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Working Paper 12: The congestion charge's impact 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. Many unusual events that may have had an impact on retail sales in central London happened in close succession in 2003 (e.g. the closure of the Central Line and the Iraq War). This makes it difficult to isolate the effect of the congestion charge which was introduced at about the same time.

This paper investigates the congestion charge's impact using a variety of regression models applied to two variables of interest:

(i) a total retail sales index for central London (monthly)
(ii) John Lewis retail sales data for six stores (weekly).

The results from the analysis broadly suggest that the charge had a significant impact on sales at the John Lewis store in Oxford Street (inside the charging zone) over the period studied. However the analysis also suggests the charge did not affect overall retail sales in central London, an area larger than but encompassing the congestion charging zone. When estimating the impact of the congestion charge, the study attempts to control for other factors that may influence retail sales.

1. 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 7am and 6:30pm Monday to Friday were subjected to a £5 per day charge, unless they were eligible for a residents' discount or were exempt. Exemptions were 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 (TfL), traffic in the zone was reduced by 16 per cent (30 per cent for cars while motorcycle, taxi, bus and cycle traffic increased)[1]. This translates into a 32 per cent reduction in congestion, measured in terms of delay per kilometre. Average traffic speeds have increased from 13 kilometres per hour (km/h) to 17 km/h. TfL estimates that the number of car trips into the zone has fallen by around 65-70,000 per day, of which 35-40,000 are transfers to public transport, 10-15,000 transfers to other non-public modes, 15-20,000 displaced through trips and around 5-10,000 are taking place at other times or other destinations or not at all.

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) closure, fear of terrorist attack, economic downturn, or increasing competition from other sources[2]. Another survey from 2003 by London First[3] 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 hard data have taken longer to emerge, as data only becomes available with a lag. Taking data up to June 2003, Carmel[4] 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[5], analysing weekly sales data for six John Lewis stores including one within

[1] Transport for London, 2003, Congestion charging: Six months on. Available at: http://www.tfl.gov.uk. Accessed January 10, 2003.
[2] E Winsor-Cundell, 2003, The Retail Survey: Impact of the Congestion Charge on the Retail Sector, London Chamber of Commerce and Industry. Available at: http://www.londonchamber.co.uk. Accessed July 15, 2004.
[3] London First, 2003, London Businesses Still Back Congestion Charging, Press Release August 2003
[4] A Carmel, 2003, The causes of recent poor retail sales performance in central London, London's Economy Today, Issue 11
[5] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

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.

This paper revisits the question of the CC's impact on retail with new data. The approach in Quddus et al[6] for modelling John Lewis sales data is extended to include additional explanatory variables and a differenced model is also specified. A second set of models is estimated to test the impact of the charge on the retail sector as a whole in central London[7]. 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. This paper presents the results of applying similar econometric models to two different dependent variables:

i) John Lewis sales at six stores in the London area (three classes of models presented: log-linear weekly sales, differenced log-linear monthly sales and a log-linear weekly sales panel data model).
ii) Total central London retail sales (two classes of models: log-linear monthly sales and differenced log-linear monthly sales).

Broadly speaking the results suggest that while the impact on John Lewis Oxford Street appears to be statistically significant, the impact on the retail sector as a whole in central London appears not to be so. This paper's interpretation section discusses how to reconcile these results.

[6] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.
[7] 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.

2. Theoretical Framework

Retail sales are a form of consumer expenditure and so would be expected to be driven by the same sorts 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 which affect these. In addition there may be some explanatory factors that are specific to retail.

In the case of the model trying to explain sales at John Lewis Oxford Street there are a range of factors that might be expected to influence the performance of one particular store including regional and local factors, and competition between this store and others 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).

3. Data Sources

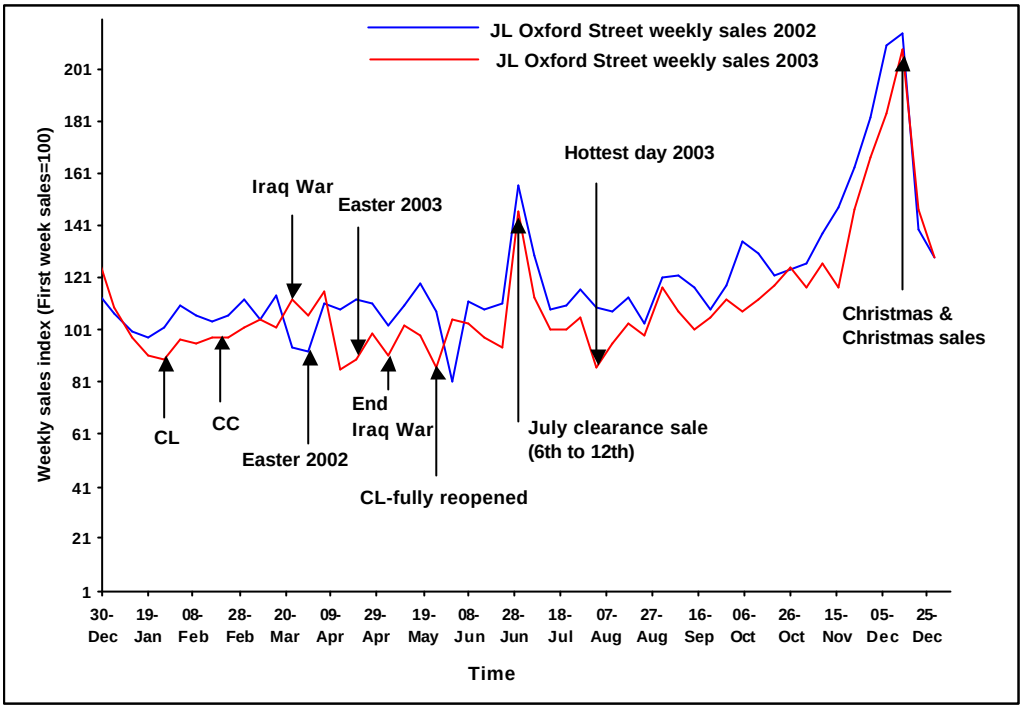
In principle, the ideal data needed to test the impact of the charge on retail sales would be a long time series of retail sales in the congestion charging zone with a substantial number of data points both before and after the introduction of the charge. However, the available data is of a relatively short time span stretching (in the case of John Lewis sales) between January 2000 and January 2004 and (in the case of total central London sales) between October 2001 and December 2004. In both cases there is 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.

