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The London congestion charge: a tentative economic appraisal☆,†

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Abstract

Pre-charge and post-charge data (particularly on speed and road usage) in the London congestion charge zone is used to estimate demand and cost curves for road usage. Pre-charge congestion costs are estimated, and shown to be small (0.1% of the area GDP). They are largely (90%) eliminated by the charge, which produces an economic benefit. Charge proceeds are about three times larger than the value of the congestion. Unfortunately, the yearly amortisation and operation costs of the charge system appear to be significantly higher than the economic benefit produced by the system. The London congestion charge, which is a great technical and political success, seems to be an economic failure. It could be defined as mini Concorde.

1. Introduction

The very notion of urban congestion pricing was introduced—in London— in the 1960s (Smeed, 1964; Walters, 1961). It was subsequently endorsed by all or most economists. However, very few cities (with the notable exception of Singapore) put the idea into practice. This is why the congestion charge experiment introduced—in London again—in 2003 is particularly interesting. David Banister's view is widely shared by transport economists: 'Congestion charging in Central London is the most radical transport policy to have been proposed in the last 20 years and it represents a watershed in policy action' (Banister, 2003, p. 259). In addition, pre and after charge data gives a unique possibility to try and see how important are in practice the theoretically large merits of a congestion charge.

The London congestion charge, its physical impacts, and its political acceptability have been described elsewhere in detail (Banister, 2003). A congestion charge zone of about 22 km^2 (a circle with a radius of 2.7 km) has been defined in downtown London, comprising about 370,000 inhabitants and 1.2 million jobs. This is a relatively small area, representing about 1.5% of the Greater London area and 5.2% of its population—and a much smaller proportion of the hard-to-define but economically significant London agglomeration. Since February 2003, vehicles driven in this zone between 7h30 and 18h30 on week-days must pay a charge of 5 pounds or 7.2 euros[2] per day. The average charge paid is actually lower, because of exemptions[3] and reduced charges for some people[4], not to mention charge evasion.

The congestion charge is generally seen as a great success. It is a technical success. The payment and monitoring system, after some initial difficulties, functions well. The zone traffic reduction objectives have been reached. The number of vehicle km in the zone declined by about 15%, and their speed increased by about 17%. Bus

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[2] A 1 pound=1.44 euros, the average exchange rate in 2003, is used throughout this paper.

[3] Motorbikes, taxis, handicaped persons, buses, power-fueled motor vehicles, public utility vehicles are charge exempt.

[4] Residents of the zone pay only 50 cents of a pound perd ay −10Ù of the full charge.

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patronage in the charged zone increased. Politically, the charge is a also a great success. Most Londoners are satisfied with the system, and Ken Livingstone, the mayor who introduced it, was widely applauded for it, and was re-elected in 2004, in part because of the congestion charge.

But, is it an economic success? This question is the focus of this paper. How important were the potential benefits of a congestion charge? Have they been reaped? Has the level of the charge been correctly defined? How do the actual benefits compare with the costs of operating the system?

Such an economic appraisal is difficult, and necessarily tentative, for several reasons. First, the congestion charge is relatively recent. Short-term behavioural reactions may not hold in the medium-term. Some of the changes induced by the charge (for instance changes in business location) will require several years to materialise. Second, some of the recorded changes in transport patterns (which are often uncritically attributed to the congestion charge) may in reality be caused by exogeneous events. The most glaring example is the drop in subway patronage in 2003, which is mostly the consequence of the temporary closure of a subway line. Third, very little information is known about what happens outside the charged zone, in the 'rest of London', as a consequence of the charge. Fourth, the congestion charge is the most important element, but not the only element, of the policy changes introduced in 2003. Bus supply, in particular, was significantly increased. There is, therefore, an ambiguity in all evaluation: are we interested in the impacts of the congestion charge only, or in the impacts of the package that included the congestion charge? For all these reasons, any pronouncement about the London congestion charge must be prudent, and seen as tentative.

This paper is an attempt to provide a quantitative analysis of the scheme. It is based on earlier work by Prud'homme (1999, 2000) and Prud'homme and Yue-Ming (2000) on congestion in the Paris area. Most of the data utilized comes from Transport for London (subsequently TfL) website (www.tfl.gov.uk). The paper begins with a simple model of congestion. It continues with a modified version for the case of London, and proceeds to establish the cost and demand curves that make it possible to provide quantitative estimates of the main characteristics of the London system. These estimates in turn make it possible to answer some of the important questions raised by the scheme.

2. A simple model of analysis

Let us consider a diagram representing the quantity of road usage on one axis and the unit (i.e. per km) costs of road usage on the other, as in Fig. 1. This can be applied to a given road, or to a given area—such as the London congestion zone. In this case, road usage can be measured in vehicle km.

