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OFFICE OF FAIR TRADING

MODELLING THE EFFECTS OF TAXI REGULATION

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1. Introduction

This report provides an overview of the regulatory environment across a number of local authorities (LAs) in the UK, and investigates empirically the impact of entry and quality-of-service regulation on the three identified factors influencing consumer welfare. OXERA has employed econometric techniques to model level of fares, waiting time and quality of service in the taxi markets across 30 LAs in the UK. The effect of entry and quality-of-service regulation has been captured by including indicators of the regulatory environment as explanatory variables in the specification of the model. The impact of regulated fares on factors that influence consumer welfare could not be identified, as all LAs sampled for the econometric modelling still have fare regulation in place. The empirical analysis draws on the following datasets: the Office of Fair Trading (OFT) LA surveys; Halcrow consumer surveys and unmet-demand studies; and the Office of National Statistics (ONS) census data.

The report is structured as follows:

- section 2 details the data available for the empirical analysis;
- section 3 discusses the indicators of consumer welfare used for the modelling exercise;
- section 4 gives an overview of the proxies for entry regulation which informed the specification of the econometric models;
- section 5 describes the regulatory environment in place across a number of LAs in the UK;
- sections 6, 7 and 8 present the results of the econometric modelling;
- section 9 draws the results together and concludes;
- Appendix 1 presents a full description of the datasets used for the modelling;
- Appendix 2 describes the general-to-specific methodology adopted for the econometric modelling;
- Appendix 3 explains the statistical output diagnostic tests reported with the results of the modelling;
- Appendix 4 presents the full results of the waiting-time modelling.

2. Data Description

This section presents a detailed analysis of the data available for the modelling. Section 2.1 describes the datasets on which the analysis is based; section 2.2 lists the LAs included in the modelling; and section 2.3 describes the variables available for the modelling and presents the summary statistics. Finally, section 2.4 analyses the correlation among the key variables used for the modelling.

2.1 Sources of data

The econometric modelling draws on the following datasets:

- *the OFT's LA survey*—the OFT carried out a survey of LAs in 2002, which asked questions about the nature of the taxi markets in each authority and the extent of regulation. The OFT received responses from 253 LAs;
- *the Halcrow unmet-demand studies and consumer surveys*—LAs refusing to issue new licences for hackney carriages often undertake an *unmet-demand* study to ascertain whether there is any demand for hackney carriages which is not being met. LAs can only refuse to issue new licences if there is no unmet demand for hackney carriages. In examining the regulatory regime, LAs also often undertake surveys of consumers' opinions and views on the taxi markets. The results of these studies and surveys (conducted by Halcrow) were made available to OXERA for its modelling;
- the ONS census data.

For each data source, the level of data aggregation, the number of observations available, and the year of the study are detailed in Table 2.1. The year of the Halcrow unmet-demand studies and consumer surveys varies across LAs, spanning the period 1997–2002.

Table 2.1: Sources of data

Source	Type	Level	Observations (no.)	Year
OFT	LA survey	LA	253 LAs	2002
Halcrow	47 consumer surveys	Individual	12,521 respondents covering 39 LAs[1]	1997–2002
Halcrow	Unmet-demand studies	LA	43 LAs	1998–2002
ONS	ONS census data	LA	Available for all LAs	2001

Note: [1] More than one survey is available for some LAs.
Source: OXERA analysis.

Appendix 1 provides a detailed description of the datasets used for the modelling.

2.2 LAs included in the modelling

Given that the econometric modelling draws on all sources of data, the available sample of LAs is restricted to the 30 LAs sampled by both Halcrow and the OFT. For each LA included in the econometric modelling, Table 2.2 lists the type of entry regulation in place in 2002 and at the time of the Halcrow survey. The table shows that only four of the 30 LAs have unlimited entry regulation currently in place in the hackney carriage market, namely Cambridge City, Peterborough, Forest Heath and North Devon. Two of these have only recently deregulated the hackney carriage market and so still had entry restrictions in place at the time of the Halcrow survey: Cambridge City deregulated in July 2001, although it issued a total of 41 new licences in 1995, 1997 and 1999 in response to Halcrow's unmet-demand studies; Peterborough fully deregulated in January 2001.

The number of hackney carriages and PHVs per 1,000 people and the number of PHVs per hackney carriage is also reported. LAs with unlimited entry appear to have a higher number of hackney carriages and a lower number of PHVs per 1,000 people than LAs with limited entry. The number of PHVs per hackney carriage is significantly lower in LAs with no entry restrictions in place. Although the results should be interpreted with caution, given the limited sample size of LAs with unlimited regulation, these preliminary findings appear to suggest that the ratio of PHVs to hackney carriages could be an appropriate proxy for entry regulation. This issue is explored in more detail in section 2.4, where a comprehensive analysis of the available indicators of entry regulation is presented. Regardless of the type of entry regulation in place, all LAs regulated hackney carriage fares. Section 3 presents a broader overview of the interaction between different forms of regulation across LAs, drawing on the OFT dataset of 253 LAs.