The John Lewis sales data and explanatory variables

Sales data for six branches was 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 time period, all six John Lewis branches were usually open from Monday to Saturday, but not Sundays and public holidays. The stores do, however, have different opening hours. 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 the six branches in question for 205 weeks (30 January 2000 to 3 January 2004) was obtained, leading to a cross-sectional (*N* = *number of branches* = 6) time-series (*T* = *number of weeks* = 205) panel data set with a total of 1230 (*N´T*) observations.

The comparative time plot of weekly sales for John Lewis Oxford Street between 2002 and 2003 is shown in Figure 3.1. 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 CC, the beginning and 'ending' of the Iraq War (IW), and various annual events. This plot also suggests that weekly sales in 2003 are consistently lower than 2002 sales. Retail sales are usually influenced by the Easter holidays with sales usually being high just before Easter and lower just after Easter. However, Easter changes from year to year, for example Easter Day was 31 March in 2002 and 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.

Figure 3.1: John Lewis Oxford Street weekly sales for 2003 and 2002
(as an index to preserve confidentiality)



Source: John Lewis

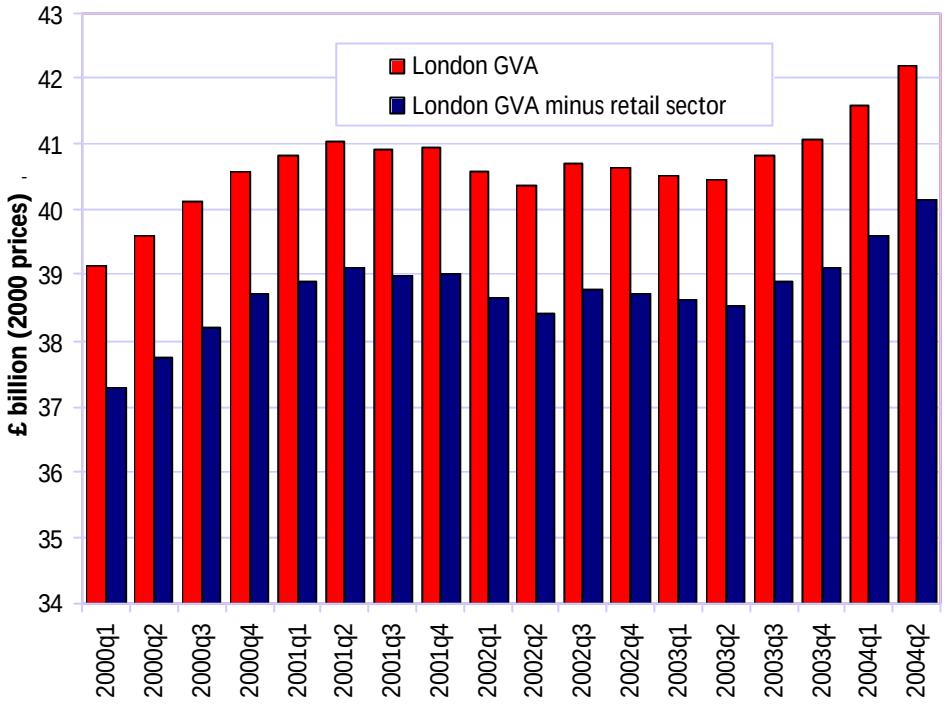
In Quddus et al[8] economic conditions were controlled for by including UK Gross Domestic Product (GDP), the exchange rate and a price index for furniture and household items – none of which were found to be statistically significant. This paper tries to extend this approach by including London specific economic variables. London Gross Value Added (GVA) data was obtained from Experian Business Strategies rather than the Office for National Statistics (ONS), because official data on London GVA is 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 the retail sector. The two series are shown in Figure 3.2. 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 independent variable is weekly or monthly. More frequent series tend to have more variation, and therefore more explanatory power, than quarterly series.

Other economic variables which were included in the John Lewis Oxford Street model include London overseas visitor expenditure, which is derived from the International Passenger Survey obtained from the ONS, and the Consumer Price Index (CPI) for furniture and household items (also from the ONS). Overseas visitor spending is included because tourist spending is important for some retailers in central London and

[8] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

the furniture and household items 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 converted into a monthly and weekly series, while the CPI for furniture and household items series is monthly and so was converted into a weekly series for the weekly models. The CPI is a UK-level variable as an appropriate regional price index does not exist.