$D(q)$ is a demand curve, that represents the demand for the use of the road, as a function of the unit cost of using

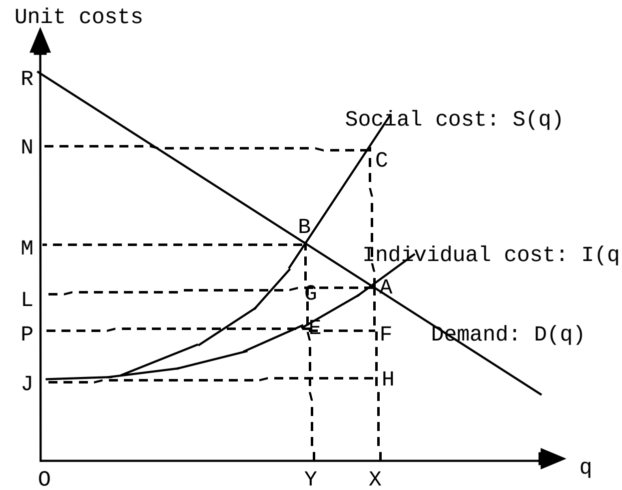

Fig. 1. Road congestion.

the road. The most important element of this unit cost is a time cost, the cost of the time needed to drive 1 km.

$I(q)$, which could be called a supply curve, is the per km cost borne by a motorist. When the motorist is alone on the road (when $q=0$), this cost is J, the operating cost of driving, plus the time cost at the maximal speed. When there are more vehicles (when q increases), the speed is reduced, the time needed is increased, and $I(q)$ increases.

An equilibrium will be reached at A, where $I(q)$ and $D(q)$ intersect, with X vehicles km driven in the zone, and a unit cost of L. At this point, the marginal driver bears a cost equal to the benefit he/she derives from road usage. Beyond, he/she would bear a cost greater that the benefit derived, and would not use the road.

This natural equilibrium is unfortunately suboptimal. This is easy to see when we consider $S(q)$, the unit social cost created by a vehicle as a function road usage. This social cost is equal to the individual cost $I(q)$, plus the cost of the additional time spent by all other vehicles because one extra vehicle is on the road. Point B, where $D(q)$ and $S(q)$ intersect, with Y vehicles km, and a unit cost M, is the optimal solution for society. Beyond that point, an additional vehicle generates a social cost greater than the social benefit it creates. This optimal situation can be reached by the imposition of a tax equal to EB—a congestion charge—that will reconcile the private cost and the social cost.

Several interesting conclusions can be derived from this analysis.

First, except when the demand curve intersects the private cost curve in its flat part, the natural equilibrium quantity of road usage is always greater than the optimal quantity of road usage: X is greater than Y. In other words, roads are nearly always congested; they are only more or less congested.

Second, the notion of an optimal quantity of road usage implies the notion of an optimal level of congestion. The objective of policies, therefore, should not be to 'eliminate' congestion—an objective that does not make much sense, since there is always some congestion—but to make sure that the optimal level of congestion prevails.

Third, the optimal quantity of road usage Y (and the associated optimal level of congestion) are a function of the demand for road usage; if the demand increases, the curve $D(q)$ moves rightward, and so does the optimal quantity; similarly, if the slope of the demand curve decreases, that is if the demand relative to price becomes more price elastic, the optimal quantity of road usage decreases.

Fourth, this points to the main difference between the engineer's approach and the economist's approach: while the engineer defines the optimal road usage and congestion as a function of road characteristics only, the economist approach defines it as a function of both road characteristics and road demand.

Fifth, the optimal tax or charge is the congestion externality (the difference between the social cost and the individual cost) at the optimum, not at the 'natural' equilibrium. It is EB and not AC, contrary to what is often suggested. A congestion charge equal to AC would overshoot, and reduce road usage to a point (not indicated on Fig. 1) much to the left of Y, that would be suboptimal.

Sixth, congestion costs should be defined as what is lost by society for not being at the optimum, for being at A rather than at B, for having X rather than Y vehicle km. Congestion costs are, therefore, equal to BCA. They are also equal to the increase in welfare associated with the move from A to B, that is to PRBE (the utility after) minus LRA (the consumer's surplus before), which is equal to LGEP-BAG. They are the benefits of introducing a congestion charge. This point is not necessarily obvious, and requires some elaboration.

To define congestion costs, one needs a reference situation, to which the present congestion situation can be compared. This reference situation cannot be the empty road. Roads are not built to be empty. There is nothing optimal or desirable in an empty or quasi empty road with a few vehicles driving at a free-flow speed. Saying that the difference between time actually spent and time that would be spent at free-flow speed is 'time lost' does not make much sense. If free-flow speed were the implicit norm, why not apply it to public transport? We would then compare time actually spent in public transport to that norm, call the difference 'time lost', value it and present it as a 'social cost' of public transport. Fortunately, nobody engages in this futile exercise. Congestion costs are, therefore, not equal to the difference between the unit costs with X vehicle km and the unit costs with zero vehicle km, multiplied by X, that is to LAHJ—although this naive and erroneous view is often held. The reference situation cannot be either the maximum flow situation, as the engineers are tempted to suggest, because it ignores completely variations in the demand for road usage. The reference situation cannot be one in which there are no external costs, which is what is implied in the not uncommon definition of congestion costs as equal to NCAL, the product of the present marginal unit cost CA by the quantity of vehicle km. This would correspond to the empty road situation. The only meaningful reference situation is the optimal situation, and congestion costs have to be defined as the difference between the present welfare and the potential—and higher—welfare associated with this optimal situation.

