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The Impact of the Congestion Charge on Retail: the London Experience

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Abstract

The effect of London's congestion charge on the retail sector has aroused considerable interest since the introduction of the scheme in February 2003. We investigate the impact of the congestion charge using a variety of econometric models applied to a total retail sales index for central London (monthly) and weekly retail sales data for the John Lewis Oxford Street store within the congestion charging zone. The analysis suggests that the charge had a significant impact on sales at the John Lewis Oxford Street store over the period studied. However, it also suggests the charge did not affect overall retail sales in central London, an area larger than but encompassing the congestion charging zone.

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1.0 Introduction

On 17 February 2003 London introduced a pioneering congestion charging scheme. Vehicles present in a 21 square-kilometre zone enclosing the core shopping, government, entertainment, and business districts between 07:00 and 18:30, Monday to Friday, were subjected to a £5 per day charge (£8 from July 2005) unless they were eligible for a residents' discount or were exempt. Exemptions are granted to environmentally friendly vehicles (battery powered or hybrid cars), motorcycles, vehicles owned by disabled drivers (Blue Badge holders), taxis, buses, and certain other categories deemed to be essential.

The impact on traffic was sudden and dramatic. According to *Transport for London's* own data (TfL, 2003), traffic in the zone has been reduced by 16 per cent (30 per cent for cars; motorcycle, taxi, bus and cycle traffic has increased). This translates into a 32 per cent reduction in congestion, measured in terms of delay per kilometre. Average traffic speeds have increased from 13 km/h to 17 km/h. *Transport for London* estimates that the number of car trips into the zone has fallen by 150,000 per day, of which 10 to 20 per cent are displaced through trips, 50 to 70 per cent have shifted to public transport, and 20 to 30 per cent went elsewhere (used other modes, travelled at other times, or chose alternative destinations).

A series of surveys demonstrated the concern by many retailers in central London that the congestion charge (CC) was damaging sales. A 2003 survey by the London Chamber of Commerce and Industry of its members found that 76 per cent of traders reported reduced takings year-on-year, of which more blamed the congestion charge than the Central Line (CL) underground rail closure, fear of terrorist attack, economic downturn, or increasing competition from other sources (Winsor-Cundell, 2003). Another survey from 2003 by London First[1] gave a more positive assessment, although in a 16 February 2004 press release it observed that 'there may be sectors, especially retail and leisure, where the impact of the charge may not have been wholly positive'.

Studies based on quantitative data have taken longer to emerge, as such data only become available with a lag. Taking data up to June 2003, Carmel (2003) studied retail sales in central London. This study found that the onset of the decline in sales predated the introduction of the congestion charge and suggested that the most significant reasons were a general economic downturn, a fall in overseas visitors, and the closure of the CL. Quddus *et al*. (2005), analysing weekly sales data for six John Lewis

[1] London First, 2003, London Businesses Still Back Congestion Charging, Press Release August 2003.

Table 1
Mode Share of Shoppers in Central London in 2002

Mode	*Mode share (per cent)*
Bus only	17
London Underground only	34
Walk only	13
Car & Public Transport	1
Car & other	2
Car only	3
Cycle	1
Mixed Public Transport	20
Taxi/Minicab	2
Train only	7

stores including one within the charged zone, reported a significant impact on sales at the store within the zone over a period of about 11 months following the introduction of the charge.

The proportion of shoppers in central London who travel in by car is fairly low. An on-street public space survey by Transport for London in 2002 suggests that only 3–6 per cent of shoppers in central London came in by car. Table 1 shows mode share of shoppers in central London. Most shoppers interviewed in an on-street survey before the introduction of congestion charging came in by public transport (around 78 per cent).

This proportion would of course be expected to vary between different kinds of retail outlet. There is some evidence that John Lewis (JL) customers are more likely than this to travel in by car.

This paper revisits the question of the CC's impact on retail with new data. The primary focus of this paper is to test the impact of the charge on the retail sector as a whole in central London.[2] This is possible as a new data source has become available covering total central London retail sales — the London Retail Consortium's central London Retail Sales Monitor (LRSM) index. Retail outlets within the congestion charging zone that depend more on car-borne shopping might be affected more than others. Therefore, the sales data from the JL Oxford Street store, which depends more heavily on car-borne shopping, are investigated. The approach in Quddus *et al.* (2005) for modelling JL Oxford Street sales data is extended to include additional explanatory variables, and an alternative monthly differenced model is also specified. This paper presents the

[2]Central London here is defined to coincide with the area covered by the London Retail Consortium's central London Retail Sales index. It includes Knightsbridge and High Street Kensington as well as the congestion charging zone.

results of applying similar econometric models to two different dependent variables:

(1) Total central London retail sales (two types of model: log-linear monthly sales and differenced log-linear monthly sales).
(2) John Lewis Oxford Street store within the congestion charging zone (two types of model: log-linear weekly sales and differenced log-linear monthly sales).

Broadly speaking the results suggest that while the impact on JL Oxford Street appears to be statistically significant, the impact on the retail sector as a whole in central London appears not to be so.