Figure 3.2: Time series data for 'London GVA' and 'London GVA minus retail'
(constant 2000 prices)



Source: *Experian Business Strategies*

London Retail Sales Monitor data and explanatory variables

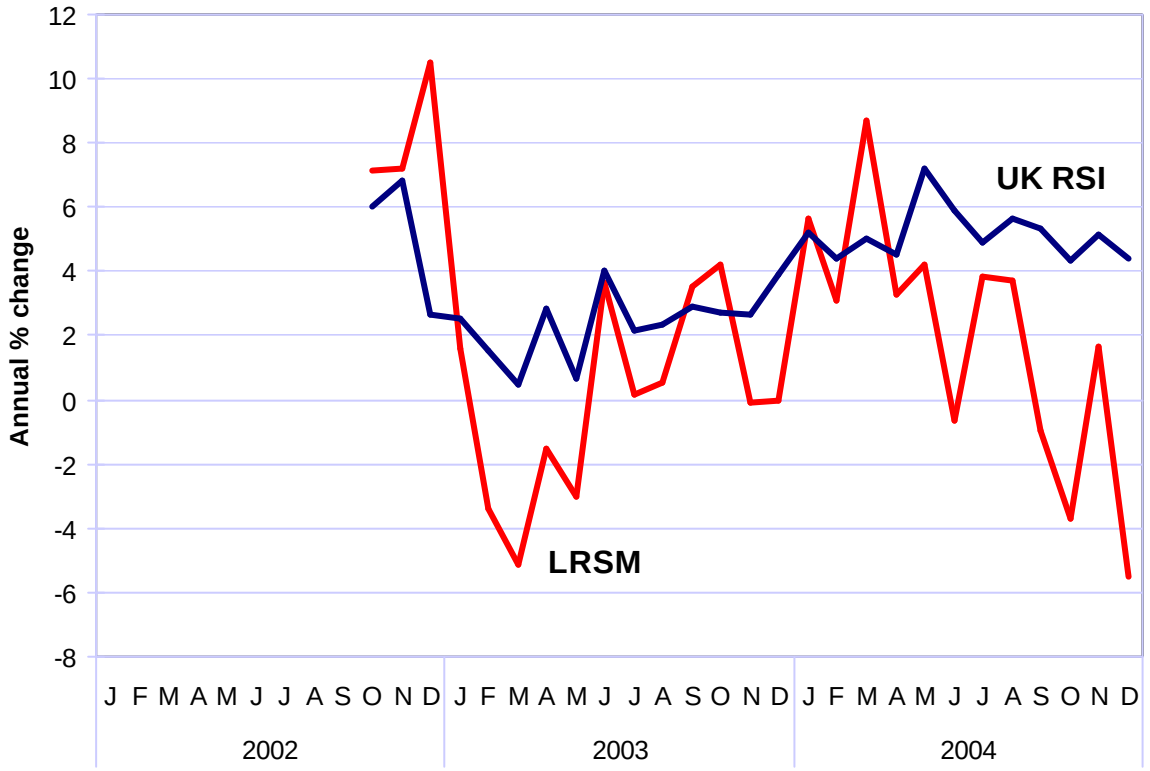
Data on total central London retail sales became available in 2004 in the form of the London Retail Consortium's LRSM. This is a monthly index of retail sales in central London compiled by KPMG. Access to this series was granted to GLA Economics on a confidential basis. The index covers an area made 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 ODPM, in 1999 around 80 per cent of central London retail sales were inside the charging zone[9].

For UK retail sales, the UK Retail Sales Index (UKRSI) from the ONS was used, which is a monthly series. To represent the CC, a dummy variable was created which took the value

[9] ODMP, 2002, Producing boundaries and statistics for town centres, London Pilot Study Summary Report, London: TSO

0 up until March 2003 and the value 1 thereafter. The CL closure effect was also modelled using a dummy variable (taking the value 1 between February and June 2003). London unemployment was used to attempt to capture any differential trends in economic conditions in London compared to the UK. The variable used was the International Labour Organisation (ILO)'s definition of unemployment data for London obtained from the Labour Force Survey. This data can be obtained from the ONS on a monthly basis.

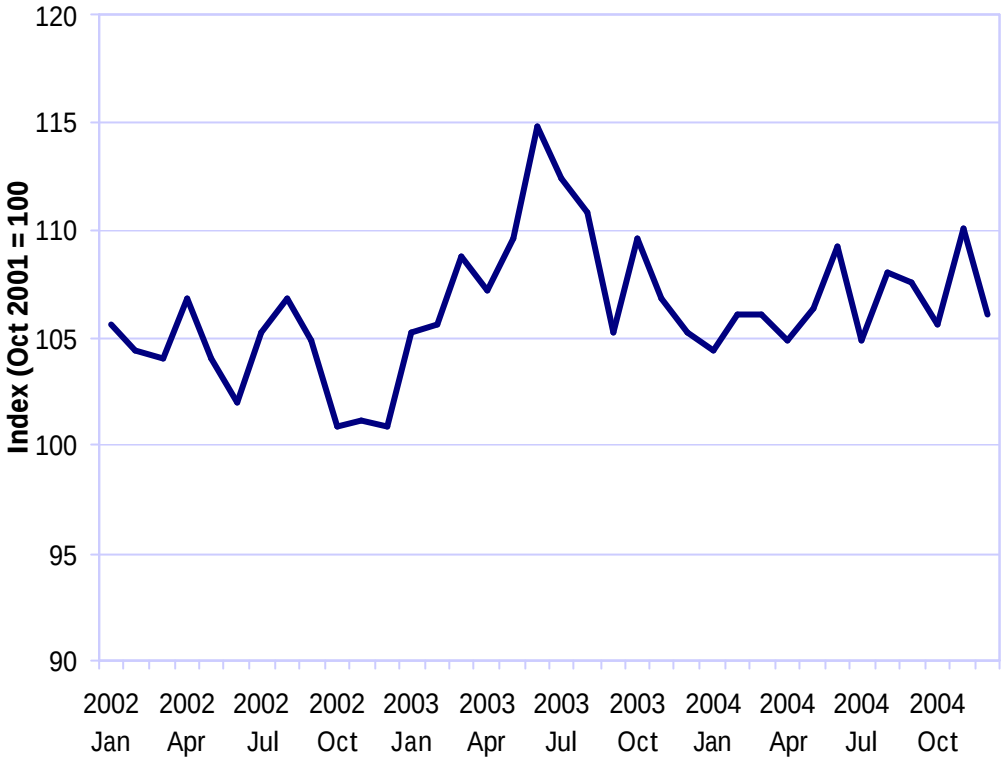
Figure 3.3: Time series data for Central London Retail Sales Index (LRSM) and UK Retail Sales Index (UK RSI)
(in annual changes to preserve LRSM confidentiality)



Source: The London Retail Consortium and ONS

London unemployment (ILO definition) is available from the ONS on a monthly basis and can act as a proxy for London income and London-specific economic conditions. Figure 3.4 shows the data for London unemployment.