Seven, the amount of the congestion charge paid, MBEP, is larger, often much larger, than the economic benefits brought by the congestion charge. To an economist, this is not a problem, because the charge is a transfer, not an economic cost. Drivers may of course have a somewhat different view.

Finally, transaction costs (collection costs in the case of a charge) should be deducted from the benefits of congestion reduction. Economists have a tendency to ignore transaction costs. As we shall see in the case of London, this tendency might be misleading.

3. A slightly modified model for London

The data available on the London congestion charge experiment makes it possible to implement this model, or a slightly modified version of it, in order to throw some light on this experiment. The modification is the following. There is no a priori reason why the actual charge would be exactly the optimal charge EB. Let us assume it is not, and that it is $E'B'$. Such a charge moves the equilibrium point from A to B', and road usage from X to Y'.

Road usage is defined as the number of four-wheel vehicles km per day in the charged zone at charged hours. Buses are excluded, because their cost function and their contribution to congestion are very different from those of other vehicles. Buses km, however, accounted for only 3.5% of total vehicles km in 2002. In 2002, before the introduction of the charge, road usage thus defined was 1,390 thousand vehicles km per day, according to TfL. In 2003, after the charge (and, assuming all other things equal, because of it) it was 1,160 thousands, a 16.5% decline which is the main achievement of the charge[5]. In other words, we have (in 1,000 vehicles km):

$$X = 1,390$$

$$Y' = 1,160$$

4. Cost curves for London charged zone

The next step is to write the equation of the cost curve $I(q)$, expressed in euros per vehicle km. It consists of a fixed

[5] This decline is slightly larger than the figure generally given (15%) because this figure is calculated on the total number of vehicles km, including buses km.

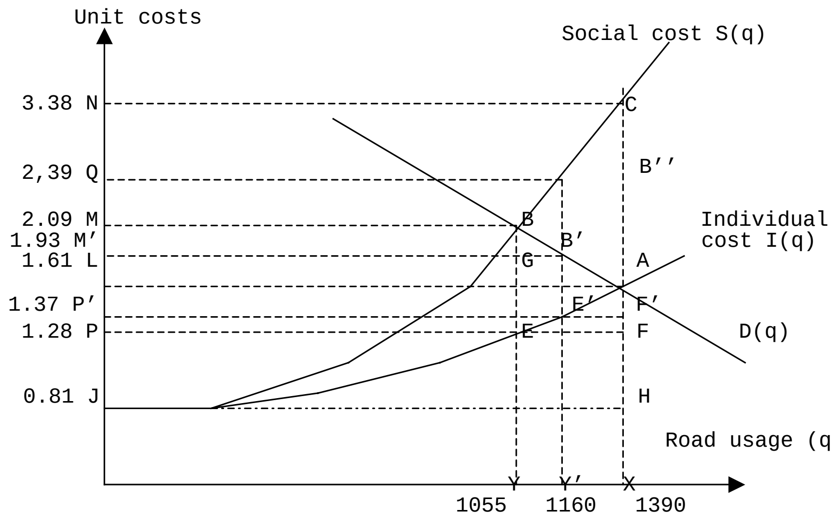

Fig. 2. Road congestion with a congestion charge.

part, representing amortisation and fuel costs, and of a variable part, which is the value of the time spent driving 1 km. The fixed part is estimated (Glaister, 2003) to be 0.15 (euros per km)[6]. The variable part is equal to the time spent (t, in hours), which is a function of speed (s, in km/hour), which is itself a function of road usage (q), multiplied by the value of time (v, in euros per hour):

$$I(q) = 0.15 + tv = 0.15 + [1/s(q)]v \quad (1)$$

To go further, we need an estimate of $s(q)$, the speed as a function of road usage, and of v, the value of time. For the value of time, the ROCOL (2000) report proposes 15.6 euros per hour. This is high number. The values used in the Paris region, particularly to justify transport investments, are significantly below, and they are considered high by many. We will nevertheless keep this 15.6 euros per hour estimate in this paper. Since, there are on average 1.34 persons per vehicle, this puts the value of time per vehicle at 20.9 euros per hour.