2.0 Theoretical Framework

Retail sales are a form of consumer expenditure and so would be expected to be driven by the same kinds of factors that drive consumption. In other words, any model purporting to explain retail sales should start from the premise that the explanatory variables should be similar to ones in a consumption function. Income and wealth would be powerful influences, along with factors that affect these. In addition, there may be some explanatory factors that are specific to retail.

In the case of the models explaining sales at John Lewis Oxford Street, there is a range of factors that might be expected to influence the performance of this store including regional and local factors, as well as competition between this and other stores locally and regionally. For the model of central London retail sales, regional and local factors also need to be taken into account, but competition is only with stores outside central London (in this case, outside an area larger than but encompassing the charging zone).

Responses of car-borne shoppers to the charge may include a change of mode, destination or trip time (referred to collectively as substitution effects). Alternatively, car-borne shoppers may absorb the charge leading to a reduction in disposable income and reduced consumer expenditure (other things being equal), albeit TfL's spending of the money raised by the charge will generate some off-setting effects. Responses will be conditioned by the state of information about the scheme. While residents of central London may have been well aware of the charge, the payment mechanisms, the boundary of the zone and the period of operation, this awareness can be expected to decline with distance from the zone. Moreover, the propensity to use a car for shopping may increase with distance of the trip origin from the zone. Responses to the charge would also be expected to change as information disseminates, shoppers adapt to the charge, and shops adapt to changing shopper behaviour (for example, by opening on Sundays).

The Central Line of the London Underground was closed for several months between January and March 2003 as the result of a train derailment at Chancery Lane station on 29 January 2003. Full service was not restored on the Central Line until June 2003. Although no one was seriously injured in the derailment, it brought to light a safety risk with the engines of all the trains used on the Central Line, which as a result had to be checked.

Since the Central Line is one of the main lines serving Oxford Circus (Oxford Street), Bond Street, and Tottenham Court Road, the closure might be expected to have impacted on retail spending in these areas. While some shoppers would be likely to continue coming in to these shopping centres by alternative modes, such as other underground lines or the replacement bus services, some might redirect their retail spending to other locations.

3.0 Data Sources

In principle, the ideal data needed to test the impact of the charge on retail sales would be a long time series of retail sales both inside and outside the congestion charging zone with a substantial number of data points both before and after the introduction of the charge. However, the data available are of a relatively short time span, stretching (in the case of total central London sales) between October 2001 and December 2004 and (in the case of John Lewis sales) between January 2000 and January 2004. In both cases there are more than three years' worth of data, though the John Lewis sales data is weekly while the total central London sales data is monthly. This section describes the data used in more detail.

3.1 London Retail Sales Monitor data and explanatory variables

Data on total central London retail sales became available in 2004 in the form of the London Retail Consortium's LRSM. This is a monthly index of retail sales in central London compiled by KPMG. Access to this series was granted to GLA Economics on a confidential basis. The index covers an area made up of postcodes mainly inside the charging zone such as the West End but it also includes a few areas outside the zone such as Knightsbridge and High Street Kensington. This is not ideal but it is not possible to construct an index just for the charging zone within the short- to medium-term. In any case the index is likely to be dominated by sales in the West End. According to analysis by the Office of the Deputy Prime Minister (ODPM), in 1999 around 80 per cent of central London retail sales were inside the charging zone (ODPM, 2002). It should be noted that the LRSM is a relatively short series stretching back only to October 2001. Hence, there is not the long time series that would be necessary to establish really robust relationships.

For UK retail sales, the UK Retail Sales Index (UKRSI) from the Office for National Statistics (ONS) was used, which is a monthly series. To represent the congestion charge, a dummy variable was created which took the value 0 up to March 2003 and the value 1 thereafter. The Central Line closure (CL) effect was also modelled using a dummy variable (taking the value 1 between February and June 2003). To capture any economic trends specific to London, Claimant Count unemployment for London was used. This can be obtained from the ONS on a monthly basis.

As Figure 1 shows, the LRSM is a very volatile series with clear seasonal patterns. The patterns are similar in the UKRSI series, but there they are more muted. The difficulty of trying to test for a CC impact using a dummy variable is illustrated in the Figure 1. Dummy variables do

Figure 1
Time Series Data for Central London Sales Index (LRSM), UK Retail Sales Index (UK RSI) and the Congestion Charging dummy (CC) — LRSM in Annual Changes to Preserve Confidentiality