Table 2.2: LAs included in the econometric modelling

	LA	Year of Halcrow survey	Entry: Year of Halcrow survey	Entry: Year of OFT LA survey (2002)	No. of hackney carriages per 1,000 head of pop. (2002)	No. of PHVs per 1,000 head of pop. (2002)	No. of PHVs per hackney carriage (2002)
1	Blackpool B.C.	1998	Limited	Limited	1.8	3.07	1.71
2	Bradford M.D.C.	2002	Limited	Limited	0.48	2.99	6.23
3	Brighton & Hove	2002	Limited	Limited	1.85	1.71	0.92
4	Bristol City Council	2002	Unlimited	Limited	1.71	1.76	1.03
5	Burnley B.C.	1998	Limited	Limited	0.38	3.17	8.34
6	Calderdalem B.C.	2000	Limited	Limited	0.34	2.49	7.32
7	Cambridge City	1999	Limited	Unlimited	1.87	2.77	1.48
8	Cardiff C.C.	2001	Limited	Limited	1.57	2.66	1.69
9	Carrick D.C.	2002	Limited	Limited	0.77	0.93	1.21
10	Castle Point Borough Cl	2000	Limited	Limited	0.43	2.31	5.37
11	Cherwell D.C.	2001	Limited	Limited	0.71	1.45	2.04
12	Congleton B.C.	1999	Limited	Limited	0.34	0.73	2.15
13	Edinburgh City Council	2002	Limited	Limited	2.7	—	—
14	Ellesmere Port & Neston	2001	Limited	Limited	0.43	2.32	5.40
15	Exeter City Council	2002	Limited	Limited	0.46	1.62	3.52
16	Forest Heath D.C	1997	Unlimited	Unlimited	2.3	0.65	0.28
17	Hull City Council	1999	Limited	Limited	0.7	3.74	5.34
18	Leicester City Council	2000/01	Unlimited	Limited	1.14	2.09	1.83
19	Manchester City	2001	Limited	Limited	2.07	5.85	2.83
20	North Devon D.C.	1998	Unlimited	Unlimited	1.43	0.21	0.15
21	Nottingham City Council	1997/98	Limited	Limited	1.12	3.68	3.29
22	Peterborough C. C.	1998	Limited	Unlimited	0.88	2.3	2.61
23	Sefton M.B.C.	2000	Limited	Limited	0.96	5.28	5.50
24	Selby D.C.	1999	Limited	Limited	0.38	0.85	2.24
25	South Ribble B.C.	2000	Limited	Limited	1.88	0.5	0.27
26	Sunderland City Council	1998	Limited	Limited	1.01	1.92	1.90
27	Thurrock Council	2000	Limited	Limited	0.67	1.4	2.09
28	Torridge D. C.	2001	Limited	Limited	0.71	0.52	0.73
29	Wansbeck District Cnl	1998	Limited	Limited	0.49	0.87	1.78
30	Wigan Council	2002	Limited	Limited	0.45	1.98	4.40
	Average: limited entry				**0.98**	**2.24**	**3.16**
	Average: unlimited entry				**1.62**	**1.48**	**1.13**

Source: OXERA analysis.

2.3 Indicators of consumer welfare (dependent variables)

Appendix 2 provides summary statistics of the data used in the modelling, and examines the distributions of the potential dependent variables.

The 'Taxi Markets Literature Review' identified level of fare and waiting time as the two main characteristics of taxi service provision that influence consumer welfare. In addition, there is a variety of quality-of-service measures that may be relevant for consumers, some of which are already covered by quality-of-service regulation—for example, driver's knowledge. In order to gauge the relative importance that consumers place on a range of factors that could affect welfare, in the revealed-preference (RP) survey undertaken by OXERA as part of the consumer survey study, consumers were asked to rate how important the factors were. The results of this question are given in Table 2.3.

Table 2.3: Welfare factors identified in the RP survey (%)

	Low (1–4)	Med (5–6)	High (7–10)
Importance of:			
Safety of the vehicle	2.4	3.9	93.7
Driver's knowledge of the area	3.0	5.4	91.6
Cleanliness of the vehicle	3.7	6.7	89.7
Convenience of the service	3.8	7.7	88.5
Waiting time	5.6	8.4	86.0
Price	4.6	10.0	85.4
The taxi being metered	11.1	10.1	78.9
The total journey time door to door	9.9	17.2	72.9
The traditional look/design of a 'Black cab'	53.3	20.0	26.7

Source: RP Survey, Q1.

Hence, the available empirical evidence points to level of fares, waiting time and quality of service as the three major factors that influence consumer welfare in the taxi markets. This implies that consumer welfare is positively affected by lower fares, lower waiting time and an increase in quality of service/safety. Table 2.4 lists the variables used in the econometric analysis to model these three factors. The quality-of-service variable captures the quality of the hackney carriage service only, while information on consumers' satisfaction with PHV services is not available from the Halcrow consumer survey. Similarly, *Excessdemand* and *Avpassdelay,* which measure waiting time at rank, do not include the PHV market, given that PHVs are generally booked by telephone only. All the other variables listed in Table 2.4 cover both the PHV and hackney carriage markets.

Table 2.4: Dependent variables in the three modelling exercises

	Factors affecting consumer welfare (dependent variable)	Variable
Model 1	Level of fare	Threemiletrip_IND, Threemiletrip_LA and Threemiletripmd_LA
Model 2	Waiting time	Waitingtime_IND, Waitingtime_LA, Excessdemand, Excessdemand_offpeak, Excessdemand_peak, Avpassdelay, Avpassdelay_peak and Avpassdelay_offpeak
Model 3	Quality of service	Quality_IND, Quality_dv_IND, Quality_LA and Quality_dv_LA

Source: OXERA analysis.

While the factors influencing consumer welfare have been clearly identified, estimates of the weights attached by customers to the various elements entering the welfare function are not available from the empirical literature. Hence, consumer welfare could not be estimated and each of the indicators of consumer welfare had to be modelled separately. On the other hand, some preliminary estimates of the weights attached to the single attributes entering the welfare function are available from the 'Consumer Survey Report'.

The variables available for the econometric modelling for level of fares, waiting time and quality of service are described below.

2.3.1 Level of fares

Information on perceived fares for a daytime three-mile trip is available from Halcrow's consumer surveys.

