods and services sold at the market and produced by the government (Category 3).
4. Goods and services sold at the market and produced by private firms' (Category 4). (Musgrave 1959, 43, brackets authors')

A Category 3 good can be exclusively funded by market revenue or subsidised by allocation from the general revenue.

Like Musgrave, Samuelson conceived of the producer of goods in terms of a simple dichotomy of private firm/enterprise against government. There is no middle ground between a private firm and the state. Coasians, by contrast, conceive of providers of goods in terms of diverse contractual arrangements, ranging from firms that escape regulations (including such organised criminals as 'wreckers'[2] mentioned in Ashley et al. (1967, 166–167) and Van Zandt (1993, 49)) to firms run as government departments. In fact, however, both Musgrave and Samuelson accepted an asymmetric view of the public–private dichotomy. They shared a broad understanding of the 'private market' but a very restrictive view of 'government provision' of any good (Musgrave–Samuelson Proposition).

> Note that socially consumed goods and services are *largely produced by free private enterprises*. The government pays for a hospital or typewriter, but these are produced by *free private enterprise*. And so it is with most government expenditure or productive goods. (Samuelson, 1964, 151, italics authors')

But what is a 'free private enterprise'? Samuelson's famous 1964 textbook does not provide any explanation. However, he qualified it to mean a 'mixed-economy private enterprise' or 'relative *laissez-faire*' (Samuelson, 1964, 796). In other words, *the private enterprise in question need not be totally free from government control*.

What then is 'government production' from the view of Pigou, Musgrave, and Samuelson? The answer must be that such a provision is funded by direct taxation (i.e. Categories 1 and 3). While either a public good or a private good can be financed in this way, according to the logic of Samuelson, a public good (in a descriptive sense) can only be provided as a Category 1 good, funded by direct taxation. This interpretation is that correctly identified by Coase (1974) in his critique of Samuelson. To be more precise, in light of the Musgrave–Samuelson Proposition, such a good cannot be funded by any indirect taxation. Besides, Samuelson viewed the lighthouse as a classic Category 1 good. In other words, *only a public good (in a descriptive sense) can be provided as a Category 1 good, funded exclusively by direct taxation, and a lighthouse is such a Category 1 good* (Samuelson Proposition).

Drawing attention to the pitfalls in the views of Mill, Sidgwick, Pigou and Samuelson, Coase's 1974 paper on the lighthouses in England is famous among libertarian economists for its revelation that these maritime facilities were provided by private merchants who recouped their investment by light dues collected by agents from ships at ports. Coase's point was very simple: there existed in England private lighthouses and they were not funded out of general revenue, thus the Samuelson Proposition was fallacious. The verdict of Coase in his original text (1974) against

2 It was said that they erected lighthouses to entice ships to run into bays they used as traps and then to rob the consequent wreck. The historicity of this is highly doubtful – there is no unequivocally attested case. (See Bathurst, 2005a, 14–15.)

Samuelson was that the lighthouse in England has been *exclusively* provided out of user charge or toll but not direct taxation or general tax revenue (Coase's Verdict.) This verdict succeeds in destroying the lighthouse as a Thesis 3 public good but is silent on its possibilities as a Thesis 2 public good. Coase succeeds in exposing the fallacy of the assumption of Mill, Sidgwick, Pigou and Samuelson that the lighthouse could only be priced at sea. The reality is, as Coase points out, that it is priced in port. Yet Samuelson can argue that even though the lighthouse can be and has been priced, it should not be or have been priced at all on efficiency grounds as the marginal cost of its services, and hence the price, is zero.

Critical questions about Coase's lighthouse paper

Coase's historical analysis of the lighthouse had remained unchallenged for almost 20 years when the work of Van Zandt (1993) appeared. This work did not much ruffle the libertarian understanding. Prior to Zandt's critique, which was endorsed by Kuran (2001), Lovell (1991) had objected to Coase's analysis in terms of the inefficiency of private lighthouses. Recently, another round of criticisms of Coase's lighthouse analysis has appeared in the works of Bertrand (2006); Klein (2006) and Levinson and Odlyzko (2007). The works of Van Zandt and Bertrand, in particular, however, have been qualified by critical examinations by Barnett II and Block (2007a, b). Taylor (2001) did not openly criticise Coase but brought into the limelight a significant omission in Coase's research, namely the fact that it was the ship owners and merchants who drove the British parliament into converting Trinity House into a lighthouse monopoly, a significant point which we shall find echoed in the story of Hong Kong's Gap Rock Light, documented in Part II of our article (Lai et al., forthcoming in *TPR*, 79.5).

The question of free enterprise

Such recent criticism of Coase's lighthouse paper has sought to dispute its validity as establishing the case for *free enterprise*, as the private lighthouses were regulated and eventually taken over by the Trinity House, a medieval charity, and the consumers had no choice whether to use the service.

A very important theoretical question raised by Barnett II and Block (2007a, b) is whether a free enterprise or market (regulated or not regulated) is compatible with mandatory, involuntary or forced payment. In other words, *does the consumer of the lighthouse throughout history (whether it was funded by indirect tax (toll) or direct tax) have the choice of not using the lighthouse service and/or not paying up any 'spot' charge at the point of consumption or later at the end of the voyage* (the Barnett–Block Question)? In short, does the consumer

have the choice of not paying or consuming? If the answer is yes, then Barnett and Block would be wrong.