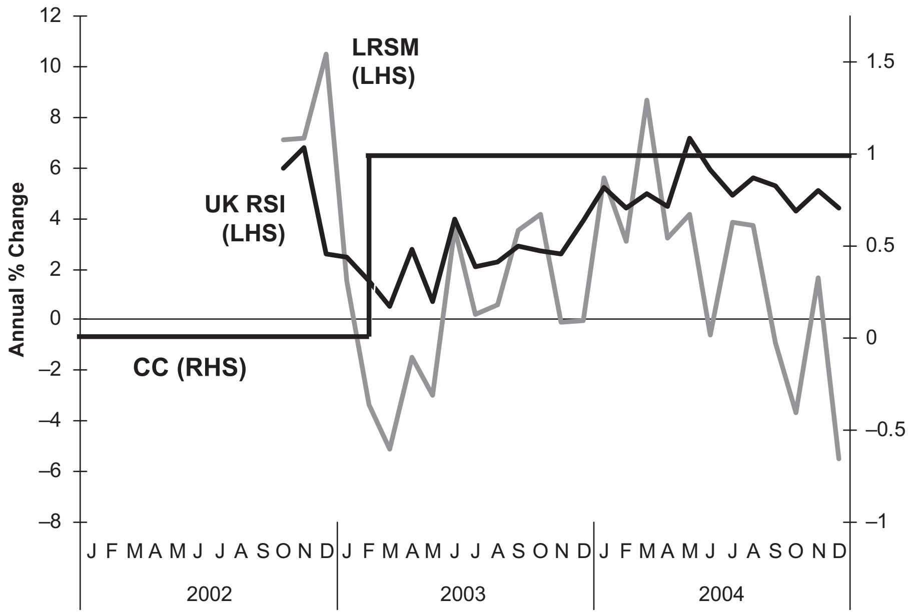
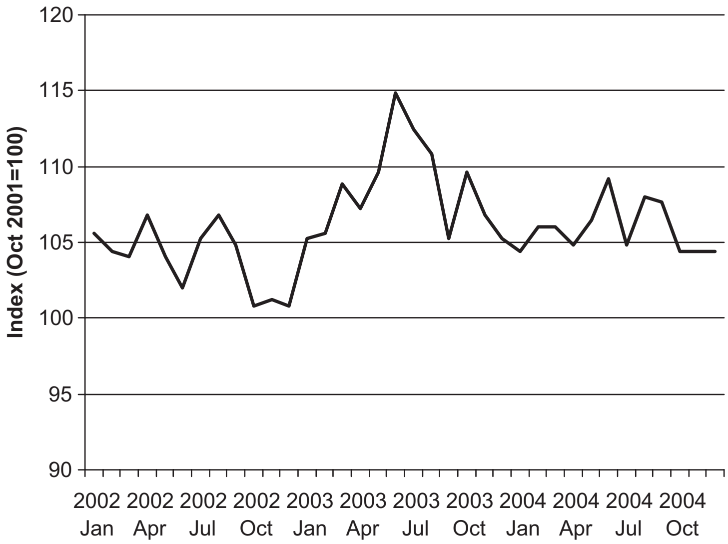


Figure 2
London Unemployment (LonU) (Claimant Count)



not contain much variation and are fairly blunt instruments for testing associations between different factors.

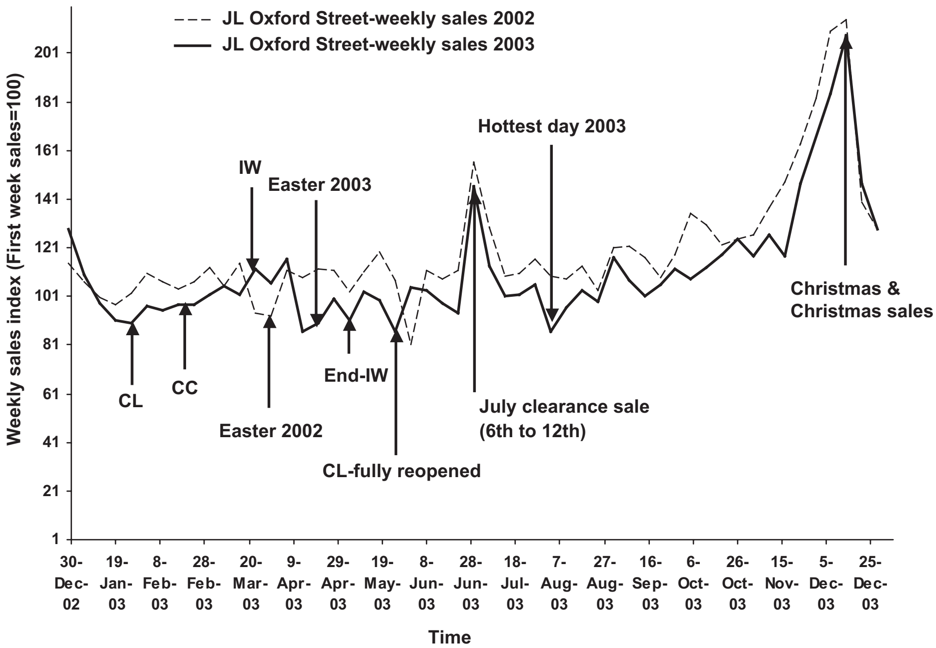
London unemployment (claimant count) is available from the ONS on a monthly basis and can act as a proxy for London income and London-specific economic conditions. Figure 2 shows the data for London unemployment (LonU).

3.2 The John Lewis sales data and explanatory variables

Sales data for the JL Oxford Street branch were analysed for the period of 30 January 2000 to 3 January 2004. This period includes three years before the CC and nearly one year afterwards. Within this period, the store was usually open from Monday to Saturday, but not Sundays and public holidays. It was decided to end the period of analysis on 3 January 2004 because John Lewis started to open their Oxford Street store on Sundays from 4 January 2004, making a before and after comparison of the impact of the CC more difficult as Sunday trading increases total weekly sales. Weekly sales data for 205 weeks (30 January 2000 to 3 January 2004) were obtained.