Threemiletrip_IND, *Threemiletrip_LA* and *Threemiletripmd_LA*—in the Halcrow consumer survey, respondents were asked to state their perceived fare for a daytime three-mile trip. Individual observations on perceived fares have been used for the modelling at the individual level (*Threemiletrip_IND*). For the modelling of fares at the LA level, the perceived fare in each LA has been defined as the mean of the individual perceived fares in every LA (*Threemiletrip_LA*). To cross-check the robustness of the results, the modelling at the LA level has also been run using the median of the individual observations (*Threemiletripmd_LA*) as a dependent variable. The distribution of the perceived fare at the individual level has been truncated at £30.[1] The adjustment is grounded on the assumption that £30 is likely to be the upper-limit fare for a three-mile taxi journey. Hence, all responses stating a perceived fare above £30 are likely to contain significant measurement errors. Given that the Halcrow consumer surveys have been conducted in different years across LAs, perceived fares have been adjusted for inflation and expressed in 2002 prices.

At the individual level, respondents stating their perceived fare ((*Threemiletrip_IND*) are likely to be influenced by the type of taxi journey they have experienced in the past—for example, a respondent who has experienced exclusively hackney carriage journeys is more likely to remember a hackney carriage fare for a three-mile trip, while a respondent accustomed to using PHV services is likely to report perceived PHV fares. This implies that average perceived fares at the LA level (*Threemiletrip_LA*) are a blend of PHV and hackney carriage fares. Moreover, average fares are likely to be skewed to the higher hackney carriage fares in those LAs where the majority of the respondents tend to catch hackney carriages more often than PHVs. Similarly, in LAs where a relatively high percentage of respondents use PHV services more frequently, the average fare is likely to be closer to the fare for a PHV journey.

Given that the aim of modelling the level of fares is to capture the effect of entry and quality-of-service regulation on actual fares, perceived fares is the appropriate variable to model. A key reason for modelling perceived, instead of regulated, fares is that perceived fares include the PHV market. To the extent that consumers can choose between hackney

[1] Only eight respondents reported a perceived fare above £30 in all the surveys (three of these were in the reduced sample of 30 surveys used for the econometric modelling).

carriages and PHVs—at least in the telephone segment of the market—it is appropriate to take into account PHV fares in the modelling.[2]

Moreover, while regulated hackney carriage fares are unlikely to respond to changes in the competitive environment, perceived fares are instead expected to capture the effect on level of fares of:

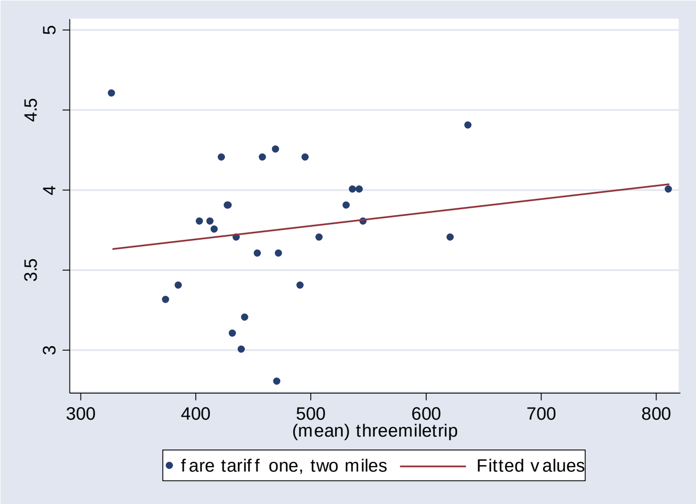
- *competition between hackney carriages*—modelling the effect of entry regulation on actual fares allows the downward pressure on the level of fares that could follow from entry deregulation to be estimated. Indeed, if deregulation spurs price competition in the hackney carriage market, hackney carriage service providers may be forced to set actual fares below the regulated cap in order to avoid losing market share. Hence, even if regulated fares have not changed, the fall in actual fares represents a gain in consumer welfare, which should be accounted for;

- *competition between PHVs and hackney carriages*—modelling perceived fares allows the competitive constraint on hackney carriage fares exercised by the PHV market to be captured. Indeed, PHV service providers may be able to undercut hackney carriage fares, especially if they have a high occupancy rates owing to unmet demand. The competitive constraint exercised by PHVs is likely to be higher in LAs with limited entry in place, where the number of PHV per 1,000 head of population (Phvhd) is generally significantly higher (see Table 2.2).

Given that perceived fares are a blend of regulated and unregulated fares, perceived and regulated daytime fares are expected to be positively correlated. Indeed, the scatterplot of perceived and regulated daytime fares shows a slightly positive relationship between regulated and perceived daytime fares (see Figure 2.1).

[2] The choice of modelling the perceived fare is also consistent with the modelling of waiting time, where both the PHV and hackney carriage markets are covered (although data on excess demand at rank does not include waiting time for PHV journeys, which are generally booked by telephone). For the modelling of quality of service, the PHV market was not covered owing to lack of available information.

Figure 2.1: Scatterplot of regulated and perceived daytime fares, *Fr_t1_2m* (£) and *Threemiletrip* (p)



Note: The observation to the far right is Cherwell, where a mean perceived fare of £8.11 was reported on a base of 491 observations. The median perceived fare in Cherwell was £8.27.
Source: OXERA analysis.

2.3.2 Waiting times

The most accurate measure of waiting time available is drawn from the Halcrow consumer survey, where respondents are asked to report the waiting time for the taxi journey made in the last month. The methodology used to construct a measure of average waiting time from individual data is discussed below:

- *Waitingtime_IND* and *Waitingtime_LA*—the average-waiting-time variable is built on waiting-time data from the Halcrow survey, and has been constructed from the total waiting time at ranks, at home or in the street, according to the way the taxi was obtained. The total waiting time at the rank includes the walking time to reach the rank. If the taxi is booked by telephone and required immediately, the waiting time is defined as the waiting time after acceptance of the booking. If the taxi is booked by telephone but not required immediately, the waiting time is calculated as the differential between the actual and the expected time. Individual observations on waiting time have been used at the individual level (*Waitingtime_IND*), while, at the LA level, *Waitingtime_LA* is defined as the average of waiting time reported by the respondents in that LA.