Speed s is a declining, and largely linear, function of road usage q:

$$s = \alpha - \beta q \quad (2)$$

α, the speed on empty roads (when road usage $q=0$) is given by TfL as 31.6 km/h. Since we know the average speed in 2002 (when q was equal to 1,390) which was equal to 14.3 km/h, we can calculate β, which turns out to be 0.01245. We therefore have:

$$I(q) = 0.15 + 20.9/(31.6 - 0.0124q) \quad (3)$$

The social cost curve $S(q)$ can easily be deduced from $I(q)$. It is equal to the individual cost curve $I(q)$, plus the derivative $I'(q)$ multiplied by road usage q:

$$S(q) = I(q) + I'(q)q \quad (4)$$

$$S(q) = 0.15 + 20.9/(31.6 - 0.0124q) + 0.26q/(31.6 - 0.0124q)^2 \quad (5)$$

[6] This is an approximation; fuel consumption is also in part influenced by speed, which is also influenced by road usage; but the estimates provided do not vary much (from 0.14 to 0.16); we retained 0.15 for the sake of simplicity.

5. Demand curve for London charged zone

The following step is to determine the equation of the demand curve $D(q)$. We know one point of this curve, the equilibrium point A in 2002, because we know the speed at the time. Its coordinates are 1.61 (euros per vehicle km and 1,390 (thousand vehicles km per day). We can also figure out the coordinates of point B', the equilibrium point in 2003 after the charge, for which we already know the number of thousands vehicles km per day, $Y'=1{,}160$. The individual unit cost for this point is equal to the fixed cost plus the time cost plus the charge paid.

The first two elements are given by equation $I(q)$. With $q=1{,}160$ we have $I(q)=1.37$ euro. This is a measure of $E'Y'$ or P' in Fig. 2. The average charge paid per vehicle km driven can be determined by dividing the total charge collected by the number of vehicles km. The amount of the yearly charge is 115 million pounds, or 165.6 euros. Since there are about 255 chargeable days per year, this is 451,000 pounds or 649,000 euros per chargeable day—and 0.56 euro per vehicle km. The unit cost borne by users is therefore increased to 1.93. This, by the way, indicates a −0.83 price elasticity of demand for road usage in the chargeable zone.

A and B' are both on the demand curve $D(q)$. With the coordinates of A and B', it is easy to calculate the equation of the demand curve:

$$D(q) = 3.54 - 0.00139q \quad (6)$$

6. Significant magnitudes for London charged zone

Equipped with these equations, we can determine the coordinates of all the points represented in Fig. 2, and produce the numbers in Table 1.

The optimal situation ($q = Y$) is obtained, as mentioned before, when the demand curve and the social cost curve intersect, that is when $S(q) = D(q)$.

Congestion costs are defined as BCA in the case of the pre-charge situation, and as BB″B′ in case of the present situation. By definition, congestion costs are zero in the case of the optimal situation. In principle, these costs are defined as the difference between the integrals of the social cost curve and the demand curve over the YX (or $Y'X$) values of q. In practice, the difference between the BCXY and BAXY (or between BB″$Y'Y$ and BB′$Y'Y$) quadrangles is an acceptable approximation, although it certainly overestimates the true value of congestion costs.

Alternatively, congestion costs can be defined as the difference between the consumer's surplus plus the government's gain after and the consumer's surplus before the introduction of an optimal charge. In practice, there is a slight difference (20 thousands euros per day) that may reflect the overestimate just mentioned.

A third approach to congestion costs is to look at the changes introduced by a move from the pre-charge situation (A) to the optimal situation (B). They are equal to the difference between the benefits of the move to the X remaining road users, LGEP, and the losses it inflicts upon the Y–X excluded road users, BAG. This approach produces numbers approximately similar to the numbers produced by the other two approaches.

The benefits of the charge policy are the reduction in congestion costs, relative to the optimal situation, the reference situation.

Table 1
Motor vehicle transport in the london congestion charge zone

	Pre-charge situation	Present situation	Optimal situation
Road usage q (1000 veh km)	1390	1160	1055
Speed s (km/h)	14.3	16.3	18.5
Time for 1 km (min)	4.2	3.6	3.2
Individual cost I (euro/veh km)	1.61	1.36	1.28
Social cost S (idem)	3.38	2.39	2.09
Charge (idem)	–	0.56	0.81
Marginal congestion cost (idem)	1.77	0.46	–
Congestion costs (1000 euros/day)	296	24	–
Benefits[a] (idem)	–	272	296
Charge proceeds (idem)	–	650	854
Collection costs (idem)	–	689	689
Benefits net of costs	–	−417	−393

Source: See Annex A.

[a] Benefits for bus users, for increased reliability, and environmental improvements are not included.