The comparative time plot of weekly sales for the JL Oxford Street store between 2002 and 2003 is shown in Figure 3. Different events that occurred in 2003 are also indicated on the plot by arrows. These are the Central Line (CL) closure, the application of the Congestion Charge (CC), the beginning and ‘ending’ of the Iraq War (IW), and various annual events. This plot

Figure 3
Time Plot of John Lewis Oxford Street Weekly Sales for 2003 and 2002



also suggests that weekly sales in 2003 are consistently lower than 2002 sales. Retail sales are usually influenced by the Easter holidays, being high just before Easter and low just after Easter. However, Easter changes from year to year, for example Easter Day was 31 March in 2002 but 20 April in 2003. The comparative time plot of weekly numbers of transactions for John Lewis Oxford Street exhibits a similar pattern to the weekly sales, but is not shown here for brevity.

In Quddus *et al.* (2005) economic conditions were controlled for by the inclusion of UK GDP, the exchange rate and a price index for furniture — none of which were found to be significant. This paper tries to extend this approach by including London-specific economic variables. London GVA (Gross Value Added) data were obtained from Experian Business Strategies rather than the ONS, because official data on London GVA are only available with a significant lag. In addition the problem of endogeneity (the independent variable London GVA includes the dependent variable John Lewis Oxford Street sales) was avoided by obtaining a data series for London GVA minus retail. The two series are shown in Figure 4. Clearly GVA minus Retail tracks London GVA fairly closely. It is also important to note that GVA, like most economic data, is a quarterly series whereas the dependent variable was weekly or monthly. More

Figure 4
Time Series Data for London GVA and London GVA minus Retail (Constant 2000 Prices)

frequent series tend to have more variation, and therefore more explanatory power, than quarterly series.

Other economic variables which were included in the JL Oxford Street model include London visitor expenditure (London overseas visitor expenditure which is derived from the International Passenger Survey obtained from the ONS) and the CPI for furniture and household items price index (also from the ONS). Overseas visitor spending is included because tourist spending is important for retailers in central London and the furniture index is an attempt to include some price information in the model since, other things being equal, higher retail prices should mean lower retail sales. Overseas visitor expenditure is a quarterly variable and so was interpolated, but the CPI for furniture and household items series is monthly. The CPI is a UK level variable as an appropriate regional price index does not exist.

4.0 Model Specification

The general approach of this paper is to estimate a series of regression models explaining retail sales over time (either for total central London or the JL Oxford Street store). The regression models test how far the data on retail sales depend on other factors that may affect retail sales. Both types of model include variables for the CL closure, and both control for seasonal fluctuations. The impact of the CC is then tested by including a variable for the charge and seeing whether it yields a statistically significant coefficient.

The variable representing the CC adopted in this paper is a dummy variable that takes a value of 1 during the times when congestion charging was operating and a value of 0 at all other times. This variable is a relatively blunt instrument to measure an impact from the congestion charge as it assumes that there is an effect that is unvarying in strength over time. Although the charge itself did not vary during this period there is no reason to assume that its effect on retail sales was similarly unvarying. It is also a blunt instrument in the context of this study because the periodicity of the data does not permit great precision in the time-identification of the effect (monthly). Compared to the ideal variable, which might be something like the number of people in cars travelling into the zone on a daily basis, the dummy variable in our study lacks precision, but no better variable is available. Three different types of regression model are used in this study. They are described below.

4.1 Modelling of LRSM and retail sales of the JL Oxford Street store

Quddus *et al*. (2005) showed that the association of sales with the congestion charge, the closure of the Central Line, the state of the economy, the consumer price index, the number of overseas visitors to London, trend, and seasonality could be best established using a log-linear model instead of a linear model. Therefore this model form is selected to model the time series data of individual stores.

A log-linear model with first degree autoregressive error term, AR(1), can be written as

$$\ln y_t = \alpha + \boldsymbol{\beta} \ln \boldsymbol{X}_t + \boldsymbol{\theta} \boldsymbol{D}_t + \varepsilon_t, \tag{1}$$

where the errors satisfy

$$\varepsilon_t = \rho\varepsilon_{t-1} + \eta_t.$$

y_t is the value of sales for period t (say, week t), $\boldsymbol{X}_t$ is a $k \times 1$ vector of continuous explanatory variables, $\boldsymbol{D}$ is a $m \times 1$ vector of dummy explanatory variables, ε is white noise, $\rho\,(-1 < |\rho| < 1)$ is the autocorrelation coefficient, and η_t is independent and identically distributed error term with zero mean and variance σ^2. $\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ are appropriately sized vectors of parameters to be estimated.

