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The London Congestion Charge

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By the 1990s, the average speed of trips across London was below that at the beginning of the twentieth century—before the car was introduced (Newbery, 1990, p. 35). Traffic speeds in central London had fallen more than 20 percent since the 1960s, from an average 12.7 mph for the morning peak period in 1968 (and a high of 14.2 mph in 1975) to 10 mph in 1998. Even in the larger area of inner London, drivers in 1998 spent almost 30 percent of their time stationary during peak periods and more than half their time traveling at speeds of less than 10 mph (Department of the Environment, Transport and the Regions, 1998). By 2002, the all-day average travel speed in central London was just 8.6 mph (14.3 km/hour), compared to an uncongested (night-time or "free flow") average speed of around 20 mph (32 km/hour). Congestion, measured in terms of minutes of delay per mile compared to uncongested conditions, averaged 3.7 minutes/mile (2.3 min/km) (Transport for London, 2003a, p. 11). With more than one million people entering central London between 7:00 and 10:00 a.m. on an average workday, and more than one-quarter of those by road, the cost of congestion was clearly considerable.

Public concern over levels of traffic congestion was high. An independent survey in 1999 identified public transport and congestion as the two most "important problems requiring action"—selected by 46 and 33 percent of London residents, respectively, compared to 20 percent for crime or law and order. Ninety percent of London residents said "there is too much traffic in London" (ROCOL, 2000, chap. 2, p. 5).

Proposals for congestion charging in London have been made since the early 1960s. New car registrations in the United Kingdom doubled from 500,000 in 1958

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to over one million in 1963, and concerns over congestion led the Ministry of Transport to commission what became known as the Smeed Report in 1964 (Ministry of Transport, 1964). The report concluded that existing vehicle taxes had little impact on congestion and recommended the introduction of direct road user charges that would take into account the very different congestion costs of different journeys. At about this time, Vickrey (1959, 1963) and Walters (1961) formalized Pigou's (1912, 1920) ideas on the application of marginal social cost pricing to the case of congested roads.

However, urban congestion pricing schemes were generally thought to be unworkable (for example, Ministry of Transport, 1967, *Better Towns with Less Traffic*). In theoretical terms, the difficulty was that while identifying optimal congestion charges for a single road or bridge is relatively straightforward, calculating optimal charges for a network of roads is hard. Congestion at intersections is a critical feature of network congestion, and optimal charges therefore vary by road and by intersection as well as by the time of day (Newbery, 2005; Santos and Newbery, 2001; Newbery, 1990). Moreover, simulation exercises show that the benefits of congestion charging schemes depend critically on the location of the cordon that defines the charging area, but the theory of optimal cordon design has proved largely intractable (Santos and Newbery, 2001; Verhoef, 2002; Shepherd and Sumalee, 2004; Sumalee, 2004). In practical terms, the cost of collecting tolls in an urban area was expected to be high. Moreover, the complicated nature of any system of variable charges, by time of day and even perhaps by road, would make enforcement difficult and undermine the desired effects on driver behavior. The perceived difficulties of determining the appropriate cordon and level of charge, along with the feared costs of enforcement and compliance meant that, for many years, the idea of congestion charging had little practical appeal.

But in early 2003, London imposed a daily charge for driving or parking a vehicle on public roads within central London between the hours of 7:00 a.m. and 6:30 p.m. on workdays. Traffic congestion has declined substantially, and the program is largely popular. This article describes the origins of the London congestion charge, how it overcame practical and theoretical difficulties, and what effects it has had. The introduction of the London congestion charge is, in important respects, a triumph of economics. It represents a high-profile public and political recognition of congestion as a distorting externality and of road pricing as an appropriate policy response.

The Birth of the Congestion Charge

Concerns about London's traffic congestion in the 1990s led the national Department of Transport to create the London Congestion Charging Research Program. Its 1995 report (MVA Consultancy, 1995) concluded that a congestion charge would reduce congestion, offer rapid payback of the initial setup costs, and generate net revenues as well as broader net economic benefits. The report

proposed a £4.00 toll (one British pound currently equals approximately $1.85 in U.S. dollars) on vehicles entering a central London area that is effectively identical to the charging zone ultimately chosen.

This proposal led to a working group for a Review of Charging Options for London (ROCOL), which issued a 2000 report, *Road Charging Options for London.* The 1995 report had suggested a charge for each trip entering the zone (equivalent to a "fare"). In contrast, the ROCOL report focused on an "area license" that would allow the payee to travel into, around, and out of the charging zone as frequently as desired. The report concluded that, to have a noticeable impact on congestion in London and to produce significant revenues, the initial focus of any scheme should be central London, rather than the larger "inner London" area. A paper license scheme was rejected on the grounds that effective enforcement would be prohibitively expensive. The report recommended two alternatives: an area licensing scheme for central London based on video camera enforcement and a workplace parking levy.

The final impetus to the London congestion charge came with the election of Ken Livingstone as the first Mayor of London in May 2000, following a decision by the new Labour government to grant limited autonomy to new municipal governments. Livingstone is a high-profile London political figure who, as leader of the Greater London Council until its abolition in 1986, was the focal point of London protests against the policies of Margaret Thatcher. After narrowly losing the Labour nomination, Livingstone had run for Mayor as an independent, with overwhelming popular support. Prominent in his platform was a commitment to introduce congestion charging.