Collection costs can be estimated with TfL data (www.tfl.gov.uk). Operating costs in 2003–2004 were 138.8 million euros. They consist mostly of the payment made to Capital, the private entity to which the operation of the scheme was contracted out. Such payments obviously include the depreciation and the opportunity cost of capital of the investments made by Capital. But in addition, the UK government made investments in the pre-charge period. Investment costs over the 2000–2003 period are reported to be 245.7 million euros. Assuming a 5% opportunity cost of capital[7] and a (rather conservative) 10% depreciation rate, these investment costs amounts to 36.9 M. euros per year. Total collection costs in 2003 were therefore about 175.7 M. euros per year, or 689 thousand euros per chargeable day.

7. Questions about the London congestion charge scheme

Table 1, which is the heart of our work, allows a number of interesting conclusions.

How important are (were) congestion costs?—First, Table 1 tells us how important congestion costs (as defined here) in the charged zone were before the introduction of the charge, or, in other words, what was at stake. Congestion costs amounted in 2002 to about 296 thousand euros per chargeable day[8]. This is about 75 M. euros per year (excluding congestion on week-ends and other days excluded from the congestion charge). This is what a congestion charge is expected to eliminate, and this elimination is the main raison d'être and the main benefit of such a system. How important is it?

It is a very small part of the GDP of London, and even of the GDP generated in the chargeable zone. In 2001, the GDP of Greater London, or more precisely generated in the Greater London area, was 255,000 million euros. Congestion costs in the chargeable zone represented a mere 0.03% of the economic output of Greater London.

There were in 2001, about 4.5 M. workers in the Greater London area, and 1.2 M. workers in the chargeable zone. Assuming that labour productivity was the same in the chargeable zone and in the Greater London area—a very conservative estimate, because this productivity is likely to substantially higher—we can estimate the output of the chargeable zone at 68,000 M. euros per year. Congestion costs in this area represented about 0.11% of the GDP of the area. This is very much in line with the findings of Prud'homme (1999, 2000) for the Paris area.

[7] The UK Government's test discount rate is reported to be 3.5%; using this low value (can the UK Government really finance all public investments with an internal rate of return higher than 3.5%?) would decrease our estimate of collection costs by 3.7 M. euros.

[8] This is 4.3 times less than the number produced by the naive and frequently used method of comparing the effective cost (1.61) with the zero road usage cost (0.81) and multiplying by the effective road usage (1390).

Congestion costs can also be related to the utility derived from motor vehicle usage. This utility is equal to what users pay, plus the consumer surplus they obtain, that is to area RAXO in Fig. 1. In 2002, this can be estimated to 3,579 thousands euros per day, to be compared with the 296 thousands euros per day of congestion costs. This is a ratio of about 8%. Thus, in 2002, traffic congestion costs represented about 8% of the utility generated by traffic.

Is the present charge optimal?—Second, Table 1 tells us whether the present level of the congestion charge (5£ per day) is optimal or not. On the one hand, it can be said that the charge level is too low. The optimal road usage would be require a move from Y' to Y, that is a further 9% reduction in traffic. This would be obtained with an increase in the charge level of 0.56 to 0.81 euro/vehicle km, a 45% increase. Because of a rough proportionality between the charge per day and the charge per vehicle km, this means that the charge should be increased from 5 to 7.2£ per day.

On the other hand, it must be observed that the economic benefits associated with such an increase would be very small. This increase would reduce congestion costs, but would reduce them by only 24 thousand euros per day. The present charge already captures nearly 90% of the potential benefits of a charge. Increasing the charge by 45% to increase benefits by 10% would meet with some resistance.

This finding is also dependent upon the value of time. With the Paris value of time, a different result is obtained. The present charge level appears very close to the optimal level (B' and B become very close).

It can also be observed that a reduction in the relatively high level of fraud, which would result in an increase in the effective charge (as calculated), would also contribute to make the formal 5£ per day charge closer to optimal.

Are charge proceeds greater than economic benefits?—Table 1 makes it possible to compare the charges proceeds, the amount of money that is collected, with the economic benefits of the system. It appears that presently, the ratio is 2.4. With an optimal charge, it would be 2.9. In other words, what users pay in charges is two or three times larger than what they get in congestion reduction. Similar or even higher ratios are common in congestion charge schemes. This does not worry economists. They note that charges, unlike congestion, are not economic costs. Charges are transfers, and the product of the charge can be put to useful, welfare producing, uses. This (correct) view is not always easily accepted by the general public.

Is the congestion scheme economically justifiable?—The standard economic theory of congestion ignores management and collection costs, and assumes them to be zero. In Table 1, it looks only at the line 'benefits', sees a positive number, and concludes that the scheme is justified. In reality, operating a system like the one that has been introduced in London is costly. It involves the use of economic resources, and the expenditures made to that effect are indeed economic costs. We considered the investments, which have been made for the system, to determine an investment component of the yearly cost (equal to 5% for the opportunity cost of capital, plus 10% for the depreciation), and added it to the operation component. The result is very high indeed. It is presently roughly equivalent to the charge proceeds. It would be lower than the charges proceeds with a higher, optimal, charge. In any case, it is much higher than the economic benefits of the scheme. The benefits net of costs of the scheme appear to be negative.