4.2 Differenced models for LRSM and JL Oxford Street store

In the above econometric models, the dependent variable is the weekly sales, whereas some of the explanatory variables, such as economic variables (for example, GVA, CPI), are monthly or quarterly. It may not be appropriate to explain the variation in weekly sales with the monthly or quarterly economic variables that cannot be obtained in weekly form. Therefore, it may be more appropriate if the above econometric models could be estimated using monthly sales. The intrinsic problem of using monthly sales is the short period (48 months) of available time-series data. With only 47 observations per store, it may not be feasible to estimate a total of 19 parameters ($\boldsymbol{\beta}'$ and $\boldsymbol{\theta}'$). Therefore, a differenced model is proposed that can automatically eliminate seasonality from the data. The model that relates monthly sales y to a sequence of factors $x_1, \ldots, x_n$, namely $y = f(x_1, \ldots, x_n)$, can be linearised as follows:

$$dy = \frac{\partial y}{\partial x_1} dx_1 + \ldots + \frac{\partial y}{\partial x_n} dx_n. \tag{2}$$

In our case the model is log-linear, so

$$d \ln y = \frac{\partial \ln y}{\partial \ln x_1} d \ln x_1 + \ldots + \frac{\partial \ln y}{\partial \ln x_n} d \ln x_n, \tag{3}$$

where

$$\frac{\partial \ln y}{\partial \ln x_i} = \frac{\partial y}{\partial x_i} \cdot \frac{x_i}{y}, \tag{4}$$

is the elasticity of monthly sales with respect to the factor i.

Monthly sales follow a seasonal pattern (see Figure 3), so everything else being equal we expect January 2001 sales to equal January 2002 sales, and so on. Hence the following differenced model may be applied to remove monthly seasonal variation:

$$\begin{aligned} \ln y_t - \ln y_{t-12} = {} & \beta_1(\ln x_{1,t} - \ln x_{1,t-12}) \\ & + \ldots + \beta_n(\ln x_{n,t} - \ln x_{n,t-12}). \end{aligned} \tag{5}$$

In the case of dummy variables, $\ln x_{i,t} = 1$ if factor i is present in period t and $\ln x_{i,t} = 0$ otherwise. The dummy variables considered were the presence or absence of congestion charging and the closure or otherwise of the Central Line.

The addition of a constant (β_0) allows for exponential growth in sales:

$$\begin{aligned} \ln y_t - \ln y_{t-12} = {} & \beta_0 + \beta_1(\ln x_{1,t} - \ln x_{1,t-12}) \\ & + \ldots + \beta_n(\ln x_{n,t} - \ln x_{n,t-12}). \end{aligned} \tag{6}$$

This model can be fitted by OLS, which provides consistent estimates of $\beta_0, \beta_1, \ldots, \beta_n$ (see Verbeek, 2000).

5.0 Results

5.1 Central London retail sales index

The relationship between the congestion charge and total central London retail sales was investigated using the central London retail sales index (LRSM) which is a monthly series. A range of explanatory variables were tested. Two main model structures are presented here — a log-linear model and a differenced model. The results and interpretation for these are presented below.

5.1.1 Log-linear model results

Table 2 shows the estimation results for two versions of the log-linear model. Model A has just one dummy variable representing the congestion charge effect and Model B splits this variable into two:

- CC 2003, which takes the value 1 in the months that congestion charging was in operation during 2003 and 0 elsewhere, and
- CC 2004, which takes the value 1 in the months that the charge was operating during 2004 (effectively all of 2004) and 0 at other times.

Both models use monthly dummy variables to account for seasonal fluctuation. The interpretation of the results is as follows.

Effect of the congestion charge and the Central Line In Model A the effect of the congestion charge is not significantly different from zero at the 95 per cent confidence level. In addition, the coefficient for the CC effect in Model A is positive, suggesting that the charge is associated with a positive impact on retail sales in central London.

In recognition that dummy variables are rather crude instruments that may pick up lots of different effects, this result was probed further by splitting the CC dummy into two — shown in Model B. This testing of the time-invariance of the CC dummy revealed two things. First it showed that the CC dummy is not time-invariant. While the dummy for 2003 (CC 2003) remains statistically insignificant, the 2004 variable is significant with a coefficient of -0.0475. This corresponds to an effect of $100 * \{\exp(\theta) - 1\}$ or -4.6 per cent. It cannot, however, be properly called a congestion charging effect as it operates only during 2004 and

Table 2
Model Estimation Results for Central London Retail Sales Index

	Central London Retail Sales Model: Loglinear Dependent variable = ln(LRSM)					
	Model A — One CC variable			*Model B — Two CC variables*		
Explanatory variables	*Coef.*	*t-stat*	*p-value*	*Coef.*	*t-stat*	*p-value*
LnUKRSI	0.4032	2.13	0.04	1.0445	5.31	0.00
LnLonU	−0.2044	−1.32	0.20	−0.1497	−1.32	0.20
CC	0.0059	0.44	0.66	—	—	—
CC 2003	—	—	—	−0.0024	−0.24	0.82
CC 2004	—	—	—	−0.0475	−3.12	0.01
Central Line	−0.0257	−2.50	0.02	−0.0379	−4.75	0.00
January	0.4836	32.98	0.00	0.4898	45.35	0.00
February (reference)						
March	0.2540	17.05	0.00	0.2366	20.54	0.00
April	0.0606	3.51	0.00	0.0212	1.39	0.18
May	0.0708	4.20	0.00	0.0354	2.43	0.02
June	0.4334	24.44	0.00	0.3943	25.45	0.00
July	0.2776	14.33	0.00	0.2246	12.29	0.00
August	0.0754	4.38	0.00	0.0400	2.71	0.01
September	0.3700	22.77	0.00	0.3330	23.21	0.00
October	0.1756	9.08	0.00	0.1148	5.93	0.00
November	0.2161	6.10	0.00	0.0913	2.43	0.02
December	0.7389	11.31	0.00	0.5046	7.22	0.00
Constant	Omit	2.47	0.02	Omit	0.26	0.80
Observations	39			39		
R-squared	0.997			0.998		
Adjusted R-Squared	0.995			0.997		

not 2003, while congestion charging was a constant influence during both years. It is likely that this effect points to a missing variable in our analysis — it may be the impact of cumulative interest rate rises by the Bank of England and the slowdown in the housing market, which we have not been able to include in the model. Circumstantial evidence favouring this hypothesis is the slowdown in the retail sales indices during the latter part of 2004.