If the answer is no, then Coase would be wrong to claim that there was a 'private lighthouse market' even when there was no government regulation of the supplier because there was 'compulsory consumption' and/or 'compulsory payment', 'involuntary payment' or 'forced payment'. An alternative approach to the same doubt would be to argue that that an unregulated (monopolistic) provider is, in fact, another form of government. In any case, the answer to the Barnett–Block Question depends critically on whether: (i) the consumer really has no other choice of consumption and (ii) the actual basis of pricing.

'Compulsory consumption' is distinct from 'compulsory payment'. Forced consumption, which means that the consumer has no other alternative *and* consumption is compulsory under the pain of punishment, may not entail any payment, as a good may well be provided free. Thus, 'free education' in some jurisdictions means that by law, parents must send their children to state-regulated schools even though no fees are charged. 'Involuntary payment' is a superficially similar but distinct concept that needs clarification. According to the rationality postulate, individuals will only pay up to the whole of their total valuation of a good. Any amount in excess would amount to outright expropriation.[3] In varying degrees, any consumption involves an element of 'involuntariness' in the sense that to different consumers, a good has always some unwanted attributes tied-in with desired attributes. These attributes (which may well be regarded as different goods) are *bundled together* and offered on a take it or leave it basis. An air ticket, for instance, is not just the cost for transporting a person from one place to another in a plane but also cabin services, seating, entertainment, insurance premiums, and airport charges. The same goes for a private car: it does not just comprise the outer body, but also its internal machinery and upholstery, just to name two theoretically separable examples. To what extent payment is involuntary is therefore a matter of degree and would depend on the methods of metering services adopted. In the lighthouse literature, Cerin (2006) considered the question of the existence of a tie in sale between the use of lighthouses and the port.

As a referee of this paper pointed out, what was missing in Coase was the consideration of the lighthouse as a 'natural monopoly'. Suppose, as must be obvious, that this 'monopoly' would not build a second, competing lighthouse, for the same harbour or hazard. In that case, can we say that there is only a limited degree of 'free enterprise'? The answer to this begs the question and would depend on whether this firm is a franchised company or not.

Coase did not consider the question as to the freedom to consume and thus to pay either. The right to levy a 'light due' was determined by law: a ship using a harbour was obliged to pay the light due also. Any failure to pay the light due would be

3 A close cognate here is the idea of the cost of advertising being a Balogh tax compulsorily levied on consumers.

subject to legal process for recovery, as evidenced by a court case in Part II. There was thus limited freedom to consume. And lighthouses would not be provided privately if payment could not be made compulsory. This sounds reasonable. However, the critical question is whether the ship owner can opt out of a port subject to excessive tolls. In effect, since the light is bundled in with the port as part of the port facilities (even if as a separately designated item on the port facilities bill), the focus shifts not to competition between lights but to competition between ports. Thus if port A charges high light dues, but it is possible for someone to develop port B nearby with lower dues, there is competition involving lights even where building an alternative light for any *one* port is not possible.[4]

At any rate, the free enterprise criticism of Barnett and Block II has two problems. First, it ignores the fact that the actual intention of Coase was simply to refute the Samuelson Proposition. Second, it is also ultra-libertarian for demanding a free enterprise to be one that is both totally unregulated and has no monopolistic power.

However, these issues aside, neither Coase and supporters nor their critics paid attention to three factors: (a) the technological interaction between lighthouse and the ship; (b) the impact of technological development on the institutional arrangements of lighthouse funding; or (c) the implications of the choice of pricing method adopted by the English lighthouses for Samuelson's case of the lighthouse as a Thesis 2 public good, which should be priced at zero to attain efficiency. The first two factors are discussed in the sub-section immediately below and the last factor in the following sub-section.

4 It is slightly to one side of our core argument focused on the technology of ships and lighthouses, but a critical element in the debate on free competition in early lighthouses is the change in the very nature of ports, and hence of the possibility of inter-port competition, as the pre-industrial economy gave way to an industrial economy. There are two strands to this:

(a) with pre-industrial cargoes, both quantities and nature of goods were less specialist, and hence less point destination-specific;

(b) with primitive, human-power load and discharge from or onto simple landing stages or even low tide flats giving onto a hinterland with universally poor transport infrastructures, almost anywhere could and often did serve as a port.

This changed radically in the industrial era. At that moment, a port started to have unique added value (industry and skills clusters, integrated hinterlands with good transport infrastructures, etc.). Because of that it attracted cargoes that increasingly had no other feasible destination. The added cost of good lights to identify the port and direct ships into it would then not have deterred shipmasters because they had no alternative destination. More to the point, nearby port-pretenders would in any case have been unable to compete because the costs of entry would have risen dramatically. Early lighthouses and post-industrial lighthouses functioned in distinctly different worlds fulfilling distinctly different roles.