After an 18-month period of extensive public consultation—which some observers have argued was a critical factor in making the scheme publicly acceptable—Livingstone decided to propose an area licensing scheme applied to central London. Livingstone's decision to choose area licenses, rather than parking levies, was supported by evidence that it would be more effective in reducing congestion and was consistent with his campaign promise to introduce congestion charging.

How the Congestion Charge Works

The London experience demonstrates how introducing real-world congestion charges requires not only careful modeling and analysis of traffic patterns and commuting behavior, but also a thorough assessment of compliance and enforcement issues, which present a range of practical, political, and technological challenges.

Amount of the Charge

On February 17, 2003, London imposed a £5.00 daily charge (increased to £8.00 in July 2005) for driving or parking a vehicle on public roads within the congestion charging zone between the hours of 7:00 a.m. and 6:30 p.m., Monday

to Friday, excluding public holidays. Economic analysis played a decisive role in determining the appropriate level of congestion charge. For the reasons noted above, it was neither feasible nor appropriate to use a measure of the marginal cost of congestion as the basis for the charge.[1] Mayor Livingstone relied, instead, on the extensive modeling of household behavior and the resulting traffic patterns undertaken by the London Congestion Charging Research Program and, especially, the ROCOL report (2000). The predicted impact on congestion was then used, in the ROCOL report, to estimate the net economic benefits of alternative levels of charge. Both the predicted impact of the scheme and the costs and benefits are discussed further in a separate section below.

In adopting the initial £5.00 congestion charge, the Mayor was endorsing the recommendations of the ROCOL report. The report evaluated the impact of setting the charge at £2.50, £5.00, and £10.00 under various scenarios. Assessing the scenario in which the congestion charge was assumed to be accompanied by "associated transport measures" (principally, a £100 million package to improve bus transport), the estimates presented in the report indicated that while the impact on traffic levels and net revenues increased proportionally with the level of the charge, estimated net benefits did not. Although there was considerable uncertainty regarding the level of net benefits, the point estimates suggested that a £5.00 charge might yield net benefits almost 40 percent higher than a charge of £2.50, with little additional benefit from a £10.00 charge (ROCOL, 2000, pp. 89–90). These considerations in favor of a £5.00 charge were undoubtedly reinforced by political concerns regarding the public reaction should the charge be set as high as £10.00.

In making the case for the recent increase in the charge from £5.00 to £8.00, Mayor Livingstone continued to stress economic considerations. An increase to £8.00 would, he argued, result in a significant further reduction in congestion (from a reduction of 30 percent with the current £5.00 charge to an estimated reduction of 34–38 percent); an increase in net revenues (from £80 million/year to £115–125 million); and a rise in net benefits (from £50 million/year to an estimated £70–100 million). Moreover, since, by agreement with central government, all congestion charge revenues would remain earmarked for public transport for a further ten years, the net revenues could be expected to increase the impact still further. He argued against a smaller, incremental increase in the charge (say, to £6.00) on the grounds that it might have little impact for behavioral reasons, because "the difference is sufficiently small for people to carry on and say, 'I will pay it.' " He also rejected a more substantial increase to £10.00 on the grounds that the additional benefits were too small (net benefits would only rise to an estimated £75–110 million) to justify the additional burden on charge payers and the resistance to the change that might arise (London Assembly, 2005).

[1] It is nevertheless interesting that a recent attempt to estimate the marginal cost of congestion in London (ignoring the network complications discussed earlier) concluded that the £5.00 charge would correspond to the optimal congestion charge if, on average, charge payers undertake journeys of about two miles, or just over half the width of the charging zone (Santos and Shaffer, 2004).

A much discussed feature of the London scheme is the flat-rate nature of the charge. One of the historical objections to congestion charging in London and elsewhere has been the infeasibility of implementing a system with the degree of time variation in the charge that was assumed necessary for such a scheme to be effective.

The decision to opt for a single rate charge is supported by London travel speed statistics, published by the Department of Transport. Although off-peak daytime travel speeds in *outer* London are, as one might expect, markedly higher than those during the morning and afternoon peaks (Transport for London, 2003b, p. 63), the same is not true in *central* London. Over the period 1968 to 1998, off-peak daytime travel speeds in central London averaged 11.6 mph, compared to 11.9 mph in the morning peak and 11.6 mph in the evening peak period. Average speeds may even have converged over time; the off-peak daytime travel speed recorded in the 1998 survey was 10.0 mph, compared to 10.0 mph and 10.2 mph in the morning and evening peak periods, respectively (Department of the Environment, Transport and the Regions, 1998). A similar flat pattern was evident in central London traffic levels, as measured in vehicle-miles driven within the charging zone in 2002 (Transport for London, 2003b, p. 77). If congestion is similar throughout the day, then a flat charge throughout the day makes sense.