The Central Line dummy variable is significant in both models with a fairly large coefficient. In Model B the coefficient implies that the Central Line effect had a negative impact on central London retail sales of around 3.6 per cent (though of course it did not last for a full year).

Economic variables In line with the theoretical framework for this study, economic variables for income (London GVA, or London GVA minus Retail) and wealth (UK household net assets) were tested, but no satisfactory relationship was found with central London retail sales (LRSM). Different combinations and lag structures were tried, but whenever the coefficients were statistically significant, the coefficient signs were usually negative, implying a counterintuitive and theoretically unsound negative impact of income and wealth on retail spending. This may be because of the shortness of the time series and the difference in time periods — income and wealth variables are only available on a quarterly basis and so need to be interpolated, entailing an artificial smoothing of the series. This may mean that there is insufficient variation left in the series to pick up the variation in a volatile monthly series such as the LRSM. Variables for tourism expenditure were also tried, but again no theoretically consistent relationship was found.

The approach eventually adopted was to use UK retail sales (UKRSI) as a proxy for all factors that affect retail sales in general throughout the country, and London unemployment (LonU) to capture any London specific economic factors. UKRSI is significant in both Model A and Model B and the coefficient is of a plausible sign and magnitude. In particular, in Model B the coefficient is around one, implying that central London retail sales tend to change in the same proportion as national retail sales. This seems intuitively correct. Central London's retail market is not isolated from the influences that affect retail in the rest of the UK. London unemployment is not significant at the 95 per cent level, but the sign and size of the coefficient are consistent with theory (higher unemployment is associated with lower retail sales).

The potential drawback of using UK retail sales is that the assumption of independence of the explanatory variables and the error terms may be violated; that is, UK retail sales may be an endogenous variable. Since central London retail sales is only a small part of total UK retail sales this may not be expected to be a significant problem. Nonetheless, an instrumental variables regression was run with lagged values of UKRSI as the instruments and a Hausman test performed to check whether the Ordinary Least Squares (OLS) coefficients were consistent. The null hypothesis that the OLS coefficients are consistent could not be rejected at the 5 per cent or even 10 per cent level. Tests were also performed for unit roots in the LRSM and UKRSI series as such series can often be non-stationary. The null hypothesis of stationarity could not be rejected in either case.

5.1.2 Differenced monthly model results

Though no evidence of misspecification was found in diagnostic tests of Model B, a differenced model was tested to see whether it supported the

Table 3
Model Estimation Results for Central London Retail Sales

Central London Retail Sales Model: Differenced Dependent variable = DLnLRSM			
Explanatory variables	*Coef.*	*t-stat*	*p-value*
Differenced LnUKRSI	0.6507	1.23	0.23
Differenced LnLonU	−0.1584	−1.02	0.32
Differenced CC	0.0107	0.68	0.50
Differenced Central Line	−0.0230	−2.03	0.06
Constant	−0.0119	−0.55	0.59
Observations	27		
R-squared	0.5163		
Adjusted R-Squared	0.4284		

results of Model B. Since the data are monthly, twelfth differences were used. The results are presented in Table 3 below and they support the results from the log-linear model.

The impact of the congestion charging dummy variable is again not statistically significant, and again the coefficient is positive. The effect of UK retail sales (Differenced LnUKRSI) is not significant, but the coefficient remains of a plausible sign and size; similarly for the effect of London unemployment. The only effect which remains significant is the impact of the Central Line closure.

In summary the models of total central London retail sales show no statistically significant effect of the congestion charge.

5.2 JL Oxford Street store

5.2.1 Log-linear model results

The association of the John Lewis Oxford Street sales and the explanatory variables is established using a log-linear model with an AR(1) disturbance. Tests were performed for unit roots in the weekly sales and GVA minus retail series as such series can often be non-stationary. The null hypothesis of stationarity could not be rejected in either case. The result is presented in Table 4 (the constant has been omitted to preserve confidentiality). Two types of model are presented. The first model uses John Lewis Oxford Street weekly sales and the second uses John Lewis Oxford Street monthly sales. Some of the variables in the monthly model seem to be insignificant. Perhaps this is due to insufficient degrees of freedom in the model as

Table 4
Model Estimation Results for John Lewis Oxford Street Weekly and Monthly Sales

JLOS Model: Loglinear with AR(1)
Dependent variable = ln(weekly or monthly sales at JLOS)