The question of technological interaction between the lighthouse and the ship and the interface between technology and institutional arrangements

Coase's analysis, though being correct in finding fault with Samuelson's example, leaves open a first-order institutional economic question as to why the Trinity House eventually became a legal lighthouse monopoly, crowding out all but a very few private lights for local use only. To answer this highly pertinent institutional economic question beyond the legalistic narrative of Taylor (2001), which demands dynamic thinking, we have to understand the internal logic of maritime technology, its evolution and institutional responses.

Advances in the technology of shipping had a strong influence on the role and technology of the lighthouse, and accordingly lighthouse economics. We can start with the most significant technological innovation, which was the invention of the steamship. But to this we must add the rapid advances – part effects, part causes of increased sea trade in the eighteenth century – which had already begun transforming both navigation[5] and the tools on which a navigator relied to practise his art.[6] This changed the whole nature of what a lighthouse was for. The more recent introduction of the GPS has in turn revolutionised the status of lighthouses to the point that a pattern of development will come full circle:

> no lighthouses → early 'port identification' lighthouses → 'aids to navigation' lighthouses → no lighthouses.

Prior to the steamship age, the role of the lighthouse was mainly as a land- or seamark for a port. Neither free-riding nor investment costs posed a great problem and any private arrangement for light due collection at the port the lighthouse marked could finance a private lighthouse industry adequately.

However, once the steamship came into play, there was an upsurge in demand for much better lighthouses serving a significantly different purpose. No longer mere port markers, although certainly still that, but with new and multiple roles: as leading

5 The art of knowing where a ship has been, where it now is and predicting where it will be at a given time in the future

6 The signal developments were the calculation of accurate ephemerides and their publication in readily available almanacs, the invention of the chronometer for the accurate measurement of time at sea (and hence the solution of the problem of longitude), the invention of the difference engine (by Jesse Ramsden, which allowed mass production of precision measuring instruments like sextants, station pointers and rules), and the rapid advances in hydrographical surveying resulting in accurate charts and more extensive and informative sailing instructions. The cumulative effect was, with the advent of the steamship, utterly to change the nature of navigation and as a consequence the role of the lighthouse. Far from it being solely a means of identifying a port by day and night, it became a vital element in coastal and offshore navigation. Offshore, it allowed the early identification of hazards on route, and hence allowed them to be passed more closely with greater safety. Coasting, provided the range of each light overlapped with the next, it allowed the steamship navigator, in a vessel relatively independent of wind and current, to plot a night passage closer to hazards than had ever previously been the case.

lines into ports; as hazard alerts for offshore shoals and reefs a ship might meet on passage between ports; as aids to navigation[7] because, thanks to their presence and ubiquity steamship passages[8] could be accurately planned to take the shortest, and hence swiftest and most economical route.

Free-riding and investment funding became growing problems, thus driving out the private operators and putting lighthouses into the hands of either (a) one single franchise (the Trinity House in the case of the England in the nineteenth century) or (b) a government department (the Harbour Department in the case of colonial Hong Kong in the same period).

The question of pricing methods

Coase's analysis of the English lighthouse is also silent on the price theory question as to choice of the pricing strategy, hence missing the second case of Samuelson based on Thesis 2, i.e. the lighthouse should not be priced as it is a zero marginal cost service. Specifically, why was there a light due that varied according to tonnage of a ship (Coase, 1974, 365; see also note 7) rather than being a flat fee for any ship chosen? Besides, why was tonnage rather than the actual weight or value of cargo the basis of light due levy? Interestingly, both questions can be addressed using Coasian thinking although this matter too is one on which Coase's original article was less than precise. The answers to the questions are important for a better understanding of the solutions to potential public good problems under Theses 2 and 3.

Why price discrimination?

Both historic examples of fixed fee and price-discriminating fee exist for lighthouses. The Cordouan lighthouse in Bordeaux, France charged a fixed fee (Hart-Davis and Troscianko, 2002). Most jurisdictions, like England and Hong Kong, however, adopt price discrimination according to tonnage, allowing some free-riding (where marginal cost (MC) is positive) through cross-subsidising between larger tonnage and smaller tonnage ships. The comparison between the fixed fee per ship and a price-discriminating fee according to tonnage has more than historical significance.

7 There is an important distinction with significant legal implications between an 'aid to navigation' – like a lighthouse, beacon or buoy, and a 'navigational aid' – like a compass, sextant, or chart. Simplifying rather, we may say that with the former, the navigator uses it to assist in position finding, but relies on some other agency to ensure that the aid in question is where the chart or navigational publication declares it to be and thus fit for use. With the latter, the navigator also uses it to assist in position finding, but the maintenance in good condition of the aid and thus its fitness for use is entirely the responsibility of the navigator.

8 There is a significant distinction between a 'voyage' – a legal-commercial concept – which lasts from a port at which a seaman signs on, and which may visit a multiplicity of ports, until the ship returns to its home port and a seaman is signed off, and a 'passage' – a navigational concept – which describes the trajectory a ship follows between a point of departure and a point of arrival, which may involve a number of legs of different lengths on different courses.