- *Excessdemand*—data on excess demand is available from Halcrow's unmet-demand studies for 27 of the LAs included in the modelling exercise. Halcrow has calculated excess demand for each hour of the day as the proportion of ranks where there are two or more passengers waiting at any time in the hour. Data is available from 8am until 2am. OXERA has defined daily average excess demand as the average excess demand in the hours between 8am and 2am, weighted by passenger delays (minutes) in each hour, where the weighting accounts for difference in passengers' delay throughout the day. OXERA has also defined average peak excess demand (*Excessdemand_peak*) and off-peak excess demand (*Excessemand_offpeak*) as the weighted average of excess demand between 6pm and 2am and between 8am and 6pm, respectively.

- *Avpassdelay*—data on passenger delays is available from Halcrow's unmet-demand studies, where passenger delay is defined as the average number of minutes waited at each hour of the day (between 8am and 2am). OXERA has calculated average passenger delay at the LA level (*Avpassdelay*) as the average passenger delay between 8am and 2am. OXERA has also defined average peak passenger delay (*Avpassdelay_peak*) and off-peak passenger delay (*Avpassdelay_offpeak*), using the same breakdown defined for excess demand.

2.3.3 Quality of service

The only available evidence on customers' satisfaction with quality of service is drawn from Halcrow's customer surveys, where respondents were asked whether the hackney carriage service could be improved. The *quality_LA* variable is defined at the LA level as the percentage of respondents satisfied with the current level of service (see below for an explanation of how the variable has been constructed). However, this variable is only an imperfect proxy for actual quality of service, given that overall satisfaction could be mainly related to the actual level of fares and number of hackney carriages. Ideally, only customers' perception on the level of quality should be included as an indicator of consumer welfare in the regression model of actual quality of service. To circumvent this problem, the *quality* variable has been restated by recoding as 'dissatisfied customers' only those respondents stating that 'better drivers' and 'better vehicles' are priority improvements for them, and all the other respondents as 'satisfied customers'. Although this is the only possible adjustment to be made to the available quality variable in order to obtain a better proxy for the actual level of quality of service, this adjustment is imperfect, to the extent that respondents who did not state 'better drivers' and 'better vehicles' as priority improvements are also dissatisfied with the actual level of quality of service. For example, it might be that some respondents stated level of fares as a reason of dissatisfaction because this factor was the highest in their priority list, but they would have pointed out other aspects of service that could be improved, had they been given the opportunity. The modelling exercise for the quality of service has been run using both *quality_LA* (*quality_IND* at the individual level) and *quality_dv_IND (quality_dv_IND* at the individual level*)* as dependent variables, although the modelling of *Quality_LA* and *Quality_IND* did not yield any significant result. The results of the modelling are reported in section 8. The construction of the quality-of-service variables is discussed below:

- *Quality_LA* and *Quality_IND*—these variables are based on information from the Halcrow consumer survey where respondents were asked whether the hackney carriage service could be improved. Respondents stating that the service does not need improvement were coded as 'satisfied customers'. The *Quality_IND* variable is defined at the individual level as a dummy variable equal to 1 if the respondent was satisfied with the hackney carriage service. At the LA level, *Quality_LA* is defined as the percentage of respondents satisfied with the hackney carriage service. Respondents stating that improvements in the hackney carriage service could be made have also been asked to report their preferred improvements among the following: 'more taxis', 'more ranks', 'shared taxis', 'better vehicles', 'better drivers', and 'cheaper fares'.

- *Quality_dv_IND* and *Quality_dv_LA*—in the Halcrow consumer survey respondents who identified 'better vehicles' or 'better drivers' as priority improvements were coded as 'customers dissatisfied with the quality of drivers and vehicles provided by the hackney carriage service', while all other respondents were coded as 'satisfied with quality of service'. Hence. *Quality_dv_IND* is defined as a dummy variable equal to 1 if the respondent is satisfied with the quality of drivers and vehicles provided by the hackney carriage service. Similarly, *Quality_dv_LA* is defined as the percentage of respondents who are satisfied with the quality of the vehicles and drivers provided by the hackney carriage service. The key difference between this variable and the above is that the *Quality* variable captures overall satisfaction with hackney carriage service provision, while *Quality_dv* includes only satisfaction with the quality of service.

2.4 Indicators of entry regulation

This section discusses the available indicators of entry regulation, which have informed the econometric modelling. Given that only four of the 30 LAs had fully deregulated entry in the hackney carriage market in 2002, there is not enough variability in the *Entryreg* variable—a dummy variable equal to 1 if entry is fully deregulated—to inform the econometric modelling. Furthermore, this variable does not capture intermediate degrees of entry regulation. Even authorities with regulated entry can issue new licences provided that unmet-demand studies show that there is excess demand in the hackney carriage market. This implies that the dichotomous variable, *Entryreg*, would fail to distinguish between cases of stringent and relaxed entry regulation. This, in turn, suggests that more refined indicators of entry regulation need to be identified for the econometric modelling.

A number of alternative measures to proxy for the stringency of entry regulation have been identified, and these are discussed in turn below.

2.4.1 Indicators related to number of hackney carriages, PHVs and rank spaces

Other factors that could be a proxy for entry regulation include:

- the number of hackney carriages per 1,000 head of population (*Hackvhd*);
- the number of PHVs per 1,000 head of population (*Phvhd*);
- the ratio of PHVs to hackney carriages (*Phvhack*); and
- the number of ranks per head of population (*Rankspop*).