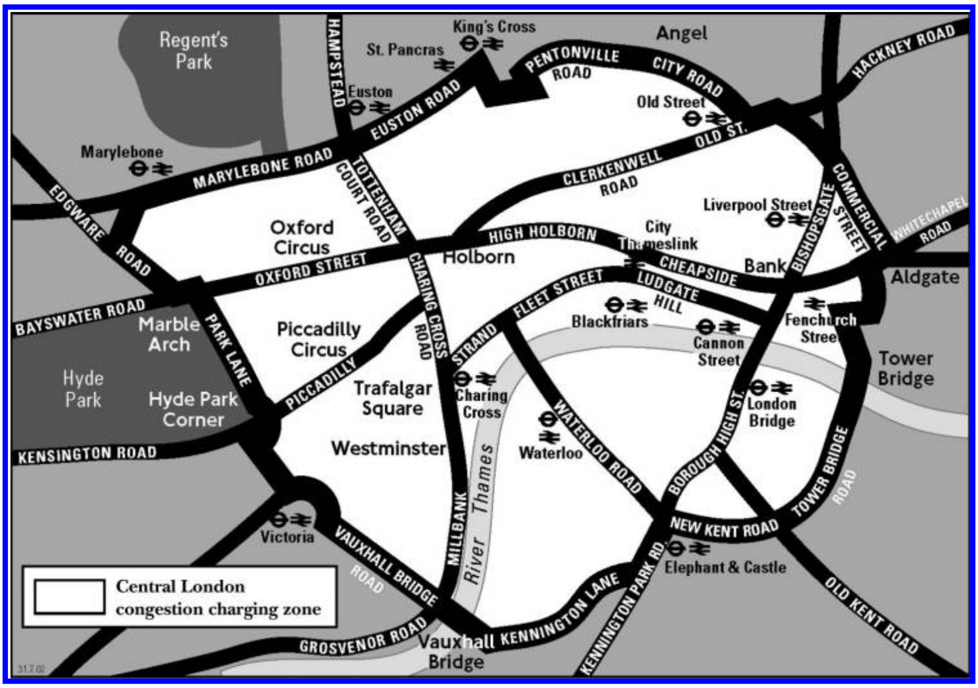
The Geography of the Charging Zone

The congestion charge is an area license, or "day pass," that allows unlimited travel into and around the charging zone. The congestion charging zone, illustrated in Figure 1, covers the area known as "Central London," which includes the financial center (the "City of London") as well as Parliament and the principal government offices, the major tourist sites, and the main centers of business, law, and entertainment (the "West End").[2] Although the zone covers an area of only eight square miles, little more than 1 percent of the total area of Greater London, it includes the main areas of worst congestion. Central London is defined as the area inside the Inner Ring Road, which is made up of the roads shown on the map. Since around one-quarter of the central London traffic was, before the charge was introduced, simply passing through, an important consideration in the choice of the Inner Ring Road as the boundary of the zone was its usefulness as a peripheral route to accommodate through traffic diverted by the charge. The charge is payable only by vehicles traveling inside the zone and not those on the ring road.

The standard charge applies to private cars and commercial vehicles entering the zone during the charging hours. As mentioned earlier, individuals who live within the zone are entitled to a 90 percent discount on the charge, and do not have to pay the charge if their car remains parked off-street or in a residents' parking bay throughout the charging period. Some vehicles are exempt from the charge, including motorcycles and bicycles; buses and taxis registered in London;

[2] In September 2005, the Mayor announced that the charging zone would be extended westward in early 2007 to include the boroughs of Kensington and Chelsea.

Figure 1
The Congestion Charging Zone



Source: Transport for London, 2006.

vehicles used by disabled individuals; alternative fuel vehicles; emergency vehicles; and vehicles used by some medical staff and fire fighters. Rental cars are not exempt from the charge. It is the driver's responsibility to pay the charge on each day of travel within the charging zone.

Logistics of Payment

The charge may be paid in advance, on a daily, weekly, or annual basis, or on the day of travel. To discourage people from paying at the last minute, payments made between 10 p.m. and midnight are subject to a surcharge, bringing the total charge to £10.00 (unchanged after July 2005). There are no tollbooths around the charging zone. Instead, a variety of payment mechanisms are available, including retail outlets, kiosks, by telephone, over the Internet, and by text message using cell phones. While use of the text message and call center payment channels has remained relatively stable since the scheme was introduced (accounting for around 22 and 14 percent of all payments, respectively), the two dominant channels have changed over time. Payment through retail outlets has declined, from more than 35 percent in the first year to less than 30 percent in 2005, dropping below the level of payment by Internet, which has increased from around 25 percent initially. The

total number of charge payments has remained relatively stable at around 110,000 per day (Transport for London, 2005b, p. 142).

Individuals submit their vehicle registration number when paying the congestion charge, and this number is then entered into a database for trips within the charging zone (during the hours of operation) for a particular day or period.

Enforcement

Video cameras at every entry point and in mobile units within the zone capture images of vehicles entering, leaving, or driving within the zone.[3] Automatic number plate recognition technology is then used to identify the vehicle registration number. The current automatic number plate recognition system has a 70–80 percent success rate for a single pass; the average detection rate is estimated to be 85–90 percent, as almost all vehicles in the charging zone pass multiple camera sites. A recent report on detection technologies concluded that while the current level of accuracy would not support an account-based charging system (for which a vehicle would have to be detected in order to be charged), it is sufficient for the enforcement of the current pre-pay system; individuals must pay the charge without knowing whether they have been detected, and even the reduced penalty charge (if paid within 14 days) is more than six times the daily charge (Transport for London, 2005c, pp. 19, 52).

At the end of each day, the numbers captured are compared to the database of paid or exempt vehicle registrations. If a match is made, the images and vehicle details are removed from the database. If no match is made, the numbers are sent to the Driver and Vehicle Licensing Agency (the national agency responsible for issuing all drivers licenses and collecting the annual car tax), which supplies the name and address of the vehicle's registered owner as well as the vehicle make and model. The final step of the process is a manual check of the image to confirm that the registration number captured by the plate recognition system is correct and that the vehicle type corresponds with the information supplied by the Driver and Vehicle Licensing Agency.

The registered owners of vehicles that have not paid the charge as required are then sent penalty notices for £100 (£80 before July 2004). As with parking tickets in London, the penalty is reduced to £50 if paid within two weeks and increases to £150 if not paid after a month.