A Coasian political-economy explanation for the choice of price discrimination, which dilutes the free enterprise criticism, is that a pricing regime embodying cross-subsidy and hence benefiting the whole shipping industry incurs less transaction costs than one that just serves a segment of the industry by a flat rate per vessel. First, it overcomes Samuelson's case based on Thesis 2, which implicitly assumes a fixed light due, by equating marginal valuations of all consumers with their individualised prices. Besides, price discrimination has positive social effects on the shipping industry by allowing cross-subsidisation. Indeed, French economist Jules Dupuit (1844) explained that perfect price discrimination is an efficient method of addressing the efficiency and revenue questions for a zero marginal cost good. The example Dupuit used is the bridge which, like the light house, requires capital to build but, once built, the cost of serving an extra user is zero. Interestingly, Dupuit's paper was cited in footnote 11 of another significant work of Coase, 'The marginal cost controversy' (Coase, 1946), in which Coase challenged the criticism of a uniform marginal price.

Why ship tonnage not goods weight?

'Tonnage'[9] is a term that means the cargo carrying capacity of a ship rather the weight of the cargo per se, although there is no difference in analysis. That the goods carrying capacity is preferred to actual weight of goods carried in fee assessment makes much sense in terms of transaction costs. Plainly, it is far less costly to meter capacity than weight, not least because all ships, at point of construction, are measured for official registration purposes in terms of their gross and net tonnages.

Reverting to the comment above about Coase's original article, it is his failure to note the theoretical significance of charging light dues according to tonnage, i.e. the practice of price discrimination which achieves marginal pricing as well as the long period of trial and error in establishing the measurement tonnage-based system where his lack of precision is to be found. A system based on tonnage (i.e. measured capacity, not weight) predated any extensive lighthouse provision in Britain and ran

9 The modern spelling of the measurement ton is a corruption of the medieval English 'tun', the standard barrel of a fairly constant capacity (roughly 252 gallons of wine weighing approximately 2240 lbs (or a long ton)) in terms of which early 'tunnage and poundage' dues were levied – dues on weight of cargo. By 1720, when the Builders Old Measurement system was standardised, any reliance on cargo weight (or deadweight to use the technical term) had been abandoned in favour of a volumetric measure which took the old 'tun' (become ton), to be equivalent to 94 ft^3 of hold space. In 1854 this rather hit-and-miss method based on a very crude formula relating a ship's length of keel and its beam was replaced by the Moorsom System, which standardised on one measurement ton being 100 ft^3, which is now (as 2.83 m^3) the international standard. The system was named after Admiral George Moorsom, chairman of the British Parliamentary Committee established in 1849 to sort matters out, and which decided to assess ships on the earning capacity of any ship, not what it was actually carrying. 'The tolls were collected at the ports by agents ... The toll varied with the lighthouse and ships paid a toll, varying with the size of the vessel, for each lighthouse passed ... It was normally a rate per ton (say 1/4d or 1/2 d) for each voyage' (Coase, 1974, 364–65).

through until some two centuries after the founding of Trinity House and some 130 years after their receiving the right to control lighthouse provision. This again is an area where the complex interactions of naval architectural changes, the growth of sea trade (and hence the rise of new and different ports to replace or supplement old medieval centres of sea trade), developments in navigational technique and the rise of the nation state and a central exchequer controlling a national revenue are rather overlooked actors in the drama. A full study of this issue would thus need to look carefully at what roles were played by what elements in the provision of British lighthouses, respectively, by Trinity House and private operators. For without understanding the extent to which the early part of the British lighthouse story had more to do with the actualities of medieval and mercantilist economies – which necessarily interfered with any free market operation – it is bold to conclude that the early private lighthouse erectors were agents acting in a free market.

A model of lighthouse provision

We shall construct a model of lighthouse provision based on the factual information of Coase to better organise our exploration of the actual use of lighthouses by ships in our case study on lighthouses along the Chinese coast.

The two-way convertibility of a good

In accordance with the analysis in the above section, the model treats the lighthouse as both a *convertible* good that may be private and at the same time a public good depending on: (a) the technology of the lighthouse (which affects the marginal costs of serving an extra ship, which may not necessarily be the same as the marginal costs of consumption of lighthouse services by ships[10]) *vis-à-vis* (b) (i) the technology of pricing and (ii) the technology of shipping (which affects both what a lighthouse is, operationally, and therefore the excludability of the lighthouse service). To simplify our discussion, as a start, let us assume that in serving an extra ship, the marginal cost (MC) of a lighthouse is zero with either meaning of MC. This is likely the case where the lighthouse is simply a port-identifier with no keeper or signalling services. We will then evaluate the impact of positive MC in servicing; in all situations, the marginal and

10 Note another way to differentiate the marginal costs of *serving an extra ship* with the marginal costs of *consumption of lighthouse services by ships* is to view the former as a variable cost of operating a lighthouse that relies on a working crew not independent of sea traffic. The marginal costs of consumption in the sense of adding dis-utility to existing ships on the sea could be zero. Graphically, the former is the variable cost of maintaining the operation of lighthouse that can be represented by a typical MC curve while the latter is represented by a shift down in the marginal valuation of each unit of ship as additional units of ship are added. The two types of marginal costs are conceptually very different.

average cost functions are assumed to be horizontal functions. The model conceives of reversible transition among situations depicted in Figures 1, 2 and 3.[11]

Zero MC lighthouse

Referring to Figure 1a, we may postulate that given zero MC and a fixed light due, the profit-maximising equilibrium is E_p, but the socially efficient but commercially unattainable equilibrium is E_s, assuming that the transaction costs of collecting light dues (at the spot or at port) are zero given the prevailing technology. The public may bargain with the owner of the lighthouse in the distribution of the monopoly rent and the loss in consumer surplus implied by charging the profit maximising monopoly price. In other words, the consumer would want a bigger consumer surplus (pushing down *P*a), which means a lower total light due revenue as would be indicated by a smaller rectangle. If the bargaining parameter is limited only to a fixed fee, the range of public choice over the fixed fee is *P*a to *P*o. A fixed light due per ship means that some ships (Q_p to Q_s) are to be excluded from the market. This could be the case of the Cordouan Light.