To assess whether the above-listed variables are robust indicators of entry regulation, the 253 LA responses received from the OFT LA survey have been split in two groups according to whether they have entry regulation in place. An equality mean test has then been conducted to explore whether these variables are significantly different across the two groups of LAs. Table 2.5 shows that the mean values of *Hackvhd*, *Phvhd* and *Phvhack* significantly differ between limited and unlimited LAs, while there is no significant difference in the total number of rank spaces per head of population across the two groups of LAs. In particular, the following remarks can be made in relation to the results of the equality mean test.

- *Number of hackney carriages per 1,000 head of population (Hackvhd)*—this is significantly lower in LAs with entry restrictions in place. The hypothesis that the difference in the mean across the two groups is zero is rejected at a 5% significance level. In LAs with entry restrictions in place, the number of hackney carriages available per 1,000 head of population is slightly below 1, while, in fully entry-deregulated LAs, it is equal to 1.2.

- *PHVs per 1,000 head of population (Phvhd)*—there are significantly more PHVs per 1,000 people in LAs with entry restrictions in place. This finding is consistent with the fact that unmet demand (that is not satisfied by hackney carriages) is likely to be higher in markets with entry restrictions in place. Hence, for a given population, taxi markets characterised by excess demand are likely to attract more PHVs.

- *Ratio of PHVs to hackney carriages (Phvhack)*—LAs with entry restrictions in place are found to have higher ratios of PHVs to hackney carriages. LAs with fully deregulated entry are more likely to have a higher number of hackney carriages and a lower of number of PHVs compared with those with regulated entry. The equality mean test rejects at the 10% significance level the hypothesis that the difference in the mean of *Phvhack* across the two groups of LAs is equal to 0.

- *Number of ranks per head of population (Rankspop)*—Table 2.5 shows that the number of total spaces at ranks is not affected by the type of entry regulation in place in the LA. Indeed, the equality mean test accepts the hypothesis that the difference in the mean of *Rankspop* across the two groups of LAs is equal to 0.

Table 2.5: Equality mean tests

	Entry		Equality mean test		Average whole sample
	Unlimited	Limited	H_0: mean diff. = 0	P-value	
Number of hackney carriages per 1,000 head of population (*Hackvhd*)	1.261	0.904	Rejected	0.000	1.089
Number of PHVs per 1,000 head of population (*Phvhd*)	1.048	2.004	Rejected	0.000	1.506
Number of PHVs per hackney carriage (*Phvhack*)	2.162	4.112	Rejected	0.068	3.100
Number of rank spaces per head of population (*Rankspop*)	0.00055	0.00054	Accepted	0.907	0.00055

Note: The null hypothesis of the equality mean test is H_0: mean(unlimited) – mean(limited) = 0.
Source: OXERA analysis.

The equality mean tests examine whether there is a significant difference in the mean between two sub-samples of the dataset—in this case between those LAs where entry is regulated and those where entry is not regulated. These show that there are relatively more hackney carriages per head when entry is unlimited and there are more PHVs per head and per hackney carriage when entry is limited. There are significant differences between regulated and unregulated areas in three out of four proxies for entry regulation, indicating that these three variables may be good proxies for modelling the effects of entry regulation.

2.4.2 Excess demand

OXERA has attempted to assess whether LAs with entry restrictions in place are characterised by significantly higher excess demand. If excess demand were found to be significantly different in LAs which have deregulated entry, excess demand could be used as an indicator for entry regulation.

Data on excess demand was supplied from Halcrow's unmet-demand studies, which have been conducted over a number of years in several LAs and give details of the excess demand for taxis for each hour in a representative day. The years of the Halcrow unmet-demand study are listed for each LA in Table A1.11 in Appendix 1. Information on entry regulation was supplied from Halcrow and matched to the excess demand data. Table 2.6 tests whether there is a statistical difference in each hour between those LAs that limit entry restriction and those that do not. A t-test was formed for each hour to test the hypothesis that the mean excess demand in LAs with limited entry is different to those that with deregulated entry.

Table 2.6: Testing whether excess demand is significantly different in unlimited LAs, by hour

Hour	Was excess demand significantly different in unlimited LAs?	Hour	Was excess demand significantly different in unlimited LAs?
8:00	Not enough observations	18:00	Not enough observations
9:00	Not enough observations	19:00	No
10:00	No	20:00	No
11:00	No	21:00	No
12:00	Yes	22:00	No
13:00	No	23:00	No
14:00	No	24:00	No
15:00	No	1:00	No
16:00	No	2:00	Yes
17:00	No		

The t-tests show that in only two of the hours observed is there a statistical difference between the mean excess demand in areas with limited and unlimited entry. When a pooled sample is tested, no significant difference is found between the mean waiting time in limited and unlimited LAs.

Although the reliability of the results is affected by the low number of observations and the fact that information on entry regulation was not available at the time of the unmet-demand study, this analysis indicates that excess demand does not vary significantly across limited and unlimited LAs.

2.4.3 Summary of entry regulation variables

This section has explored possible indicators of entry regulation to inform the econometric modelling. When the sample is split into two groups on the basis of whether entry regulation is in place or not, the dummy variable, *Entryreg*, is not sufficient to capture the strictness of entry restrictions. Moreover, the variable cannot be used to inform the modelling exercise owing to the limited number of LAs that had fully deregulated entry in the hackney carriage market at the time when the Halcrow consumer survey was undertaken. Hence, it is necessary to look for more refined indicators capturing differences between stringent and relaxed entry restrictions. In the larger sample of OFT data, LAs with fully deregulated entry are characterised by significantly:

- higher number of hackney carriages per 1,000 head of population (*Hackvhd*);
- lower number of PHVs per 1,000 head of population (*Phvhd*);
- lower ratio of PHVs to hackney carriages (*Phvhack*);

- higher excess demand at ranks, but only at 12am and 2am.

Hence, the variables *Hackvhd*, *Phvhd*, *Phvhack* are used in the econometric modelling individually as proxies for entry regulation. Table 2.7 presents a summary of the results of the equality test mean for these three variables.