Problems of compliance and enforcement affected the scheme at the outset. One source of confusion was that both the automatic number plate recognition system and the individual payers of the charge when submitting their number plate details, had trouble distinguishing the digit zero from the letter *O*, and the digit 1 from the letter *I*. In the early weeks of the scheme, Transport for London received appeals or complaints on almost two-thirds of the penalty notices issued, most of which were due to errors in compliance or enforcement.

[3] The potential infringement of civil liberties has not been a major issue, perhaps because of the increasingly widespread use of closed-circuit television in public areas of London for crime prevention.

Transport for London took a series of steps to improve enforcement, including increased staff training and improved information for charge payers—notably, the inclusion of a picture of the vehicle on the penalty notice from July 2004 (Transport for London, 2005b, p. 146). By the first quarter of 2004, enforcement errors were down to 2 percent of appeals and the majority were associated with vehicles that had recently been sold, with the penalty notice sent in error to the previous owner. The number of penalty notices also rose steeply in 2003, from 15,000 per week in the early weeks to over 40,000 per week towards the end of the year. Actions to improve compliance together with the increase in the penalty charge from £80 to £100 in July 2004 were associated with a fall in the number of penalty notices to less than 30,000 per week by February 2005.

Looking to the future, Transport for London has recently undertaken a review of alternative detection technologies. "Tag and beacon" systems based on infrared (or microwave) detection were found to have 99 percent accuracy, but involve substantially higher compliance costs as each car must have a tag or beacon installed, as well as having readers or tollbooths for the beacons at all entrances to the zone. Systems based on the Global Positioning System (GPS), which works by installing beacons in cars that can be identified by satellite, were found to require a buffer zone of 60 to 250 meters in order to achieve 99 percent accuracy, while cell phone systems (based on the Global System for Mobile Communication or GSM) not only require that all drivers have a phone, but need a buffer of 800 to 2,400 meters—clearly inadequate to support congestion charging (Transport for London, 2005c).

Impact of the Congestion Charge

Predictions of the Impact on Traffic Levels and Congestion

Before the congestion charge was implemented, extensive modeling was undertaken to estimate its likely impact on traffic and congestion (ROCOL, 2000). The results of surveys were used to model household demand, by type of household and type of trip, for the area license. These results were fed into a separate model to assess the impact on traffic patterns (p. 67). One of the schemes assessed was a £5.00 charge for central London, which very closely resembled the scheme that was originally adopted. This congestion charging scheme was predicted to reduce car miles in central London by 20–25 percent during the charging period and to reduce total vehicle miles traveled in the zone by 10–15 percent. Most of this reduction was due to a 20 percent expected reduction in car trips, but it was partly accounted for by diversions around the charging area (pp. 69–70).

The reductions in vehicle flows were predicted to increase average traffic speeds in central London from 9.3 to 11.2 mph (15 to 18 km/h) during the morning peak period (and from 9.9 to 11.2 mph on average over the day), the improved speeds being comparable to those prevailing in the early 1980s (ROCOL, 2000, chap. 5, p. 76).

Table 1
Impact of the Congestion Charge on Traffic in the Congestion Charging Zone
(in thousands of vehicle-kilometers and percent)

	2002		*2003*		*Percentage change*
Cars	771	(47%)	507	(35%)	−34%
Vans	287	(18%)	273	(19%)	−5%
Trucks	73	(4%)	68	(5%)	−7%
Taxis	256	(16%)	312	(21%)	22%
Buses	54	(3%)	65	(5%)	21%
Motorcycles	129	(8%)	137	(9%)	6%
Bicycles	69	(4%)	89	(6%)	28%
All vehicles	1,640	(100%)	1,451	(100%)	−12%

Source: Transport for London. Data provided to the author, May 2006.
Notes: The first column for each year shows the number of vehicle-kilometers driven (in thousands), by type of vehicle, within the congestion charging zone. The second column for each year shows the proportion of total vehicles within the congestion charging zone represented by each type of vehicle.

Actual Reductions in Traffic and Congestion

The first impact studies showed that the reductions in traffic and congestion met or exceeded predictions. Moreover, the initial reductions have been sustained in subsequent periods (Transport for London, 2005b, p. 23).

The number of private cars, vans, and trucks coming into central London dropped 27 percent between 2002 (before the charge) and 2003. The 33 percent drop in inbound car traffic represents some 65,000–70,000 trips that are no longer made. Of these, Transport for London estimates on the basis of surveys that just over half have transferred to some form of public transport; about one-quarter now divert around the charging zone; about 10 percent have shifted to other forms of private transport, predominantly taxis and bicycles; and around 10 percent have either stopped traveling or shifted their trips to outside charging hours (Transport for London, 2005b). These data suggest that, as expected, the congestion charge has influenced the decisions of road users on various margins: whether to take a particular trip, which mode of transport to use, and when to travel.

The net result has been a significant change in the composition of London traffic, as measured by vehicle miles driven within the charging zone each day. As shown in Table 1, private cars, which accounted for almost half of central London traffic before the charge was introduced, now represent just over one-third, a fall of 34 percent. The level of commercial traffic (vans and trucks) has fallen slightly, but there has been a sharp rise in taxis (up 22 percent), buses (up 21 percent), and bicycles (up 28 percent).[4]

[4] A degree of caution is appropriate in interpreting these figures. On the one hand, there is evidence of trend decreases in inbound traffic and in central London traffic levels over the past two decades. Historical data suggest that overall traffic levels in central London decreased by between 5 and 15

Evidence on average travel speeds on roads inside the charging zone indicates that the impact of the congestion charge has been considerable. All-day average network travel speeds increased from a precharging average of 8.9 mph (14.3 km/h) to 10.4 mph (16.7 km/h) in May/June 2003, a rise of almost 17 percent (Transport for London, 2003a).