However, note the case where price discrimination is practised as in cases where light dues are levied on the basis of the tonnage (instead of a fixed fee applied for all ships), the outcomes are depicted in Figure 1b. The fee schedule can run along the demand curve in the case of a perfect price discrimination of the first degree, meaning that with fee charged according to each ship's willingness to pay, the fee structure will overlap with the demand curve. In practice, however, the fee schedule is below the demand curve, with the vertical intercept, P_n, below the highest point of the demand curve. The entire shipping industry is served. No ship will be excluded. Even though the individual consumer surplus may be far less than the case of a fixed-fee regime, the public may prefer this solution over the fixed-fee solution. This is so particularly if there are many small ships that will be excluded in fixed fee pricing, e.g. if the demand curve is convex with a large number of ships in the lower portion. The lighthouse provider collects more revenue under price discrimination. This should be the case of the English lighthouses prior to the steamship age. (See the discussion of steamship technology in relationship to the lighthouse service above.)

Note that the term 'tonnage', as explained in the section above, is a term that means the cargo carrying capacity of a ship rather the weight of the cargo per se, although with zero transaction costs, it will probably make more sense to price-discriminate on the basis of the value per unit of weight of the cargo. The adoption of the Moorsom

11 In all figures, the fixed costs and thus the average total costs are omitted to improve clarity in studying the diagram. The inclusion of fixed costs of building and maintenance of lighthouse is useful for the checking of profitability or breaking even. Omitting them will not have any bearing on the pricing versus welfare loss issues in the ensuing discussion.

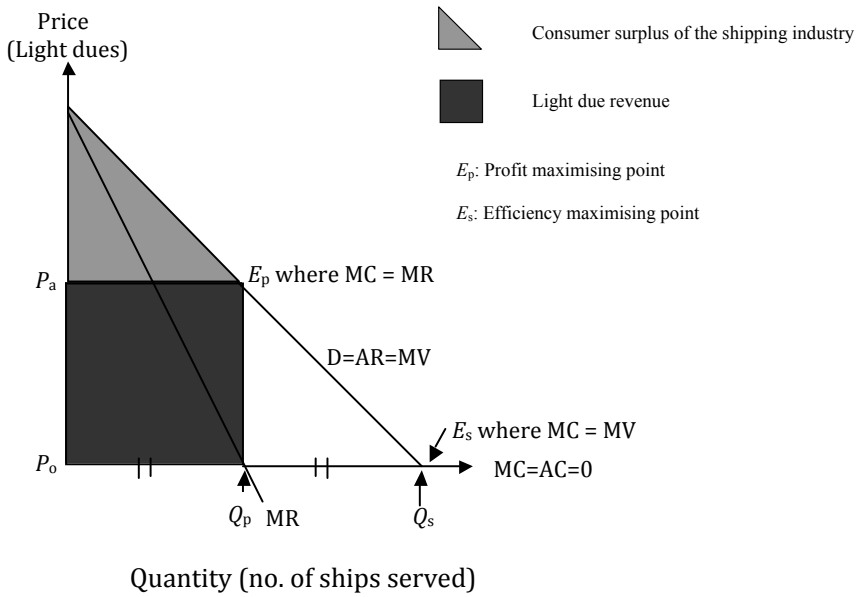

Figure 1a Profit and efficiency maximising equilibria for a zero marginal cost lighthouse charging a fixed light due per ship

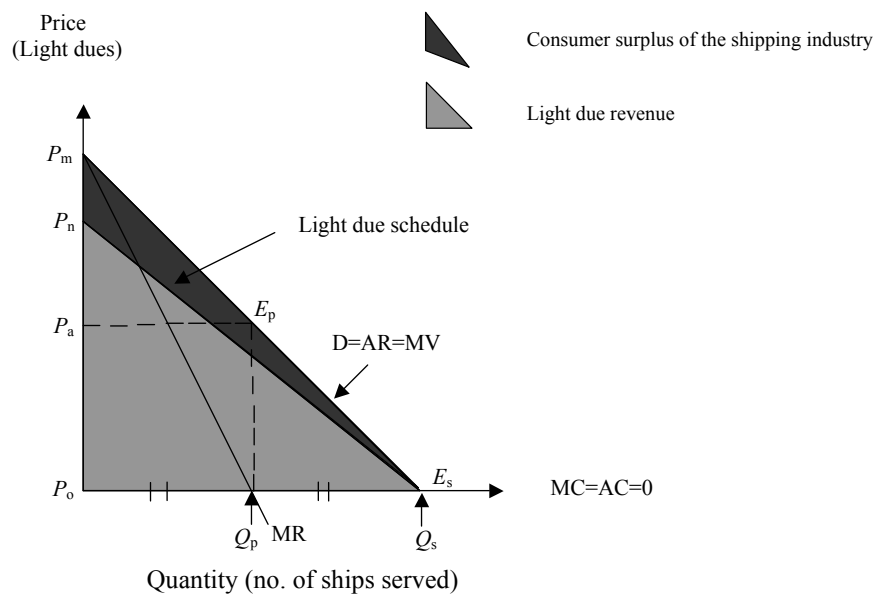

Figure 1b Efficiency maximising equilibrium and the light due schedule for a zero marginal cost lighthouse administering price discrimination according to the tonnage of ships