Table 2.7: Indicators of entry regulation—summary

Indicator of entry regulation	LAs with limited entry	Difference = mean (limited) – mean (unlimited)
Number of hackney carriages per 1,000 head of population (*Hackvhd*)	Significantly lower	–0.357
Number of PHVs per 1,000 head of population (*Phvhd*)	Significantly higher	0.956
Ratio of PHVs to hackney carriages (*Phvhack*)	Significantly higher	1.950

Source: OXERA analysis.

2.5 Other variables

In addition to the dependent variables and the variables for entry regulation, a number of other variables were used in the modelling. Controls for other aspects of the local areas that may influence taxi demand were used and constructed as follows.

- *Precact*—in line with the ONS classification, the proportion of economically active population is defined as the proportion of full-time, part-time and self-employed, full-time students and unemployed as a percentage of regional population aged between 16 and 74. The ONS classifies as economically inactive the following categories: retired, other students, people looking after home/family, permanently sick/disabled, and other.

- *Prunemp*—the proportion of unemployed is defined as the percentage of economically active unemployed across the total population aged between 16 and 74. For consistency, data on population size is also drawn from ONS census data.

- *Density*—defined as the population per hectare of land, as defined by the ONS in the 2001 census.

- *Rural*—in the OFT LA survey, LAs were asked to classify themselves as either rural, urban, or a mix of the two. For the econometric modelling, LAs were classified as rural if they defined themselves as rural or a mix of rural and urban.

3. Analysis of the Interaction between Different Forms of Regulation

This section presents an analysis of the interaction between the different forms of regulation that exist across LAs in the hackney carriage market, using the OFT dataset. In particular, the following are explored:

- the interaction between entry regulation and the level of regulated fares (section 3.1),
- the interaction between quality-of-service regulation and the level of regulated fares (section 3.2),
- the effect of entry and quality-of-service regulation on the level of regulated fares (section 3.3),
- the interaction between entry and quality-of-service regulation (section 3.4), and
- the relationship between entry regulation and application fees to obtain a licence plate/to obtain a licence to drive a hackney carriage (section 3.5).

When considering whether to apply or remove regulations, it is important to understand how the different forms of regulation interact in order to be able to understand fully the effect that any change will have on the existing regime. When regulations are set at the local level and the LA negotiates with the taxi drivers, it may be that different types of regulation are traded off against each other. For example, regulations to improve quality of service may be accompanied by a rise in the regulated fares to cover the extra cost of providing a higher-quality service. Quality-of-service regulation may also act as a barrier to entry in the market, as the high fixed costs in purchasing a Black cab or providing wheelchair access deter potential entrants into the market. In order for changes in regulation to have a positive effect on consumer welfare, the links between the types of regulation and the associated effects on the market need to be explored in full.

3.1 Interaction between entry regulation and level of regulated fares

Fare regulation has been lifted in only 12 of the LAs sampled by the OFT, with all of these also having unlimited entry. This indicates that only a minority of LAs have gone as far as deregulating fares and entry in the hackney carriage market. However, some LAs have removed or relaxed entry restrictions, and this may have influenced the level of regulated fares in that LA, even though fare regulation has remained in place.

The extent to which the level of regulated fares is driven by the type of entry regulation in place can be explored by testing the hypothesis that there is no significant difference in the level of regulated fares between LAs with limited and unlimited restrictions. To conduct this test, the sample of LAs has been split into two according to the type of entry regulation in place at the time of the OFT survey (2002).

The comparison tests reported in Table 3.1 confirm that the mean values of regulated daytime and night-time fares are similar for LAs with limited and unlimited entry. These findings suggest that areas where entry is deregulated do not have significantly different fares to areas where entry is regulated.

Table 3.1: Interaction between entry and level of regulated fares—average fare

	Entry		Equality mean test		Average whole sample
	Unlimited	Limited	H_0: mean diff. = 0	P-value	
Daytime regulated fare (*Fr_t1_2m*)	3.728	3.785	Accepted	0.380	3.756
Night-time regulated fare (*Fr_t2_2m*)	4.960	4.972	Accepted	0.930	4.966

Note: The null hypothesis of the equality mean test is H_0: mean(unlimited) – mean(limited) = 0.
Source: OXERA analysis.

3.2 Interaction between quality-of-service regulation and level of regulated fares

This section explores whether there is any relationship between quality-of-service regulation and the level of regulated fares. Four forms of quality restrictions have been considered for this exercise:

- whether the driver has to take a geographical knowledge test (*Test*);
- provision of wheelchair access (*Disabledaccess*);
- maximum age of vehicles allowed (*Age*); and
- whether only Black cabs are allowed as the type of vehicle (*Blackcabonly*).

A quality-of-service regulation index (*Qualityreg*) has also been constructed as a dummy variable equal to 1 if the LA has in place at least three of the four types of quality-of-service restrictions listed above.

Table 3.2 analyses the interaction between quality-of-service regulation and the level of regulated fares, showing that, on average, fares are not significantly higher in LAs with stringent quality-of-service regulation in place. The equality mean test confirms this result, as the hypothesis that there is no difference in the mean of the level of fares within the two groups of LAs is accepted.

Table 3.2: Interaction between fare and quality-of-service regulation—quality index (*Qualityreg*)

	Quality-of-service regulation		Equality mean test		Average for whole sample
	Not stringent	Stringent	H_0: mean diff. = 0	P-value	
Daytime regulated fare (*Fr_t1_2m*)	3.675	3.779	Accepted	0.204	3.755
Night-time regulated fare (*Fr_t2_2m*)	4.952	4.774	Accepted	0.271	4.895

Note: The null hypothesis of the equality mean test is H_0: mean(not stringent) – mean(stringent) = 0.
Source: OXERA analysis.