Figure 3.4: London unemployment



Source: ONS

4. Modelling Approach

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 John Lewis stores). The regression models test how far the data on retail sales depends on other factors that may affect retail sales. The models of total central London retail sales include variables controlling for the general retail climate (UK retail sales) and the specific economic situation in London (London unemployment). The models of John Lewis sales include variables controlling for the London economic situation (London GVA minus retail), tourism (London visitor expenditure), the price of retail goods (CPI furniture) and bus access to central London (bus journeys). 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's models is a dummy variable which takes a value of 1 during the times when congestion charging was operating and a value of 0 at all other times. Dummy variables do not contain much variation and are somewhat blunt instruments, but no better variable for the charge is available.

Three different types of regression model are used in this study:

i) Log-linear model
ii) Differenced log-linear model
iii) Log-linear panel data model.

The log-linear model is a standard type of regression model often used in econometrics. Putting the variables in logarithms allows the interpretation of the coefficients as elasticities (the percentage change of one variable with respect to the percentage change of another variable). A differenced model looks at the change (first difference) in a variable over a period of time (in this case annual differences e.g. the change in retail sales between January 2002 and January 2003). This avoids the need for seasonal dummy variables and therefore helps to estimate the model parameters efficiently. In this case the logarithms of variables were differenced, which again allows the interpretation of parameters as elasticities. For the John Lewis sales data, because there was data for six stores over time, it was also possible to fit a panel data model. A panel data model tests the movements of observations (sales) for a panel of objects (stores) over time (often known as cross-sectional, time-series observations). However, this was not possible for total central London sales as the data for all stores was aggregated into a single index. Appendix A provides a fuller technical discussion of the models used.

5. Results

The results are presented here for the impact of congestion charging on the two research variables (total central London retail sales and John Lewis store sales) and different model structures.

5.1 Central London retail sales.

The relationship between the congestion charge and total central London retail sales was investigated using the central London retail sales index (the 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 log-linear model. The results and interpretation for these are presented below.

Log-linear model results

As can be seen in Table 5.1, which shows the estimation results for two versions of the log-linear model:

- Model A has just one dummy variable representing the CC effect.
- 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.
    - 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. See Appendix A for more detail on the equation structure of the various models tested in this paper.

Effect of the congestion charge and the Central Line

In Model A the CC's effect 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 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 $100 * \{\exp(q) - 1\}$ or – 4.6 per cent. It cannot, however, be properly called a congestion charging effect as it operates only during 2004 and not 2003 while congestion charging was a constant influence during both years. It is likely that this effect points to a missing variable in the analysis – it may be the impact of cumulative interest rate rises by the Bank of England and the slowdown in the housing market which have not been included in the model. Circumstantial evidence favouring this hypothesis is the slowdown in the retail sales indices during the latter part of 2004.

The CL dummy variable is significant in both models with a fairly large coefficient. In Model B the coefficient implies that the CL 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).

Table 5.1: Estimation results for central London Retail Sales Index log-linear model

Dependent Variable = ln(LRSM)						
Explanatory Variables	**Model A - One CC variable**			**Model B - Two CC variables**		
	Coef.	**t-stat**	**p-value**	**Coef.**	**t-stat**	**p-value**
ln UKRSI	**0.4032**	**2.13**	**0.04**	**1.0445**	**5.31**	**0.00**
ln Lon Unemployment	-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		

Note: ln = natural logarithm; LRSM = London Retail Sales Monitor; UKRSI = UK Retail Sales Index

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 UKRSI as a proxy for all factors which affect retail sales in general throughout the country and London unemployment to capture any London specific economic factors. UK retail sales 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 are very highly correlated with UK 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, i.e. 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 five per cent or even ten 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.

Differenced log-linear LRSM 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 results of Model B. Since the data is monthly, annual (twelfth) differences were used. Since each month is compared with the same month in the previous year this removes the need to include monthly dummies. The results are presented in Table 5.2 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 CL closure.

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

Table 5.2: Model estimation results for LRSM – Differenced log-linear model

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		

Notes: Dln = Differenced natural logarithm; LRSM = London Retail Sales Monitor; UKRSI = UK Retail Sales Index; ln = natural logarithm; LonU = London Unemployment

5.2 John Lewis Retail Sales

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. The result is presented in Table 5.3 (the constant has been omitted to preserve confidentiality). Two types of model are presented. The first model uses John Lewis Oxford Street's weekly sales and the second uses their monthly sales. Some of the variables in the monthly model are insignificant, due probably to insufficient degrees of freedom (short time series) in the model as explained in the data section.

Table 5.3: Model estimation results for John Lewis Oxford Street weekly and monthly sales

(log-linear with AR(1) disturbance)

Dependent Variable =ln (weekly or monthly sales at JLOS)						
Explanatory Variables	***Weekly Model***			***Monthly Model***		
	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 patronage)	**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**	-	-	-
Clearence	**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		

Notes: ln = natural logarithm; JLOS = John Lewis Oxford Street; OC =Oxford Circus Underground Station; BS = Bond Street Underground Station; CPI = Consumer Price Index; GVA = Gross Value Added

The following commentary relates to the weekly sales model only.

The effect of the congestion charge

The effect of the CC 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 decreased after the introduction of congestion charging if all other factors remain constant before and after the application of the charge. This is consistent with the results of the econometric models by Quddus et al[10].