The congestion charge has had an even more significant impact on congestion levels. One way to measure congestion is in terms of the minutes of delay experienced compared to an uncongested (night-time) travel rate. On this measure, congestion has dropped an average 30 percent from the start of the charge in February 2003 to mid-2005, at the top end of expectations (Transport for London, 2005b, p. 14).

The drop in congestion levels, and increase in average speeds, reflects mainly a decrease in queuing time at junctions. Figure 2 shows time spent traveling at different speeds in the charging zone during charging hours. For each speed category, the first six shaded bars show each of the two-month periods from March/April 2002 through January/February 2003. The second six bars show the same two-month periods one year later (March/April 2003 through January/February 2004). While the figure shows small increases in the amount of time spent traveling at higher speeds, between 30 and 40 km/h (19 and 25 mph), the principal change is the drop in the time spent in traffic jams. The time spent traveling at speeds below 10km/h (6 mph) has been reduced by one-third compared to precharging levels (Transport for London, 2004b, p. 17).

Decreased congestion within the zone has also, as expected, contributed to reduced congestion and travel times on routes into the central zone. One source of data comes from what are called "moving car observer" (or "floating car") surveys, in which cars are fitted with instruments to measure the speed and travel times and the drivers are instructed to match average traffic speeds while driving a predefined schedule of routes around the network. This survey data indicates that congestion on the main radial approach roads dropped from a precharging level of 1.5 min/km to 1.2 min/km, a drop of 20 percent (Transport for London, 2004b, p. 16); for comparison, the night-time "uncongested" travel rate is about 1.5 min/km. These findings were corroborated by evidence from surveys of regular drivers between November 2002 and April 2003, which showed that journey times during the morning peak decreased an average of 14 percent following the intro-

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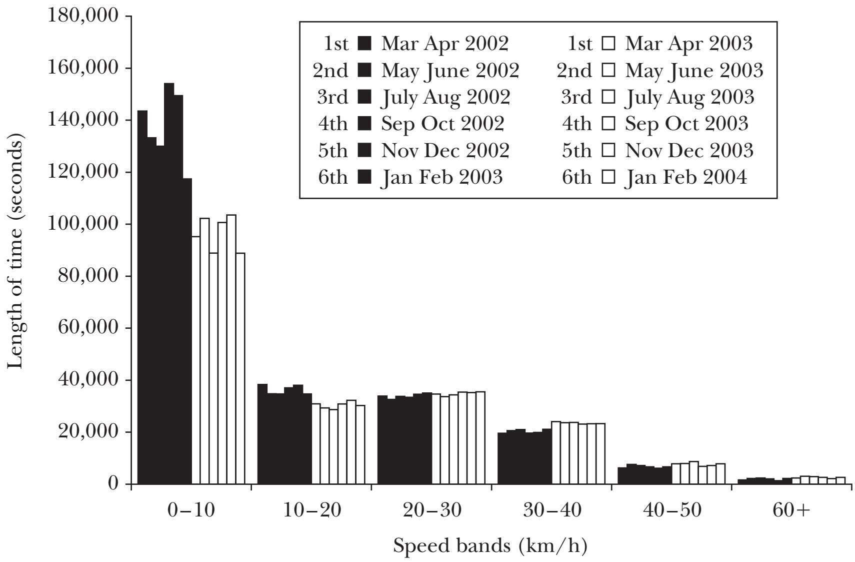
percent between 1986 and 2002, with sharper declines in the years since 1994. An even more pronounced drop is evident in car traffic, which decreased by somewhere between a quarter and a third since 1986, again more sharply since the mid-1990s. On the other hand, the significant drop in inbound and central London traffic between 2001 and 2002 was due, at least in part, to an unusually high level of road works in preparation for the congestion charge, and might have been reversed in 2003 had the charge not been introduced (Transport for London, 2003b). For this reason, comparisons between 2002 and 2003 seem unlikely to overstate the impact of the charge. Note that the first caveat, based on historical data, does not apply to estimates of the impact of the congestion charge on travel speeds and congestion, both of which had steadily worsened over time, as discussed in the introduction and shown in Transport for London (2003a, p. 12).

Figure 2
Impact of the Congestion Charge on Time Spent Traveling at Different Speeds in the Charging Zone during Charging Hours



Source: Transport for London. Data provided to the author, May 2006.

duction of charging. For an average round trip of 80 minutes, this implies a time savings of 10 minutes (Transport for London, 2004b, pp. 19–20).

There were concerns that the diverting impact of the congestion charge could lead to higher levels of congestion on the inner ring road that borders the zone, but is not included in it, as well as in areas just outside the zone. These higher traffic levels did not materialize, at least partly as a result of improved traffic management systems that adjust traffic lights to manage the flow of traffic on and approaching the ring road (Transport for London, 2003b, 2004b). Traffic changes in the bordering areas have been variable, with some experiencing small net increases in traffic (between 2 and 6 percent) in the first year of the scheme and others registering net reductions. In the second year of the scheme, traffic levels fell in almost all areas.