3.3 Modelling the factors that influence regulated fares

The analysis presented in the previous two sections shows that there is no significant relationship between the level of regulated fares and entry regulation (section 3.1) and the level of regulated fares and quality-of-service regulation (section 3.2), when each is considered separately. To cross-check the robustness of these results, this section models the effect of entry regulation on the level of regulated fares, controlling for the effect of quality-of-service regulation.

The modelling of daytime regulated fares has been undertaken using the OFT LA survey sample. The hypothesis underlying this modelling is that the fare-setting process is likely to be determined by the relative negotiating power of the parties involved. The degree of concentration in the hackney carriage market is the only proxy available for the negotiating power of the hackney carriage lobby. Other factors that could be taken into account by the LA in setting daytime regulated fares are: demand for daytime taxi journey (proxied by the proportion of people taking the taxi at different times of the day); the regulatory environment (captured by the level of entry restriction and quality-of-service regulation); and the specific characteristics of the LA (in particular, whether the area is urban or rural).

Hence, the following explanatory variables have been tested for inclusion in the general model:

- entry regulation variables matched with the year of the OFT LA survey (2002) (*Entryreg*, *ln_Phvhack*, *ln_Hackvhd* and *ln_Phvhd*);
- quality-of-service regulation (*Test*, *Blackcabonly*, *Testdiff*, *Age*, *Disabledaccess* and *Qualityreg*);
- time of the day (*Time_7am12am_LA*, *Time_12am6pm_LA*, *Time_6pm11pm_LA*, *Time_11pm3am_LA*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

The specific model reported in Table 3.3 suggests that daytime regulated fares are higher in LAs characterised by a lower ratio of PHVs to hackney carriages. This implies that regulated fares tend to be higher in LAs with unlimited entry in place, as indicated by a lower ratio of PHVs to hackney carriages. The size of the effect is very small, only around 0.5% different. Regulated fares also appear to be higher in LAs requiring hackney carriage drivers to pass a geographical knowledge test of the area.

Some caution in the interpretation of the results is needed, given that the market-share indicator is unlikely to capture fully the relative negotiating power of the parties involved in the fare-setting process, which is likely to be a determining factor in the process of setting regulated fares. Not accounting for this key factor might help explain the low explanatory power of the model, as indicated by the low R^2 of the regression. Thus, overall, it is difficult to find a good explanation of regulated fares and the only clear interaction is that areas where quality-of-service regulation is stricter have higher regulated fares.

Table 3.3: Specific ordinary least squares model (OLS), regulated fares at LA level (OFT LA survey)

ln_fr_t1_2m	Coefficient	Standard error	t-value	p- value
Ln_phvhack (OFT)	–0.016	0.006	–2.77	0.006
Test	0.045	0.017	2.65	0.009
Density	0.002	0.001	2.65	0.009
Constant	1.274	0.013	101.67	0.000
Number of observations	226			
F(3,222)	9.01			
Probability > F	0.000			
R-squared	0.109			
Adjusted R-squared	0.097			
Root MSE	0.112			
		Value	**Probability**	
RESET F(3,219)		0.210	0.891	
Heteroscedasticity		0.57	0.451	
Skewness/kurtosis		3.460	0.177	

Source: OXERA analysis.

3.4 Interaction between entry and quality-of-service regulation

The relationship between entry and quality-of-service regulation has been explored by testing whether quality-of-service regulation is significantly more stringent in LAs with entry restriction in place (section 3.4.1). Given that the correlation analysis has shown that rural areas are more likely to be characterised by unlimited entry and relaxed quality-of-service regulation in the hackney carriage market (see section 3.4.2), it is important to control for the effect of the rural factor in analysing the relationship between quality-of service and entry regulation. To do this, entry regulation has been modelled in section 3.4.2 as a function of quality-of-service regulation and number of people per hectare, which are the best proxies available for rural areas.

3.4.1 Descriptive analysis

Tables 3.4 to 3.8 show that LAs with entry restrictions are also more likely to have stringent quality-of-service regulation measures in place. For example, only 55.6% of LAs with unlimited entry require drivers to pass a geographical knowledge test, against 69.6% of LAs with entry restrictions in place. These findings suggest that those LAs that have deregulated entry in the hackney carriage market also have relaxed quality-of-service restrictions.

Table 3.4: Interaction between entry and quality-of-service regulation—knowledge test (*Test*)

'Are applicants for a licence to drive a taxi required to undertake a test of their local geographical knowledge?'	Entry		Total
	Unlimited	**Limited**	
No test	59 (44.7%)	37 (31.6%)	96
Test	73 (55.2%)	80 (68.4%)	153
Total	**132**	**117**	**249**

Note: The percentages within brackets are calculated across the total number of LAs with unlimited and limited regulation.
Source: OXERA analysis.

Table 3.5: Interaction between entry and quality-of-service regulation—provision of wheelchair access (*Disabledaccess*)

'Do all licensed taxis have to make special provision for wheelchair access?'	Entry		Total
	Unlimited	**Limited**	
No	111 (84.1%)	97(82.9%)	208
Yes	21 (15.9%)	20 (17.1%)	41
Total	**132**	**117**	**249**

Note: See Table 3.4.
Source: OXERA analysis.

Table 3.6: Interaction between entry and quality-of-service regulation—maximum age of vehicles allowed (*Age*)

'Is there a maximum age for vehicles used as a taxi?'	Entry		Total
	Unlimited	**Limited**	
No	71 (56.3%)	54 (49.1%)	125
Yes	55 (43.7%)	56 (50.9%)	111
Total	**126**	**110**	**236**

Note: See Table 3.4.
Source: OXERA analysis.