[10] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual

The coefficient (q) of the effect of the CC 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 $100*\{\exp(q)-1\}$, or - 6.9 per cent. In other words, the CC 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 CL is captured by a continuous variable which is total weekly passengers (both exit and entry) of Oxford Street and Bond Street Underground stations (referred to in Table 5.3 as OC and BS passengers). This is found to be statistically different from zero at the 95 per cent confidence level and, as expected, is positively associated with John Lewis Oxford Street's weekly sales (Table 5.3). The result suggests that a one per cent increase in Oxford Street and Bond Street Underground stations' passengers would lead to an increase of 0.5 per cent in weekly sales.

The effect of bus journeys

Following the introduction of congestion charging, bus patronage within the charged zone during the critical morning peak hour was estimated to increase by 14 per cent[11]. Oxford Street, where the John Lewis Oxford Street store is located, has very good bus accessibility. Therefore, it is worthwhile to see whether the number of bus journeys in central London, as a proxy for bus accessibility, have any impact on John Lewis retail business. TfL provided quarterly bus journeys data for central London from 2000 to 2004. Bus journeys in central London is found to be positively associated with weekly sales at John Lewis Oxford Street. This is an expected result as increased bus journeys, associated also with faster bus journeys within the charging zone, would attract more commuters/customers to travel by bus to central London. Table 5.3 shows that the elasticity associated with bus journeys is 0.93 and is statistically significant.

London economic variables

Quddus et al[12] used UK GDP instead of London GDP as an economic variable in their study. This might be the reason why they found this to be statistically insignificant, as London's economy does not necessarily follow the UK trend. Note however, that using the London GVA as an explanatory variable yields a new problem. As retail is a significant part of GVA, the explanatory variable (London GVA) may not be independent of the error term, contradicting an important assumption of the Linear Regression Model. Hence, the retail component of GVA was subtracted from London GVA. The new variable is called London GVA minus retail (see Figure 3.2) and is used to

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Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

[11] Transport for London, 2003, Congestion charging: Six months on. Available at: http://www.tfl.gov.uk. Accessed January 10, 2003.

[12] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

see whether there is a relationship between income in London and John Lewis retail sales. The coefficient is found to be statistically significant at the 95 per cent confidence level and positively associated with John Lewis Oxford Street's weekly sales. The elasticity associated with this variable is high compared to the others (see Table 5.3).

Expenditure by overseas visitors to London is also found to be positively associated with John Lewis Oxford Street's weekly sales. The CPI for furniture and household items was also included but was not found to be statistically significant.

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 Easter.

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. This paper assumes 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 (b_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 influence sales. The month of February is taken as the base month in the model. The results show that only the coefficients associated with the October, November and December variables 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* this paper means 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.

Differenced monthly log-linear model results
A differenced model presented in equation (3) in Appendix A is used to further investigate the effect of the CC on John Lewis Oxford Street's retail business. The results are presented in Table 5.4. It can be seen that the findings are consistent with the result of the monthly model presented in Table 5.3. Only the dummy variable for

the CC is found to be statistically significant. All the economic variables are found to be statistically insignificant.

Table 5.4: Differenced model estimation result for John Lewis Oxford Street monthly sales

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		

Notes: ln = natural logarithm; OC = Oxford Circus Underground Station; BS = Bond Street Underground Station; CPI = Consumer Price Index; GVA = Gross Value Added

Panel data model for all six John Lewis stores

The geographical proximity of the six John Lewis stores leads to cross-store correlation in sales, so a panel data model would be expected to offer greater statistical efficiency. A random effects log-linear model with an AR(1) disturbance is used to analyse the weekly sales of all six John Lewis branches in and around London. Several models are estimated in order to test for the trend in weekly sales of John Lewis Bluewater. The results are presented in Table 5.5 (the constants have been omitted to preserve confidentiality). The overall R^2 is found to be 0.95, which is very satisfactory in terms of model goodness-of-fit.

Effect of trend

A trend variable is included as a continuous exponential growth function of cumulative weeks. Model A presumes an identical trend across the branches. Model B assumes a general trend across the branches as well as a separate trend (as a categorical dummy) for John Lewis Bluewater. However, one trend variable (yr2003*Bluewater) for Bluewater is highly correlated with the dummy variable for the effect of the CC (CC Bluewater). Therefore, Model C is estimated excluding the effect of the CC on John Lewis Bluewater (i.e. CC Bluewater).

Table 5.5: Model estimation results for panel data model, John Lewis branches
(random effect log-linear model with AR(1) disturbance)