It was expected that reduced congestion in central London as a result of the charge would not only shorten travel times but also increase journey time reliability. This, too, was borne out. Results of the survey of "regular" drivers found that the standard deviation of travel times decreased 27 percent during the morning peak and 34 percent for return journeys (Transport for London, 2004b, pp. 19–20).

As noted earlier, before the congestion charge was levied, the level of congestion in London was remarkably constant throughout the day. This pattern was apparent after the charge was introduced, as well. In particular, there is no reduction in congestion during the midday "interpeak" period, contrary to what one might expect.

Impact on Public Transport

The congestion charge sought to reallocate road space from private cars to public transportation. The ROCOL (2000, chap. 5, p. 70) report predicted that the charge would result in a 3 percent increase in public transport trips into London (mainly more rail trips) and a 4 percent increase in public transport trips within the charging zone (mainly more bus and underground trips). However, projecting changes in public transport use was complicated by the fact that a number of measures aimed at improving bus services were implemented in the lead up to the congestion charge.

The expected increase in rail trips did not materialize following the introduction of the congestion charge, and the number of underground trips fell—although the latter was widely attributed to other factors including the prolonged closure of the Central Line, the downturn in the local economy, the war in Iraq, and the drop off in tourism. By contrast, the rise in the number of individuals entering central London by bus exceeded predictions by almost 50 percent. From autumn 2002 to autumn 2003, bus passengers entering the charging zone in the morning peak period by bus rose by 29,000, an increase of 38 percent. Transport for London (2004b, p. 40–41) estimates that roughly half the increase is due to the improved bus service and half to the congestion charge.

The reason that the rise in bus ridership exceeded expectations appears to lie in a "virtuous circle" for bus transport that can result from congestion charging (Small, 2005, p. 12). The higher price of rush-hour car travel induces some to switch to public transport, increasing revenues to transport providers. At the same time, reduced congestion leads to increased travel speeds for buses which, in turn, further encourage patronage while also reducing average costs per passenger to transport providers. Increased passenger numbers and reduced average costs enable providers to offer some combination of improved service levels (more routes, higher frequencies) and lower fares. Improved services and reduced fares stimulate further shifts from car travel to public transport, resulting in additional reductions in congestion and gains to public transport.

Small (2005) simulates these interactions. The initial 6 percent rise in patronage, as a direct effect of the rise in the cost of car travel resulting from the London congestion charge, is, in his model, magnified to 16 percent as a result of the virtuous circle (p. 14). Small also simulates these effects for a typical American city. Since the share of weekday trips that are made by public transport is much lower than the 85 percent in London (even before the charge), and fares are more heavily subsidized, the shifts to public transport resulting from road pricing are likely to be much larger in the context of U.S. cities, resulting in more dramatic reductions in fares, user costs, and costs to transport providers.

These estimates may underestimate the beneficial feedback effects from congestion charging, since they do not incorporate the effects of increased reliability in bus services. In the first full year after the introduction of charging, excess waiting times for buses (caused by service irregularity or missing buses) dropped 30 percent in the charging zone. Excess waiting times dropped further in the second

year, with an additional reduction of 18 percent in and around the charging zone in the period from March to December 2004, compared to the same period in 2003 (Transport for London, 2005b, p. 50). The resulting reduction in user costs will have further reinforced the virtuous circle.

Impact on Local Business

A congestion charge is likely to have different effects across businesses. A decrease in car trips could have an adverse impact on some retail businesses, while a reduction in congestion and in travel times could benefit others.

A department store chain called John Lewis commissioned a study on how the congestion charge affected the sales of its central London store. Using sales data provided by the store, Bell, Quddus, Schmoecker, and Fonzone (2004) found a statistically significant negative impact of the charge on sales. The authors revisited the question in a broader study published in 2005, and found a continuing negative impact of the charge at the John Lewis store, but no significant effect for total central London retail sales (Quddus, Carmel, and Bell, 2005).

A survey of 500 firms carried out in early 2004 found that 72 percent of businesses felt that the road charging experiment was working (with 14 percent saying it was a failure) and 58 percent felt it improved London's image (with 15 percent saying it gave London a bad image to outsiders). Overall, a plurality of firms felt the impact on London's economy was neutral (32 percent) with equal numbers identifying positive and negative effects (26 percent) (Clark, 2004).

Costs and Revenues

The unexpected success of the congestion charge in reducing traffic had a negative impact on revenues from the charge. At the same time, the set-up and operational costs of the scheme were considerably higher than expected. As a result, net annual revenues have fallen far short of expected levels. The ROCOL (2000) report estimated that the annual operating and enforcement costs of the scheme would be £30–50 million (on top of one-off set-up costs of the same magnitude). The annual revenues from a £5.00 charge were estimated at £230–280 million and the annual revenues from penalty payments at £30–40 million. Thus, net annual revenues were expected to be in the range £230–270 million. Even the revised, more conservative estimates from Transport for London (2002, p. 14–3) put expected net revenues in the range of £130 million to £150 million pounds.

Actual net revenues have been far lower, at an estimated £68 million in 2003–4 and £97 million for 2004–5 (Transport for London, 2003a, p. 30; 2005b, p. 138). A large part of the explanation for the lower-than-expected net revenues is that the congestion charge payments have averaged £115 million/year, or just half the level originally predicted. This shortfall in revenues is primarily due to the scheme's greater-than-expected impact on car traffic—a drop of 30 percent in potentially chargeable vehicles entering the zone compared to the mid-point prediction of 20

percent used to project revenues. Revenues have also been affected by higher-than-expected numbers of exempt or discounted vehicles, the former reflecting, in part, the success of the scheme's incentives for using low-emission vehicles.