System in 1849, explained in footnote 9, was probably due to the consideration of such costs.

Positive MC lighthouse

Now consider the case where the MC of the lighthouse serving an extra ship is not zero, as in the case of one that provides more services than merely being a landmark, the price range for a fixed fee regime as regards prices will shift upwards to P_A from P_a and quantities will be reduced to Q_{p*} from Q_p, *ceteris paribus* (as depicted in Figure 2a). The profit-maximising and efficiency maximising equilibria will be, respectively, E_p^* and E_s^*. Note that in this fixed-fee solution the range of prices over which the users of any lighthouse can bargain with the lighthouse provider will be smaller (P_A to P_B).[12] Indeed, the higher is the MC, the smaller will be this bargaining range. Thus, if transaction costs in bargaining are a direct function of the magnitude of the range, a lower bargaining cost is involved in a situation with high MC than a situation where MC is low; and thus for that factor alone, fixed fee arrangements are more likely to be adopted when MC is high. This is assuming that the distribution of ship tonnage is represented by a linear demand curve as drawn. (Additional factors of consideration on the curvature of the demand curve are noted in earlier paragraphs.)

Compare this to the case where price discrimination according to tonnage is practised for positive MC lighthouses, the benefit–cost comparison will be notably different. Because the fee schedule for price discrimination is a linear curve below the demand curve, it will intersect the MC at a point less than Q_s*. That means price discrimination involves a social subsidy to some ships (from Q_s* to the point $Q_e$where D cuts the x-axis, as shown in Figure 2b, the private subsidy is a little larger). Again, the higher MC is, the larger is the expected subsidy, and thus we are less likely to see pricing according to tonnage being adopted. This should be the situation of the early steamship age, when pressures to build more lighthouses began to build up.

The MC of the lighthouse is unlikely to be zero if: (a) the lighthouse does not simply mark the seaway, but also provides signalling services (for instance, fog signalling), rescue and ship registering services; and/or (b) light dues collection requires manpower. Marking the seaway is not costless, as fuel, transport, and administration are required. The variable cost of signalling includes, at a minimum, positive labour costs and equipment running costs, which could be avoided if the lighthouse was unmanned or not communicating with ships.

Commander W. H. Hall's *Narrative of the Voyages and services of the Nemesis, from 1840-1843; and of the combined naval and military operations in China: Comprising a Complete Account of the Colony of Hong Kong, and Remarks of the Character and Habits of the Chinese*

12 *P*A to *P*B, as compared with the range of *P*a to *P*o, is necessarily smaller, because of the mathematical property of marginal revenue, which is derived from the demand curve.

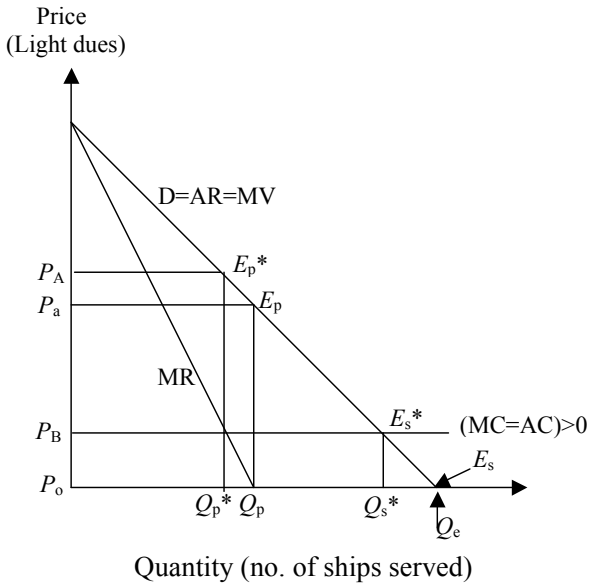

Figure 2a Profit and efficiency maximising equilibria for a zero and positive (constant) marginal cost lighthouse (under static demand and cost functions) charging a fixed light due per ship