8. Other costs and benefits

Several other associated issues can be discussed.

Environmental benefits—Less vehicles km at a lower speed means less pollutants produced, and lower pollution costs. Curiously, this benefit seems not to be appraised by TfL, probably because no improvement in air quality has been recorded in 2003. This is because vehicles km driven in the charged zone represent a small fraction (about 1%) of total vehicles km driven in the London agglomeration. Air quality in London depends upon total emissions, so that even if driving was completely eliminated in the charged zone, total emissions would only decrease by about 1%, and the improvement in air quality would hardly be noticeable. The benefits can nevertheless be estimated—and valued.

Vehicles km decreased by 230 thousands (1,390 − 1,160) per day. Taking the official French value of pollution costs in dense urban areas of 29 euros per 1,000 vehicle km (Boiteux, 2001), this translates into 6,670 euros per day or 1.7 M. euros per year.

The remaining vehicles are driven at an increased speed. The elasticity of pollution to speed is a least equal to −2 at urban speeds[9]. A 17% increase in speed means a 34% decrease in pollution emissions. This translates into an additional benefit of 11,440 euros per day or 2.8 M. euros per year.

A similar calculation can be made for the reduction in CO_2 emissions. Taking again the official French value of 7 euros per 1,000 vehicles km, the benefit associated with a reduction in traffic of 230 thousands vehicle km can be estimated at 0.4 M. euros per year.

Total environmental benefits generated by the congestion charge (ignoring additional emissions by additional buses) can be estimated at 4.9 M. euros per year. This is not negligible, but it does not substantially change the economics of the scheme.

Benefits to former bus users–The speed of buses is reported to have increased by 7%. This is a benefit for the people who were travelling by bus, and it is a benefit caused by the congestion charge. Bus users, numbering 356,000,

[9] This rough estimate is based on unpublished data communicated by UTAC, an independent organization that measures emissions of pollutants by new vehicles.

gained 1.34 min per person per day, which represent 124 thousand euros per day, or 31 M. euros per year. This is almost equivalent to half the benefit enjoyed by car users.

Benefits associated with charge-financed expenditures. It is often claimed that ear-marking of the proceeds of the charge can produce benefits that should be taken into account. If this income is invested in public transport, or in road extension, it is argued, this will produce social and economic benefits, which should be added to the main benefits of the scheme. This is not correct. Such expenditures will indeed produce social benefits (it is extremely difficult to spend public money without producing benefits) but these benefits should not be added to the benefits of the scheme. They are nothing but the counterpart of the social cost of the charge payment. Either we ignore both this social cost and this social benefit (this is what economists suggest when they say that the charge is a 'transfer'), or we value both of them. But counting the benefit and ignoring the cost (or vice-versa) is not a reasonable option. Ear-marking (or hypothecation, as it is called nowadays) does not add anything at all. Spending the charge proceeds on transport expenditures might create utility, but spending it on health or education would also be useful, and presumably equally useful.

Ear-marking may be politically very expedient because it makes it easier to sell a congestion charge. But by itself, it does not produce additional economic benefits.

A qualification may be added. Most taxes are distortive. They embody incentives that tend to discourage work or savings or investment, and to decrease output. This is why taxes with expenditures are, in general, not merely transfers, but imply a welfare loss, also called the opportunity cost of public funds. The magnitude of this welfare loss varies with the nature of the tax and the economy considered, and is not well known. It could be in the 10–30% range. A congestion tax, by contrast, is not distortive. More precisely, it distorts behaviours in a desired direction. If a congestion tax replaces an ordinary tax, the distortive effect of the ordinary tax will be saved, and the welfare loss decreased. In this case, it would be justified to consider 10–30% of the congestion tax proceeds as a benefit of the tax. Note that this would apply to non ear-marked taxes as well as to ear-marked taxes. As a matter of fact, it would apply more convincingly to non ear-marked taxes, because ear-marking suggests addition rather than substitution.

In the case of the London congestion charge, this discussion is largely rhetorical. It obviously applies to tax proceeds net of collection costs and we have seen that collection costs are nearly equal to charge proceeds.

Increase in bus supply–The congestion charge has been introduced jointly with another measure: a significant increase in bus supply. It is reported that some 250 new buses were purchased and are operated. Bus ridership in the zone increased. The two policy measures were obviously complementary. Without new buses, bus crowding would have increased, and the quality of bus trips declined for all bus users—a typical congestion phenomenon.

If bus transportation were an ordinary, market-driven, good, this would not cause any additional cost or benefit. More bus transportation would be supplied as a result of an increase in the demand for bus transportation. But bus transportation is not an ordinary good. In London, as in most other cities of the developed world, it is heavily subsidised, and users pay about half the economic cost of it. This implies a welfare loss—which is much lower than the amount of subsidy.