All John Lewis branches in and around London	Model A			Model B			Model C		
	Coef.	***t*-stat**	***p*-value**	**Coef.**	***t*-stat**	***p*-value**	**Coef.**	***t*-stat**	***p*-value**
Control Variables									
CC Oxford	**-0.1111**	**-3.23**	**0.00**	**-0.0940**	**-2.96**	**0.00**	**-0.0944**	**-2.96**	**0.00**
CC Blue water	0.1201	3.49	0.00	0.0567	0.79	0.43	**Omitted due to correlation**		
CC PeterJones	-0.0300	-0.87	0.38	-0.0097	-0.31	0.76	-0.0102	-0.32	0.75
CC Kingston	0.0297	0.86	0.39	0.0496	1.56	0.12	0.0492	1.54	0.12
CC Brent Cross	-0.0291	-0.84	0.40	-0.0114	-0.36	0.72	-0.0117	-0.37	0.71
ln(OC and BS passengers)	**0.1041**	**68.78**	**0.00**	**0.1038**	**75.79**	**0.00**	**0.1038**	**75.55**	**0.00**
ln(Bus patronage)	**1.0136**	**6.88**	**0.00**	**1.0536**	**7.24**	**0.00**	**1.0518**	**7.23**	**0.00**
ln(London GVA minus retail)	0.8892	1.54	0.12	0.6690	1.22	0.22	0.6591	1.2	0.23
ln(London visitor expenditure)	**0.1578**	**3.86**	**0.00**	**0.1657**	**4.16**	**0.00**	**0.1660**	**4.16**	**0.00**
ln(CPI furniture)	**1.7801**	**1.91**	**0.06**	**1.5541**	**1.69**	**0.09**	**1.5546**	**1.69**	**0.09**
Spatial variation									
Oxford Street		-			-			-	
Peter Jones	**0.5094**	**23.87**	**0.00**	**0.5043**	**26.12**	**0.00**	**0.5044**	**26.04**	**0.00**
Brent Cross	**0.6436**	**30.16**	**0.00**	**0.6394**	**33.11**	**0.00**	**0.6395**	**33.01**	**0.00**
Kingston	**0.4652**	**21.8**	**0.00**	**0.4604**	**23.84**	**0.00**	**0.4605**	**23.77**	**0.00**
Blue Water	**0.4683**	**21.94**	**0.00**	**0.3682**	**12.63**	**0.00**	**0.3683**	**12.59**	**0.00**
Watford (Reference variable)	-	-	-	-	-	-			
Annual events									
Easter	**0.0643**	**4.23**	**0.00**	**0.0646**	**4.20**	**0.00**	**0.0646**	**4.2**	**0.00**
Clearance	**0.2426**	**14.68**	**0.00**	**0.2425**	**14.62**	**0.00**	**0.2425**	**14.62**	**0.00**
Christmas	**0.3531**	**21.57**	**0.00**	**0.3554**	**21.49**	**0.00**	**0.3553**	**21.5**	**0.00**
Seasonal effects									
January	**0.0637**	**3.26**	**0.00**	**0.0717**	**3.68**	**0.00**	**0.0733**	**3.78**	**0.00**
February (Reference variable)	-	-	-	-	-	-			
March	-0.0287	-1.41	0.16	-0.0205	-1.03	0.31	-0.0199	-0.99	0.32
April	**-0.0758**	**-3.84**	**0.00**	**-0.0725**	**-3.78**	**0.00**	**-0.0715**	**-3.73**	**0.00**
May	**-0.0671**	**-2.86**	**0.00**	**-0.0627**	**-2.74**	**0.01**	**-0.0616**	**-2.7**	**0.01**
June	**-0.1211**	**-5.52**	**0.00**	**-0.1142**	**-5.39**	**0.00**	**-0.1132**	**-5.35**	**0.00**
July	**-0.0885**	**-3.45**	**0.00**	**-0.0871**	**-3.48**	**0.00**	**-0.0860**	**-3.44**	**0.00**
August	**-0.1136**	**-4.57**	**0.00**	**-0.1146**	**-4.71**	**0.00**	**-0.1133**	**-4.66**	**0.00**
September	**-0.0804**	**-3.1**	**0.00**	**-0.0755**	**-2.96**	**0.00**	**-0.0744**	**-2.92**	**0.00**
October	-0.0034	-0.14	0.89	0.0012	0.05	0.96	0.0025	0.11	0.92
November	**0.0692**	**2.8**	**0.01**	**0.0860**	**3.52**	**0.00**	**0.0870**	**3.57**	**0.00**
December	**0.1823**	**6.35**	**0.00**	**0.2083**	**7.34**	**0.00**	**0.2091**	**7.38**	**0.00**
Trend (Cumulative week)	**-0.000682**	**-2.27**	**0.02**	**-0.000941**	**-3.18**	**0.00**	**-0.0009**	**-3.16**	**0.00**
Separate trend for Blue Water									
Yr2000*BlueWater	-	-	-	-	-	-			
Yr2001*BlueWater	-	-	-	**0.1166**	**3.31**	**0.00**	**0.1168**	**3.3**	**0.00**
Yr2002*BlueWater	-	-	-	**0.1640**	**4.46**	**0.00**	**0.1661**	**4.52**	**0.00**
Yr2003*BlueWater				**0.1835**	**2.4**	**0.02**	**0.2351**	**5.85**	**0.00**
Constant	**Omit**	**-6.21**	**0.00**	**Omit**	**-6.13**	**0.00**	**Omit**	**-6.12**	**0.00**
Observations	1230			1230			**1230**		
Overall R-squared	0.95			0.96			0.96		
Estimated Autocorrelation Coefficent	0.58			0.54			0.54		

Notes: ln = natural logarithm; OC =Oxford Circus Underground Station; BS = Bond Street Underground Station; CPI = Consumer Price Index; GVA = Gross Value Added

Effect of the congestion charge and the closure of the Central Line

It can be seen that the effect of the CC on John Lewis Bluewater in Model A is highly statistically significant with a coefficient of 0.111. However, this variable becomes insignificant in both Model B and Model C when a separate trend is assumed for John Lewis Bluewater. This suggests that the effect of the CC on Bluewater as estimated in Model A may be now picked up by the trend variable 'yr2003*Bluewater' in Model C. It

can also be seen that other variables included in the model are of the same order of magnitude and signs across Models A, B and C.

The rest of the results are interpreted based on Model C in which there is no problem of multicollinearity. The effect of the CC on John Lewis Oxford Street (i.e. CC Oxford) is found to be statistically significant with a negative sign. This is consistent with the John Lewis Oxford Street model presented in Table 5.3. The value of the coefficient is now -0.094 meaning that the expected weekly sales of John Lewis Oxford Street fell by nine per cent following the introduction of the congestion charge holding all other factors included in the model constant.