Another contributing factor has been the level of noncompliance, which exceeded expectations. As a result of steps taken to improve compliance and enforcement (discussed above), income from penalty notices reached £70 million in 2004–2005 (Transport for London, 2005b, p. 138), twice the level expected in the ROCOL (2000) report, somewhat narrowing the shortfall in scheme revenues.

The shortfall in net revenues from the scheme has also been driven by higher-than-expected costs: implementation costs averaged £95 million in the first two years—more than twice the level expected. The higher costs are, in part, attributable to the increased enforcement expenditures resulting from measures taken to address noncompliance and to raise income from penalty notices. Nevertheless, the high resource costs of running the scheme are an important feature of the London congestion charge.

This revenue shortfall has political implications, since one selling point of the scheme was that the revenues from the congestion charging scheme would be earmarked for spending on public transport in London. Earmarking served various purposes. Mayor Livingston had promised "radical improvements" in bus services, and the revenues from congestion charge revenues were seen as part of achieving that objective. It was hoped that earmarking would reinforce the effect of congestion charging by encouraging further shifts to public transport through service enhancements. The earmarking of revenues to public transport was also intended to ensure that the scheme facilitated access to central London for all households, rather than simply increasing mobility for drivers. Earmarking was seen as important in offsetting the potentially regressive effects of the congestion charge which, as a flat-rate charge, imposes a heavier burden on low-income drivers. Thus, for a variety of reasons, earmarking played a crucial role in securing political support for the congestion charge—as predicted in the congestion pricing literature (for example, Small, 1992, 1993).

As expected, some 80 percent of scheme revenues have been spent on bus network improvements, amounting to approximately £80 million in 2003–2004. A further 11 percent was spent on road safety and the remainder on other initiatives like supporting walking and cycling). The central government announced in 2005 that the earmarking, originally scheduled for the first 10 years, would be extended for a further ten years.

Social Costs and Benefits

Estimating the social benefits and costs of congestion charging in London was a key focus of the London Congestion Charge Research Program and the subsequent ROCOL report. This work continued following the implementation of the scheme and, as noted above, was used by Mayor Livingstone in making the case for the July 2005 increase in the charge from £5.00 to £8.00.

For the purposes of social cost–benefit analysis, the costs of the scheme fall under five headings: the initial set-up costs associated with the installation of the necessary infrastructure and services; the scheme operation costs, which is the largest single cost (and consists primarily in the payments made to Capita, the private company contracted to collect the charge); the supervisory costs incurred by Transport for London, which are associated with management of the scheme and administration of contracts; the traffic management costs directly associated with the scheme (primarily associated with changes to the network of bus services); and charge-payer compliance costs. The charge payments made by drivers are not included, as they represent a transfer rather than a resource cost.

The measurable benefits of the scheme can be grouped in six categories. The first and most important of these is the time savings to drivers and passengers of vehicles that continue to use the road system after charging is introduced—including cars, taxis, buses, and commercial vehicles within and outside the charging zone. All of the London analyses have followed the standard approach of using separate values for time savings in business and nonworking time (including commuting). The inconvenience of those who switch to public transport ("deterred drivers") as a result of the charge enters negatively, valued at half the level of the avoided charge. Improved journey time reliability is another source of benefits, in addition to direct time savings, as are reduced accidents and lower carbon dioxide emissions. The net proceeds from the scheme (charge and penalty payments) are not included since they, like the charge payments, are transfers. However, it is worth noting that, given the UK government requirement that all charge revenues be spent on transport improvements, the charge payments are likely to be generating significant additional benefits in reduced travel times and accidents and in other savings that contribute to popular perceptions of the scheme's impact.

Table 2 shows the most recent detailed estimates of the social benefits and costs, which are drawn from Transport for London (2006, pp. 171–72). The table also includes the author's estimates of the opportunity and depreciation costs associated with investment in the precharge period (2000–2003), which, as Prud'homme and Bocarejo (2005) and Mackie (2005) note, are omitted from the Transport for London estimates. The total estimated annual costs of the congestion charging scheme are £163 million (£140 million if implementation costs are excluded), while the total annual benefits are £230 million.

The cost–benefit estimates produced by Transport for London have been the subject of some controversy. The robustness of their initial estimates (Transport for London, 2003a) was questioned by Prud'homme and Bocarejo (2005), who provide alternative estimates suggesting that the economic benefits represent less than 60 percent of the scheme's resource costs. Mackie (2005) argues, however, that Prud'homme and Bocarejo significantly underestimate the benefits of the scheme, by omitting the benefits to road users in Greater London outside the city center (which may account for as much as two-thirds of total benefits as a result of the large numbers involved); by using an inappropriately low value of time; and by underestimating the benefits to bus users. In addition, as Mackie (2005) notes, the

Table 2
Estimates of the Social Benefits and Costs of the London Congestion Charging Scheme
(in £ millions, 2005 prices and value, for a £5 charge)

Annual costs	
Transport for London administrative costs	5
Scheme operation costs	85
Setup costs (opportunity costs and depreciation)	23
Traffic management costs (primarily increased bus services)	20
Charge-payer compliance costs	30
Total	**163**

Annual benefits	
Time savings and reliability benefits:	
Car users	
business	65
commuting, other	45
Vans, trucks	
business	35
Taxis	
business	30
commuting, other	10
Buses	
business	2
commuting, other	40
Deterred drivers	
business	−5
commuting, other	−20
Reduced accidents	15
Reduced CO_2 emissions	3
Other resource savings	10
Total	**230**

Source: Transport for London (2006, p. 172) and author's calculations.
Note: Author's estimate of the "Setup costs" is based on an estimated cumulative initial investment of £170 million in the precharge period 2000–2003 (Prud'homme and Bocarejo, 2005, p. 283), an estimated depreciation of 10 percent, and a government discount rate of 3.5 percent (HMT Green Book, 2003).

authors' approach of estimating single demand and cost curves for road usage in London fails to take into account the differentiated nature of road usage and the heterogeneous values of time, a factor recognized to be crucial to the benefits of road pricing schemes (for example, Small and Yan, 2001; Verhoef and Small, 2004).