	Weekly model			*Monthly model*		
Explanatory variables	*Coef.*	*t-stat*	*p-value*	*Coef.*	*t-stat*	*p-value*
Congestion charge	−0.0723	−3.03	0.00	−0.1189	−2.72	0.01
ln(OC_and_BS_passengers)	0.5127	8.07	0.00	0.2431	0.88	0.39
ln(Bus journeys)	0.9302	3.38	0.00	−0.5818	−0.50	0.62
ln(London_GVA_minus_retail)	1.7027	2.54	0.01	−0.5463	−0.39	0.70
ln(London_visitor_expenditure)	0.1340	2.07	0.04	−0.0911	−0.71	0.49
ln(CPI_furniture)	0.4100	0.26	0.80	−2.9986	−1.14	0.26
Easter	0.0987	2.82	0.01			
Christmas	0.1640	4.35	0.00	—	—	—
Clearance	0.3760	10.12	0.00	—	—	—
January	0.0284	0.87	0.39	0.0521	0.80	0.43
February (Reference/base variable)				—	—	—
March	0.0516	1.47	0.14	0.1431	2.25	0.03
April	−0.0303	−0.95	0.34	0.1205	1.28	0.21
May	−0.0046	−0.12	0.91	0.1846	1.87	0.07
June	−0.0436	−1.3	0.20	0.0970	1.10	0.28
July	−0.0687	−1.63	0.11	0.2798	1.78	0.09
August	−0.0432	−1.04	0.30	0.1378	1.00	0.33
September	−0.0046	−0.1	0.92	0.2552	1.90	0.07
October	0.0340	0.83	0.41	0.3138	1.82	0.08
November	0.0849	1.93	0.06	0.4659	2.67	0.01
December	0.3014	5.88	0.00	0.7243	3.98	0.00
Trend (Cumulative week)	−0.00076	−1.48	0.14	0.0067	0.82	0.42
Constant	Omit	−3.71	0.00	Omit	1.34	0.19
Observations	204			48		
R-square	0.85			0.94		
Adjusted R-square	0.83			0.91		
Autocorrelation coefficient	0.18			−0.16		

explained in the methodology section. The interpretation of the results is as follows:

The effect of the congestion charge The effect of the congestion charge is captured by a dummy variable. This variable is found to be negatively associated with the weekly sales of John Lewis Oxford Street and is statistically significantly different from zero at the 95 per cent confidence level. This is an indication that average weekly sales are decreased after the introduction of congestion charging if all other factors remain constant before and after the application of the charge. This finding is consistent with the results of the econometric models by Quddus *et al*. (2005). The coefficient (θ) of the effect of the congestion charge represented by a dummy variable is −0.0723, indicating that the relative effect on the average weekly sales of John Lewis Oxford Street due to the presence of the congestion charge is $100 * \{\exp(\theta) - 1\}$, or −6.9 per cent. In other words, the congestion charge reduces the expected weekly sales of John Lewis Oxford Street by 6.9 per cent holding all other factors included in the model constant.

The effect of the closure of the central line The effect of the closure of the Central Line is captured by a continuous variable, which is total weekly passengers (both exit and entry) passing through Oxford Circus (OC) and Bond Street (BS) underground stations, OC_and_BS_passengers. This is found to be statistically different from zero at the 95 per cent confidence level and, as expected, positively associated with the JL Oxford Street's weekly sales (Table 4). The result suggests that a 1 per cent increase in OC_and_BS_passengers would lead to an increase of 0.5 per cent in weekly sales.

The effect of bus journeys Following the introduction of the congestion charging, bus journeys within the charged zone during the critical morning peak hour were estimated to increase by 14 per cent (TfL, 2003). Oxford Street, where the John Lewis Oxford Street store is located, has very good bus accessibility. Therefore, it is worthwhile to see whether increased bus journeys, as a proxy for accessibility by bus, have any impact on the John Lewis retail business. Transport for London provided quarterly bus journeys data for Central London from 2000 to 2004. Bus journeys in Central London are found to be positively associated with the John Lewis weekly sales at the Oxford Street store. This is an expected result as increased bus journeys enable more commuters/customers to travel to Central London. Table 4 shows that the elasticity associated with bus journeys is 0.93 and it is statistically significant.

London economic variables Quddus *et al*. (2005) used national GDP instead of London GDP as an economic variable in their econometric models. This might be the reason why the economic variable turned out to be statistically insignificant in the models as London's economy does not necessarily follow the UK trend. Note, however, that using the London GDP as an explanatory variable yields a new problem. As retail is a significant part of the GDP, the explanatory variable (London GDP) will not be independent of the sales (the dependent variable). This contradicts the assumption of the explanatory variable being independent of the error term. Hence, the retail part of GVA was subtracted from London

GVA. The new variable is named as London_GVA_minus_Retail (Table 4), which is used in this study to see whether there is a relationship between the London economy and John Lewis retail sales. This is found to be statistically significant at the 95 per cent confidence level and positively associated with John Lewis Oxford Street weekly sales. The elasticity associated with this variable can be seen to be high compared to others (See Table 4).

Expenditure by London visitors is also found to be positively associated with the John Lewis Oxford Street weekly sales. The consumer price index (CPI) for furniture and household items was also included and found to be statistically insignificant.

Annual events It is found that various annual events such as Easter, the July clearance sales and the Christmas sales affect retail activity as expected. These factors are statistically significant in the model at the 95 per cent confidence level with the expected signs. The coefficient for the July clearance sales is the highest followed by the Christmas period and the Easter period.