Bus transportation costs are independent of bus transportation quantity: marginal costs are equal to average cost in this industry. The additional bus supply and demand can therefore be treated as the initial bus supply and demand. This makes it possible to provide a gross estimate of the welfare cost associated with the recorded increase in supply and patronage.

Let us consider the demand for bus transportation AB, the unit cost CC′, and the price paid PP′. *C* is much higher than *P*, and PC is the unit amount of the subsidy (Fig. 3).

In the absence of subsidy, the equilibrium would be in *A*, with Qa unit of bus transportation consumed, at a price *C*. With a unit subsidy equal to PC, the price paid by users is *P*, and the quantity consumed becomes Qb. The total cost of providing the service is CEQbO. The total amount of the subsidy is CEBP. The additional welfare gain generated by the subsidy, and the increase in demand, is the increase in consumer surplus: CABP. The additional economic cost generated by the subsidy is AEQbQa. The variation in welfare ΔW generated by the subsidy is, therefore:

$$\Delta W = \text{CABP} - \text{AEQbQa}$$

This can be simplified with a few not unreasonable hypotheses. Let us assume that the demand elasticity is -1, and that the subsidy equals 50% of costs. It is easy to see that in such a case, CADP = DBQbQa, and that:

$$\Delta W = \text{AEB} = 1/8\text{CEQbO}$$

In other words, the welfare change, which is negative, is equal to one-eighth of the total cost of bus transportation.

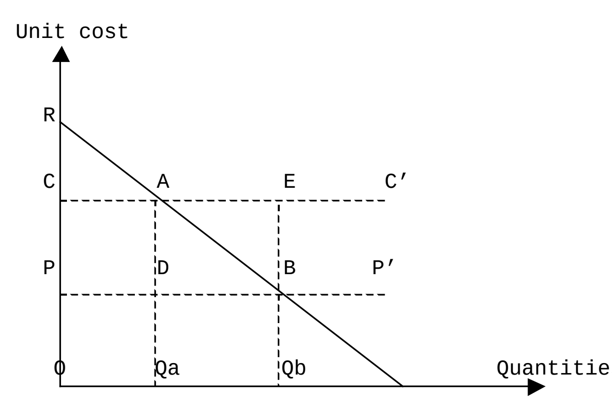

Fig. 3. Bus transportation with a subsidy.

It is reported that some 250 additional buses, purchased at a cost of 100 M. euros and operated at a yearly cost of 38 M. euros, have been introduced to accommodate the increased demand in bus transportation. Assuming an opportunity cost of capital of 5% and an amortisation rate of 10%, the yearly economic cost is 53 (15+38) M. euros.

The welfare loss associated with an increase in subsidised bus transportation can therefore be estimated at about 7 M. euros per year.Value of time–As mentioned earlier estimates of congestion costs are obtained with an official value of time of 15.6 euros per hour. In France, the official value of time for the Paris region, as indicated in Boiteux (2001), is only 8.8 euros per hour. If Paris values of time were used in London, many of the numbers estimated in this paper would be substantially changed.

Congestion costs (which are proportional to the value of time) would be decreased by 45%. Yearly congestion costs would be valued at 36 million euros per year. The benefits of congestion reduction would be reduced similarly. So would the benefits to (former) bus users. The present level of the congestion charge (5£) would probably appear too high. Since the costs would not be altered by this change, the estimated gap between costs and benefits would greatly increase.

Selecting an appropriate value of time is a delicate task. The difference between London and Paris is a priori hard to justify—although we cannot exclude the possibility that the value of time be grossly underestimated in France. It has been argued that the value selected in London is particularly high because the share of business trips (with a high value of time attached) is particularly high in the car trips made in the charge zone. This is a meaningful argument. It would probably imply the selection of a lower value of time to estimate the benefits for bus users. And it would suggest that benefits of a congestion charge would be even lower in less business-oriented areas, and/or in less developed countries or cities.

9. Conclusions

This quantitative—and tentative—exercise has produced some preliminary findings. First, the supposedly high and unbearable congestion costs that motivated the introduction of a congestion charge were in reality relatively modest: about 0.1% of the GDP produced in the charged zone. Second—as predicted by theory—these congestion costs have been largely eliminated by the congestion charge, and this elimination represents an economic gain. Third, the proceeds of the charge are about two-and-a-half times larger than this economic gain.

Table 2
Benefits and costs of the london congestion charge

	Per day (1,000 e)	Per year (million e)
Benefits		
Reduction in congestion costs	272	68
Increased speed for bus users	124	31
Environmental benefits	20	5
Total, recorded benefits	414	104
Costs		
Implementation costs		172
Subsidy to buses	18	5
Total, recorded costs	707	177

Fourth, and this might be the most important finding of this study, the economic costs associated with the system are larger than the economic gains it generates. Table 2 summarises these costs and benefits.

The gap between the two appears substantial. The economic benefits represent less than 60% of the economic costs.