The continuous variable representing the effect of the closure of the CL on the weekly sales of John Lewis Oxford Street is also found to be significantly different from zero at the 95 per cent confidence level. This is consistent with the results presented in Table 5.3. However, the elasticity of sales with respect to tube station use (OC and BS passengers) is now 0.1 compared to 0.51 in Table 5.3. This is not surprising as most of the stores included in the panel will not be accessed via the Oxford Circus or Bond Street tube stations.

The CC does not appear to have any effects on the weekly sales of John Lewis Kingston, Brent Cross or Peter Jones.

London economic variables

The 'London GVA minus retail' variable is now found to be statistically insignificant in all models in Table 5.5. However, expenditure by London visitors is highly significant and the elasticity value is consistent with the elasticity found in the time series model (see Table 5.3). The CPI for furniture and household items is has a counterintuitive sign (possibly the result of multicollinearity with other variables) but is only statistically significant at the 90 per cent confidence level.

Variation of weekly sales across branches

The locations of the John Lewis branches are found to be associated with the weekly sales as expected. This is examined by a categorical variable, *Spatial variation,* relative to John Lewis Watford. The Spatial variable for John Lewis Oxford Street is omitted due to its correlation with the variable associated with the passenger exit and entry count of Oxford Circus and Bond Street tube stations (OC and BS passengers). John Lewis Brent Cross store has the largest coefficient followed by John Lewis Brent Cross, Bluewater and Kingston.

Annual and seasonal variation

All annual events are found to be statistically significant at the 95 per cent confidence level. The 'July clearance sales' variable is found to have the biggest coefficient followed by 'Christmas sales' and then 'Easter sales'.

In summary, the models for John Lewis Oxford Street's sales show a statistically and economically significant effect of the CC.

6. Interpretation

The results from the models of total central London retail sales and the models of John Lewis 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 John Lewis 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 John Lewis 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 of Greater London and may be buying bulky items for which a car is convenient). Indeed, Bell et al[13] present some evidence which backs this up. A survey of John Lewis customers at the Oxford Street store found that almost ten per cent mostly or always used a private car (before charging). This is a far higher proportion than the three to six per cent of shoppers who use a car for shopping in general in central London according to on-street surveys for TfL (before charging)[14].

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 be part of the drop in sales for the John Lewis Oxford Street store. There is some survey data in Bell et al[15] which suggests that respondents who visited the John Lewis Oxford Street store less after the introduction of charging also visited Oxford Street generally less often. However, this survey only covered John Lewis Oxford Street Account Holders and so cannot be taken as conclusive evidence on the importance of competition effects within Oxford Street on John Lewis 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 (e.g. 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. Although, as previously noted, central London retail sales is likely to be mainly influenced by sales within the charging zone. The results from the model should be interpreted as saying that total central London retail sales has not been affected by the CC.

[13] M G H Bell, M A Quddus, J D Schmoecker, and A Fonzone, 2004, The impact of the congestion charge on the retial sector. Final Report submitted to John Lewis Partnership, London, UK.
[14] A Carmel, 2004, Congestion Charging and retail – one year on, London's Economy Today, Issue 18
[15] M G H Bell, M A Quddus, J D Schmoecker, and A Fonzone, 2004, The impact of the congestion charge on the retial sector. Final Report submitted to John Lewis Partnership, London, UK. See Fig 41.

7. Conclusions

The CC in London had an immediate and substantial impact on traffic as intended. To the extent that the car is used for shopping within the zone, some impact on retail sales, at least for individual stores, would be expected. An earlier analysis of John Lewis sales data had indicated a significant impact on sales in the Oxford Street store for the 11 months following the CC's introduction. This paper has revisited that analysis with three models (separate models for each store, a panel data model for six stores and a monthly difference model for the Oxford Street store) and used more focused explanatory variables (specifically CL patronage, overseas visitor expenditure in London, and London GVA minus retail). To broaden the analysis and examine the impact of the charge on the central London retail sector in general, similar models were fitted to total central London sales data (LRSM).

This paper's results show that the CC appears to have had a significant impact on John Lewis Oxford Street, though it is not possible to be confident about the exact size of this impact since it varies substantially between models and it was not possible to control for the impact of competition from other stores in Oxford Street. When examining the impact on sales in the central London retail sector as a whole, the results suggest that there was no impact. However, since the area covered by central London includes important shopping areas outside the charging zone, this leaves open the possibility of some spatial substitution, though this is unlikely to be substantial given that retail in the charging zone dominates total central London retail as used in this study.

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Appendix A: Model Specification

Modelling of LRSM and retail sales of individual John Lewis stores

Quddus et al[16] showed that the association of sales with the congestion charge, the closure of the CL, 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.

The basic structure of a log-linear model is as follows:

$$\ln y_t = a + \beta \ln \boldsymbol{X}_t + \gamma \boldsymbol{D}_t + e_t$$

where y_t is the dependent variable (either central London sales or John Lewis sales in period t), $\boldsymbol{X}$ is a k×1 vector of continuous explanatory variables, $\boldsymbol{D}$ is a m×1 vector of dummy explanatory variables, b and q are appropriately sized vectors of parameters to be estimated and the error term e is independent and identically distributed with zero mean and variance s^2.