Effect of seasons and trend The method of dummy variables is used to remove the seasonal component from the time series of weekly sales at John Lewis Oxford Street. We have assumed that the variable 'season' has twelve classes, the months of a year, thereby requiring the use of eleven dummy variables. If there is a seasonal pattern present in various months, the estimated differential intercepts (β_j, where $j = 1$ to 11) will reflect it only if they are statistically significant. It is possible that only some of these differential intercepts are statistically significant so that only some months may have significantly different sales. The month of February is taken as the base month in the model. The results show that only differential coefficients associated with October, November and December are statistically significant at the 95 per cent confidence level. Thus one may conclude that there are some seasonal factors operating in those months.

Econometric models that use time-series data may include a trend term. By a trend we mean a sustained upward or downward movement in the behaviour of a variable. This trend term can serve as a proxy for a variable that affects the dependent variable (weekly sales) and is not directly observable but is highly correlated with time. A trend term could be either a continuous function of time or a categorical variable. In this model, the trend term is a continuous exponential growth function of cumulative weeks starting with $t = 1$ and ending with $t = 205$. The continuous trend function is found to be statistically insignificant at the 95 per cent confidence level.

Table 5
Difference Model Estimation Result for John Lewis Oxford Street Monthly Sales

Difference Model for John Lewis Oxford Street Store			
Explanatory variables	*Coef.*	*t-stat*	*p-value*
Congestion Charge (Dummy)	−0.1141	−2.07	0.05
Differenced ln(OC_and_BS_passengers)	0.2375	0.77	0.45
Differenced ln(bus journeys)	0.0178	0.02	0.99
Difference ln(CPI)	0.1354	0.09	0.93
Differenced ln(GVA_minus_retail)	0.0264	0.18	0.86
Differenced ln(tourist expenditure)	−1.2639	−0.36	0.72
Differenced ln(net wealth)	−0.1649	−0.87	0.39
Constant	0.0140	0.14	0.89
Observations	36		
R-square	0.48		
Adjusted R-square	0.35		

5.2.2 Differenced monthly model results

The differenced model presented in (3) is used to investigate further the effect of the congestion charge on the John Lewis Oxford Street retail business. The result is presented in Table 5. It can be seen that the finding is consistent with the result of the monthly model presented in Table 4. Only the dummy variable for the congestion charge is found to be statistically significant. Most of the economic variables are found to be statistically insignificant.

6.0 Discussions and Conclusions

The effect of London's congestion charge on the retail sector was analysed using a variety of econometric models applied to a total retail sales index for central London (monthly) and weekly retail sales data for the John Lewis Oxford Street store inside the charging zone. The analysis suggests that the charge had a significant impact on sales (sales were about 7 per cent down) at the John Lewis store on Oxford Street over the period studied. However, it also suggests the charge did not affect overall retail sales in central London, an area larger than but encompassing the congestion charging zone. While estimating the impact of the congestion charge, the study controls for other factors that may also influence retail sales such as London GVA (Gross Value Added), London tourism, Consumer Price Index (CPI), the closure of the Central Line, and various annual events of importance to retail. All models provide the expected results for these variables.

The results from the models of total central London retail sales and the models of JL retail sales seem to provide different answers to the research question. However, these different results are not necessarily contradictory. It may well be the case that a store such as JL on Oxford Street has been affected by the CC even though there is no overall effect at the sector level in central London. A plausible hypothesis might be that JL Oxford Street is particularly likely to be affected by the charge because a relatively large proportion of its sales come from car-borne customers (who may come from outside Greater London and may be buying bulky items for which a car is convenient). Indeed, Bell *et al*. (2004) present some evidence that backs this up. A survey of John Lewis customers at the Oxford Street store found that almost 10 per cent mostly or always used a private car (before charging). This is a far higher proportion than the 3 to 6 per cent of shoppers who use a car for shopping in general in central London according to on-street surveys for TfL in 2002 (Carmel, 2004).

The dip in central London sales in 2004 might be a lagged congestion charge effect, although without any further evidence supporting this hypothesis we should be wary of asserting this, especially as retail sales in the UK as a whole also dipped in 2004. One recommendation for future work is to use other data series that would allow us to test the hypothesis that there was a lagged effect from the CC in 2004 against the hypothesis that there was some other (UK-wide) effect in 2004.

One important factor that it has not been possible to deal with within this study is the impact of competition. Competition with other stores (both within the charging zone and outside it) may explain part of the drop in sales for the JL Oxford Street store, although we are unaware of any evidence for this. On the contrary, there is some survey data in Bell *et al*. (2004) that suggests that respondents who visited the JL Oxford Street store less after the introduction of charging also visited the Oxford Street area less often. However, this survey only covered JL Oxford Street Account Holders and so cannot be taken as conclusive evidence on the absence of competition effects within Oxford Street on the JL Oxford Street store's performance.

The results from the model of total central London retail sales may include some spatial substitution. That is, even though no impact was found on retail sales as a whole, it is still possible that there has been some redistribution of sales from certain stores or areas to other stores within central London (for example, from Oxford Street to Knightsbridge or High Street Kensington). This would not be picked up by the model because it looked only at total central London retail sales; however, as previously noted, central London retail sales are likely to be mainly influenced by sales within the charging zone.

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