These findings are preliminary. They are based on published Transport for London data on speed and road usage before and one year after the scheme. They use a generous value of time. They assume that recorded changes were caused by the scheme. They are focused on the charged zone only, and ignore what might have happened outside the zone as a result of the charge system. We do not even know whether congestion in the rest of London decreased (because of complementarity) or increased (because of substitution). It could be that congestion decreased because the number of trips to the charged zone decreased, but it could also have increased because some drivers are now going around the zone in order to avoid paying the charge. Our findings also ignore a likely gain in transportation reliability experienced by both car and bus users, which is hard to measure and harder to value. The very high operation and collection costs, which are the main flaw of the charge, may well decrease substantially in the future. Finally, it does not take into account changes in business or residential location that could be induced by the congestion charge over the course of time.

Additional studies are required to get a better understanding of the economic consequences of this important policy experiment. However, the gap between costs and benefits appears so large at this stage that it is difficult to see how additional information could eliminate it, and turn it into a substantial net gain[10].

Appendix A: Calculations for Table 1

Eqs. (3), (5) and (6) are the equations of the the curves $I(q)$, $S(q)$ and $D(q)$ of Fig. 2. They are given in the text. They make it possible to calculate the coordinates of all the points

[10] Londoners who might not like this critical appraisal by Parisians will perhaps be relieved to know that we are much more critical of the policy conducted in Paris. It has consisted in reducing driving space, in order to increase congestion, in the hope of inducing car drivers to shift to buses. Congestion has indeed increased, but bus patronage has actually declined. This, however, is another story.

and areas in Fig. 2, i.e. of the magnitudes of interest reported in Table 1.

Eq. (6), $D(q)=3.5-0.0013q$, yields the coordinates of A(1390; 1.61), of B(1055; 2.09) and of B'(1160; 1.93), as indicated in the texte. This implies $L=1.61$, $M=2.09$ and $M'=1.93$.

Eq. (3), $I(q)=0.15+20.9/(31.6-0.1245q)$, yields the coordinates of E(1055; 1.28) and E'(1160; 1.37), which implies $P=1.28$ and $P'=1.37$.

Eq. (5), $S(q)=0.15+20.9/(31.6-0.0124q)\ +0.26q/(31.6-0.0124q)^2$, yields the coordinates of C(1390; 3.38) and B''(1160; 2.39), which implies $N=3.38$ and $Q=2.39$.

We, therefore, have as reported in Table 1, the individual cost I for the pre-charge situation ($L=1.61$), the present situation ($P'=1.37$ and the optimal situation ($P=1.28$). We also have the social cost S for the pre-charge situation ($N=3.38$), the present situation ($Q=2.39$), and the optimal situation (2.09).

The present charge $E'B'$ has been calculated directly to 0.56 (we can verify that is equal to $M'-P'=1.93-1.37$). The optimal charge would be EB = 2.09 − 1.28 = 0.81.

The marginal congestion cost in the pre-charge situation is AC = 3.38 − 1.61 = 1.77, and in the present situation $B'B''=2.39-1.93=0.46$.

The congestion cost CC in the pre-charge situation is defined as the integral of $S(q)$ between Y and X minus the integral of $D(q)$ between the same values of q. This can be approximated as CC = BCA = YBCX − YBAX. YBCX = 0.5(YB + XC)YX = 0.5(2.09 − 3.38)(1390 − 1055) = 916. YBAX = 0.5(YB + XA)YX = 0.5(2.09 + 1.61)(1390 − 1055) = 920. We, therefore, have CC = 916 − 620 = 296. The congestion cost in the present situation is BB$''B'$ and can similarly be calculated to be 24. By definition, congestion costs in the optimal situation are zero.

Two other approaches to the calculation of congestion costs can be utilised. The first one compares the consumer' surplus (including the charge paid) in the optimal situation (PRBE) with the consumer's surplus in the pre-charge situation (LRA): CC = PRBE − LRA. Noting that MBR − LRA = − LMBA, CC becomes: CC = PMBE − LMBA = (2.09 − 1.28)1055 − 0.5(1055 + 1390)(2.09 − 1.61) = 268.

The second approach to congestion benefits (again defined as the benefits of moving to the optimal situation) compares the time gain of the Y road users in the optimal situation (PLGE) with the loss to the $X-Y$ users excluded by the charge (GBA): CC = PLGE − GBA. PLG = $(L-P)Y$ = (1.61 − 1.28)1055 = 348. GBA = GB × GA × 0.5 = 0.5(2.09 − 1.61)(1390 − 1055) = 80. Hence CC = 348 − 80 = 268.

These two complementary approaches give identical results. These results are somewhat lower (by 28, or 9%) than the result obtained by the first method. This is because the straight line BC is an approximation of the curve BC that should in principle be considered to estimate BCA. We nevertheless retained the higher figure, 296 rather than 268, to be on the safe side.

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