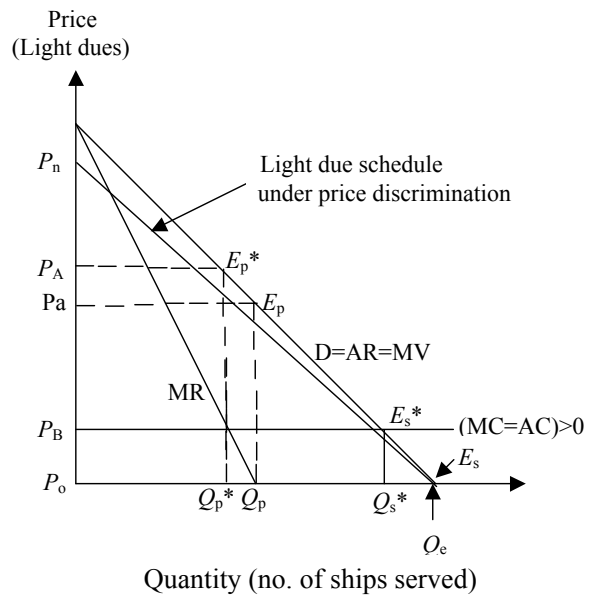

Figure 2b Efficiency maximising equilibrium and the light due schedule for a zero and positive (constant) marginal cost lighthouse (under static demand and cost functions) administering price discrimination according to the tonnage of ships

contains an interesting remark that testifies to the idea that the MC of servicing a lighthouse can be positive.

> On the 4th of November she resumed her voyage, and passed the little rocky island of Pedro Branco early on the following morning. This dangerous and sometimes half-covered rock lies nearly in the direct track for vessels proceeding up the China Sea; and on its southern side are two dangerous ledges or reefs, running out from it to the distance of more than a mile, which, at high water, can scarcely be traced above the surface. On the opposite or northern side there is deep water in not less than sixteen or seventeen fathoms, close in to the rock ; and, moreover, the tides in its neighbourhood are very irregular, not only in point of time, but also in direction and velocity. Nor are these the only dangers to be met with in this locality. Hence it will readily appear that a lighthouse placed upon Pedro Branco would be of essential utility to all navigators who have occasion to pass up or down the China Sea. A ship leaving Singapore for Hong Kong, for instance, might then start at such an hour in the evening as would enable her to make the light on Pedro Branco before morning; by which means, her true position being ascertained, she might stand on without fear of any danger. The expense of erecting the lighthouse would not be great, as the elevation would only be moderate, and the expense of *maintaining* it might be defrayed by levying a small light-duty at Singapore upon all vessels passing up or down the China Sea. (Bernard and Oxon, 1844, Vol. 1, 168–69, italics authors')

Here we read of the assumption of a contemporary naval officer that whilst building costs of the lighthouse were not expected to be met by light dues, the operational (variable) costs could be so met and that there was therefore, even in the earliest steamship days,[13] a presumption of positive MC for a lighthouse. Pedro Branco is the rock on which Horsburgh Light sits in the eastern entrance to the Singapore Strait.

While increased tonnage may not affect MC much, a greater number of ships beyond a given point will. The question is: in addition to a positive MC, whether the function is likely to shift upward over time? This question is an empirical one, but we may reasonably assume that innovations in lighthouse operations and light dues collection will shift MC towards zero over time, whether the MC function itself is horizontal or upward-sloping. The horizontal functions are drawn for simplicity of exposition only. Technology conceivably could bring the situation back to Figures 1A and 1B. But what if demand grows at the same time? This is discussed in the next sub-section.

13 The *Nemesis* was the world's first operational iron built, steam-driven warship. Interestingly she was built for the East India Company's Bengal Marine, although as soon as she was built she was commandeered by the British government for use in the impending China campaign and was thus operated by Royal Naval personnel during the infamous First Anglo-Chinese (or Opium) War. It was in November 1840, on her maiden voyage, a pioneering passage from Britain to China that represented the longest voyage thus far by a steam vessel that she passed through Singapore. See Part II for the date of Horsburgh Light's construction 11 years after Commander Hall's visit and 7 years after the publication of his book.

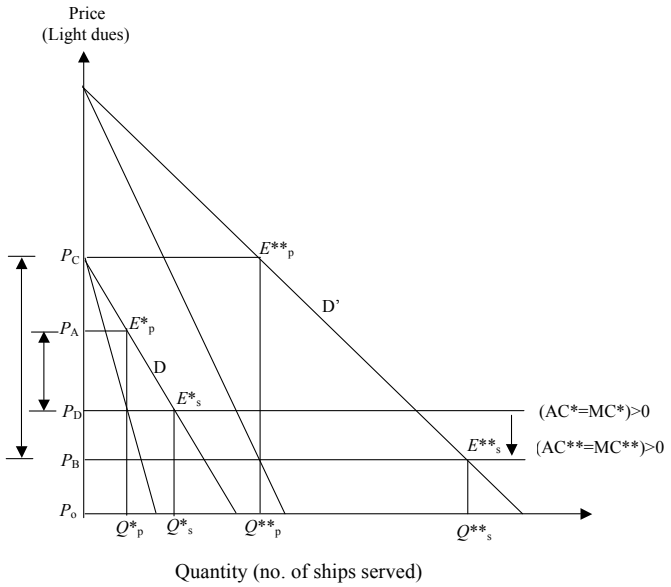

Figure 3a Profit and efficiency maximising equilibria for a positive (constant) marginal cost lighthouse (under growing demand and falling marginal cost functions) charging a fixed light due per ship