In the models of John Lewis sales, evidence was found of serial correlation. Hence a log-linear model with an AR(1) disturbance was specified and a Generalised Least Squares (GLS) estimator used to provide correct standard errors. A log-linear model with first degree autoregressive error term, AR(1), can be written as:

$$\ln y_t = a + \beta \ln \boldsymbol{X}_t + \gamma \boldsymbol{D}_t + e_t \qquad (1)$$

where the errors satisfy

$$e_t = \rho e_{t-1} + h_t$$

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

Panel data model of six John Lewis stores

The John Lewis branches within London are linked by geographical proximity[17], allowing customers to change shops relatively easily. Therefore, a pooled model including sales

[16] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

[17] M Quddus, MGH Bell, JD Schmoecker, and A Fonzone, 2005, The impact of the congestion charge on the retail business in London: An econometric analysis. Paper no. 05-1210 presented at the Annual Meeting of the Transportation Research Board, Washington D.C. and submitted to Transportation Research A for publication.

data from all the London branches may be more appropriate. The random effect log-linear model with AR(1) could be used to analyze sales data from different John Lewis branches over a specified period. This model is defined as,

$$\ln Y_{it} = a + \beta' \ln \boldsymbol{X}_{it} + \gamma' \boldsymbol{D}_{it} + n_i + e_{it} \qquad (2)$$

in which

$$e_{it} = r' e_{i,t-1} + h_{it}$$

where Y_{it} is the weekly sales for an observation unit i (John Lewis branch) in a given period *t* (a week), $\boldsymbol{X}$ is a k×1 vector of continuous explanatory variables, $\boldsymbol{D}$ is a m×1 vector of dummy explanatory variables, n_i are assumed to be realizations of an independently and identically distributed (iid) process with zero mean and variance s_n^2, e_{it} is the usual residual, r' (-1<$|r'|$<1) is the autocorrelation coefficient and h_{it} is independent and identically distributed with zero mean and variance s_e^2. β' and γ' are appropriately sized vectors of parameters to be estimated.

Differenced log-linear models for John Lewis Oxford Street and LRSM

A differenced model was also tested. One of the advantages of a differenced model is that it can automatically eliminate seasonality from the data. The model that relates monthly sales y to a sequence of factors $x_1,...,x_n$, namely $y = f(x_1,...,x_n)$, can be linearised as follows:

$$dy = \frac{\partial y}{\partial x_1} dx_1 + ... + \frac{\partial y}{\partial x_n} dx_n \qquad (3)$$

In our case the model is log-linear:

$$d \ln y = \frac{\partial \ln y}{\partial \ln x_1} d \ln x_1 + ... + \frac{\partial \ln y}{\partial \ln x_n} d \ln x_n \qquad (4)$$

where

$$\frac{\partial \ln y}{\partial \ln x_i} = \frac{\partial y}{\partial x_i} \cdot \frac{x_i}{y} \qquad (5)$$

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

Monthly sales follow a seasonal pattern (see Figure 1), so everything else being equal you can expect January 2001 sales to equal January 2002 sales, etc. Hence the following differenced model may be applied to remove monthly seasonal variation:

$$\ln y_t - \ln y_{t-12} = b_1(\ln x_{1,t} - \ln x_{1,t-12}) + ... + b_n(\ln x_{n,t} - \ln x_{n,t-12}) \quad (6)$$

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 (b_0) allows for exponential growth in sales:

$$\ln y_t - \ln y_{t-12} = b_0 + b_1(\ln x_{1,t} - \ln x_{1,t-12}) + ... + b_n(\ln x_{n,t} - \ln x_{n,t-12}) \quad (7)$$

This model can be fitted by OLS, which provides consistent estimates of $b_0, b_1, ..., b_n$ (see Verbeek[18]).

[18] M Verbeek, 2000, A guide to modern econometrics, John Wiley & Sons

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Appendix C: Abbreviations

CC	Congestion charge
CL	Central Line
CPI	Consumer Price Index
GDP	Gross Domestic Product
GLS	Generalised Least Squares
GVA	Gross Value Added
ILO	International Labour Organisation
IW	Iraq War
km/h	Kilometre per hour
ln	Natural logarithm
LonU	London unemployment
LRSM	London Retail Sales Monitor
OLS	Ordinary Least Squares
ONS	Office for National Statistics
TfL	Transport for London
UKRSI	UK Retail Sales Index

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Hindi

यदि आप इस दस्तावेज की प्रति अपनी भाषा में चाहते हैं, तो कृपया निम्नलिखित नंबर पर फोन करें अथवा नीचे दिये गये पते पर संपर्क करें

Vietnamese

Nếu bạn muốn có văn bản tài liệu này bằng ngôn ngữ của mình, hãy liên hệ theo số điện thoại hoặc địa chỉ dưới đây.

Bengali

আপনি যদি আপনার ভাষায় এই দলিলের প্রতিলিপি (কপি) চান, তা হলে নীচের ফোন্ নম্বরে বা ঠিকানায় অনুগ্রহ করে যোগাযোগ করুন।

Greek

Αν θέλετε να αποκτήσετε αντίγραφο του παρόντος εγγράφου στη δική σας γλώσσα, παρακαλείστε να επικοινωνήσετε τηλεφωνικά στον αριθμό αυτό ή ταχυδρομικά στην παρακάτω διεύθυνση.

Urdu

اگر آپ اِس دستاویز کی نقل اپنی زبان میں چاھتے ھیں، تو براہ کرم نیچے دئے گئے نمبر پر فون کریں یا دیئے گئے پتے پر رابطہ کریں

Turkish

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Arabic

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Punjabi

ਜੇ ਤੁਹਾਨੂੰ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕਾਪੀ ਤੁਹਾਡੀ ਆਪਣੀ ਭਾਸ਼ਾ ਵਿਚ ਚਾਹੀਦੀ ਹੈ, ਤਾਂ ਹੇਠ ਲਿਖੇ ਨੰਬਰ 'ਤੇ ਫ਼ੋਨ ਕਰੋ ਜਾਂ ਹੇਠ ਲਿਖੇ ਪਤੇ 'ਤੇ ਰਾਬਤਾ ਕਰੋ:

Gujarati

જો તમને આ દસ્તાવેજની નકલ તમારી ભાષામાં જોઈતી હોય તો, કૃપા કરી આપેલ નંબર ઉપર ફોન કરો અથવા નીચેના સરનામે સંપર્ક સાધો.

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