All of the above estimates focus on direct costs and benefits and make no attempt to incorporate second-best considerations, which may be significant. Parry and Bento (2002), for example, show that congestion charges on commuting traffic can stimulate or discourage labor force participation at the margin, depending on how the revenues are used.

While the net benefits of the congestion charge scheme do appear to be clearly

positive, it is evident that the total resource costs of the scheme are a substantial fraction of the benefits. These high costs have raised questions about the operational efficiency of the London scheme; for example, Mackie (2005) asks whether the scheme contains inessential elements that are not cost effective and whether the high costs reflect an element of rent-seeking on the part of the private contractor operating the scheme. The high costs also suggest the need for careful analysis before extrapolating the benefits of the scheme to other cities in the United Kingdom and elsewhere.

Conclusion

Attempts to introduce road pricing in Britain have historically encountered fierce political resistance. The famous Rebecca's Rioters of 1843 were farmers who took to the streets dressed in women's clothing and dismantled toll booths in rural Wales. More recently, increased gasoline taxes and rising oil prices triggered a fuel price rebellion in 2000, in which truck drivers in Britain blocked refineries and major roads, precipitating a serious political crisis for the government. Against this background, many politicians regarded attempts to introduce congestion charging as foolhardy.

But the London congestion charge has been both a practical success in reducing congestion and a popular success. Traffic delays inside the zone have decreased by around 30 percent, with a reduction of 15 percent in traffic circulating within the zone and 18 percent in traffic entering the zone during charging hours. Journey time reliability has improved by an average of 30 percent. Political opposition to the scheme has been minimal and popular support is now widespread.

A similar, but somewhat more muted, picture emerges from an analysis of the scheme's social costs and benefits. The benefits of the congestion charge, primarily associated with time savings and increased reliability of car and bus transport, appear to be largely in line with expectations. The resource costs of running the scheme—a factor which, as Mackie (2005) notes, is omitted altogether from the conventional diagrammatic analysis of road pricing—have been twice as high as expected, representing more than two-thirds of the scheme benefits. Net benefits of congestion prices seem to be positive, but less than commonly anticipated.

For this and other reasons, a degree of caution is appropriate before generalizing from the London experience. In the United Kingdom, the success of the London congestion charge has given rise to a new government initiative to introduce national road pricing—a major policy shift in a country where the first and so far the only toll highway is a 27-mile stretch of the M6 outside Birmingham, opened in 2003. Various studies have illustrated the potential efficiency gains from a shift to environmental and congestion-based charges, especially where accompanied by a reduction in fuel taxes (for example, Glaister and Graham, 2005). Ironically, however, the successful introduction of the London charge means that the potential additional benefits of an ambitious national scheme may be limited. The estimates produced by the Department for Transport (2004) show that the impact of congestion charging in London is responsible for more than 80 percent of the

reduction in congestion that would result from a national road pricing scheme applied to all urban and interurban roads. In fact, Newbery (2005) argues that a national distance-based road pricing scheme for interurban roads in the United Kingdom would be uneconomic, as existing fuel taxes generate much of the benefits at a small fraction of the cost; not surprisingly, the principal efficiency gains from congestion-based charging arise in urban areas. Moreover, Edinburgh voters rejected in February 2005 plans for a citywide congestion charge, which suggests that popular support for congestion charging derives from the perception of concrete benefits, not abstract principle.

London has some particular characteristics that helped to make its congestion charge a success. Traffic congestion in London was severe, even by the standards of other large cities in high-income countries. London has a comprehensive and well-functioning public transport system—including rail, subway, and bus systems—which offers good alternatives to road users. The geography and roads of London suggested the possibility of using the "ring road" around inner London as a suitable boundary for the congestion charge. In cities with a milder traffic congestion problem that face obstacles to developing their public transport system or have a geography that makes drawing a boundary difficult, congestion charges might not function as well. Moreover, any city considering congestion charges must face the practical problems of how to set and enforce charges and collect payments and then assess the net benefits of any scheme given their particular circumstances.

But the London experience also illustrates that the practical problems of congestion charges are not insurmountable. Cities around the world display high levels of traffic congestion, which impose large costs; the annual costs of congestion (including wasted time and fuel) in the 85 largest U.S. cities, for example, are estimated at $63 billion or $794 per traveler (Schrank and Lomax, 2005). Moreover, numerous studies demonstrate that the values placed by individuals on travel time and reliability are high and heterogeneous (for example, Small, Winston, and Yan, 2005). These factors suggest that congestion charging can yield significant economic benefits by inducing a more efficient use of scarce road space. A simulation exercise in Small (2005) suggests that the benefits of the London scheme should be replicable in U.S. cities. The benefits of carefully designed congestion charges in large urban areas appear, on the basis of the successful London scheme, to be both significant and within reach.

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