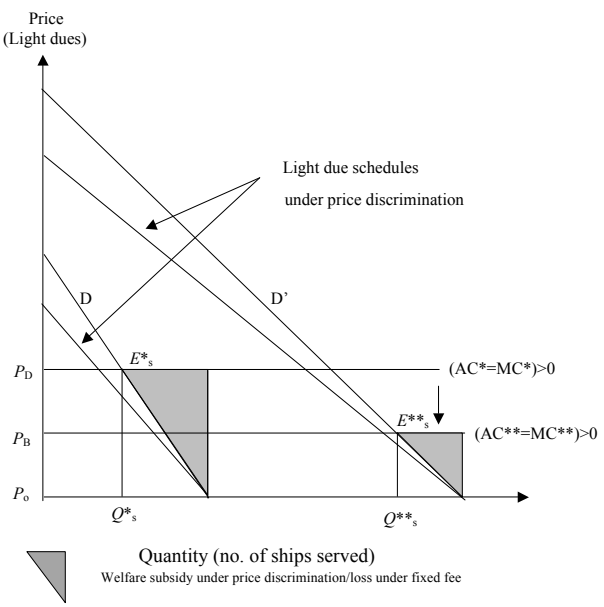

Figure 3b Efficiency maximising equilibria and light due schedules for a positive (constant) marginal cost lighthouse (under growing demand and falling marginal cost functions) administering price discrimination according to the tonnage of ships

Positive MC lighthouse facing technological and demand changes

While the MC shifts downward over time, demand for lighthouses grew due to innovations in navigation technology and expansion in maritime trade. The opening of the Suez Canal in 1869 and the effect of mass production in Europe during the Industrial Revolution eventually led to a growth in demand for shipping.[14] Figure 3a depicts these effects for a fixed fee regime. MC fell from MC^* to MC^{**}. Demand shifted outwards from D to D', thus creating a much wider price range ($P_C - P_B$) for a much greater bargaining cost than that before MC had fallen and demand increased (i.e. P_A to P_D). With technological change and increased demand, the profit and efficiency maximising equilibria will be E^{**}_p and E^{**}_s respectively. As discussed in earlier paragraphs, some shipping is kept out of the market with fixed-fee pricing. The excluded quantity of ships is larger with technological changes and the growth in demand, if a fixed-fee light due is adopted.

On the other hand, for a price-discriminating fee regime in which the entire industry is served with some marginal ships receiving subsidies, there will be a different consideration. Although there will not be any excluded ships, the welfare subsidies with a lower level of MC are likely to be smaller, even though demand could be growing. Thus, the efficiency loss using the tonnage method of pricing will be less with technological advances and growing market size. This can be seen by comparing the two shaded areas in Figure 3b. Considering the light dues collected from these small tonnage ships, it could be that such ships are totally exempted from payment (let's say ships below a certain tonnage do not have to pay). In that case, the small ships can be said to be economic free-riders on ships with much larger tonnage. It is important to note, however, that they are not technically non-excludable. Rather, it is a situation where it is economically unnecessary to exclude them as demand increases and technology advances are lowering marginal costs. From another point of view, the shaded areas in Figure 3b can be interpreted as a welfare loss under a fixed-fee regime. This should be the situation of the mature steamship age.

14 Looking at Sayer (1975), we do not see much immediate significant change in the growth of the number or ships or the tonnage of ships entering and clearing Hong Kong (HK) after 1869. The effect of the Suez Canal seemed to be more on costs rather than the demand for goods. Almost all HK traffic in the 1870s was cabotage (coastal) traffic along the China coast. International services, whether freight or passenger, were minuscule by comparison. In any case, it took at least 10–15 years for growth in Suez Canal traffic to increase appreciably, and the increase was overwhelmingly initially in passenger and cargo-passenger services. Second, international trade into/out of China was remarkably small – in-country trade always hugely eclipsing international trade (traffic in HK in 1906 was 80 per cent in-country and 20 per cent international). In short, one should not have expected the opening of the Suez Canal to have had any noticeable effect on HK tonnages.

In search for a real-life example

To recapitulate, any successful scrutiny of Coase's lighthouse example must involve not only abstract economic thinking, but also maritime technology and history, hitherto absent from academic debates. In line with this standard, the model developed above must be capable of describing real life examples. The wonderfully preserved archive materials of a British Crown Colony, Hong Kong, and the Imperial Chinese Maritime Customs Service (IMCS), headed by British personnel, allow the reconstruction of the history of many lighthouses as captured by our models, and also a highly revealing narrative of the provision of the lighthouse out of light dues. We shall consider these examples in Part II.

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Acknowledgements

The authors thank the editors and two anonymous referees for their useful comments, especially several significant issues found in Coase's original work, the idea that the lighthouse exhibits features of a natural monopoly as well as the theoretical distinction between marginal costs of consumption and marginal costs of provision of lighthouses.

The authors are indebted to Mr Tom Winstanley, estate-surveyor and fish biologist now based in New Zealand, a descendent of the Henry Winstanley who was the first Eddystone Light designer, and Capt. Pak-cheung Ip, for their useful information, and Professors Walter Block and William Barnett II for providing the manuscripts for two of their most recent papers on the lighthouse in economics. Finally, the authors are grateful to Dr Connie W. Y. Hung for her assistance in the research for Table 1 and the compilation of the six illustrative diagrams in this part of the article.