Table 3.7: Interaction between entry and quality-of-service regulation—Black cab only allowed (*Blackcabonly*)

Only black cabs are allowed as type of vehicle	Entry		Total
	Unlimited	**Limited**	
No	113 (89.0%)	86 (76.1%)	199
Yes	14 (11.0%)	27 (23.9%)	41
Total	**127**	**113**	**240**

Note: See Table 3.4.
Source: OXERA analysis.

Table 3.8: Interaction between entry and quality-of-service regulation—quality index (*Qualityreg*)

Quality-of-service regulation	Entry		Total
	Unlimited	Limited	
Not stringent	80 (77.7%)	50 (61.0%)	130
Stringent	23 (22.3%)	32 (39.0%)	56
Total	**103**	**83**	**186**

Note: See Table 3.4.
Source: OXERA analysis.

3.4.2 Modelling the factors that influence entry regulation

A more formal approach to assessing whether there is a relationship between quality-of-service regulation and entry regulation has also been undertaken, using a logistic regression methodology to identify the factors that influence entry regulation. Many rural or sparsely populated areas do not have entry regulation and *Rural* and *Density* were used along with the quality-of-service regulation index to examine whether there is a significant relationship between entry regulation and quality-of-service regulation. The quality-of-service regulation index was not significant in itself, so the components of the index were included instead. The model produced is shown in Table 3.9.

Table 3.9: Interaction between entry and quality-of-service regulation—logistic regression

Entry regulation	Coefficient	Standard error	z	P>|z|
Blackcabonly	–0.873	0.443	–1.970	0.049
Density	0.090	0.017	5.170	0.000
Constant	–0.745	0.181	–4.120	0.000

Source: OXERA analysis.

The modelling shows that the rural factor has a significant effect on the type of entry regulation, and that, after controlling for this factor, quality-of-service restrictions other than on the type of vehicle are not significantly related to entry restriction. Hence, the relationship between entry restriction and other forms of quality-of-service regulation found in section 3.4.1 is likely to be spurious and accounted for by the rural factor. On the other hand, even after controlling for the rural factor, restriction on the type of vehicle allowed (*Blackcabonly*) appears to affect the choice of deregulating the hackney carriage market. This result suggests that entry restrictions are more likely to be removed in LAs with restrictions on the type of vehicle in place, which could be explained by the fact that restrictions on the type of vehicle can substitute for direct entry restriction by acting as an entry barrier. This effect is only just significant at the 5% level.

3.5 Interaction between entry regulation and application fees

As shown in Table 3.10, LAs with unlimited entry tend to charge lower average application fees than those with entry restrictions. The equality mean test reported in Table 3.10 shows that this difference is significant for initial and renewal fees charged to license a hackney carriage. Although the average (initial and renewal) fees charged to drive a hackney carriage are also slightly lower in LAs with unlimited entry, the difference is not statistically significant.

Table 3.10: Charges made to license applicants, by type of entry regulation

	Entry		Equality mean test		Average for whole sample
	Unlimited	Limited	H_0: mean diff. = 0	P-value	
Fees charged for initial application to drive a hackney carriage	69.5	75.3	Accepted	0.333	72.1
Renewal fee to existing hackney drivers	59.3	67.7	Accepted	0.182	63.1
Fee charged to initial application to license a hackney	149.8	193.5	Rejected	0.001	169.7
Renewal fee for hackney licence	143.5	180.0	Rejected	0.002	160.6

Note: See Table 3.1 and 3.2.
Source: OXERA analysis.

3.6 Conclusions

This section has explored the interaction between various forms of regulation in the hackney carriage market across a number of LAs in the UK. While the conclusions that can be drawn from this exercise have been summarised in Table 3.11, the following points are of particular importance for the econometric modelling.

- The analysis of the effect of entry and quality-of-service regulation on the level of regulated fares does not yield definitive and consistent results. Indeed, the results of the equality mean tests suggest that the type of entry regulation in place and the strictness of quality-of-service regulation do not affect the level of regulated fares. On the other hand, the modelling exercise has shown that, after controlling for the effect of quality-of-service regulation, LAs characterised by a lower ratio of PHVs to hackney carriages are more likely to have slightly higher regulated fares. Given that lower ratios of PHVs to hackney carriages are associated with unlimited entry, the modelling suggests that LAs with entry regulation in place are likely to have lower regulated fares.[3] It is very difficult to control for the negotiating process associated with the setting of regulated fares, indicated by the low explanatory power of this model.

- LAs with no entry restrictions have generally also had lower levels of quality-of-service regulation. However, the positive relationship between entry and quality-of-service regulation appears to be determined by the rural factor, given that many rural areas appear to have deregulated (or relaxed) entry in the hackney carriage market and are also more likely to have less stringent quality-of-service regulation in place.

[3] The results from the modelling of regulated fares conflict with those from the modelling of perceived fares, as described in section 4. The reasons for using the results based on modelling perceived fares are set out in section 4.

Table 3.11: Relationships between various forms of regulation—summary

Type of regulation	Relationship	Remark
Entry regulation and fare regulation	Limited evidence that where entry is regulated fares are also regulated	All 12 LAs with unregulated fares also have deregulated entry. However, they amount to only 8.9% of LAs with deregulated entry.
Entry regulation, quality-of-service regulation and the level of regulated fares	Negative effect of entry regulation on level of regulated fares, after controlling for quality-of-service regulation Positive effect of quality-of-service regulation on level of regulated fares, after controlling for entry regulation	The relative negotiating power of the parties involved is difficult to measure and to capture in the modelling of regulated fares. Given the key impact of this factor in the setting of regulated fares, caution is needed in interpreting these results as the model's explanatory power was found to be very poor.
Entry regulation and quality-of-service regulation	Positive correlation between quality-of-service regulation and entry restrictions. The effect disappears after controlling for the rural factor.	LAs with no entry regulation have less stringent quality-of-service regulation in place. The positive relationship is determined by the rural factor, with rural areas more likely to have deregulated entry and less stringent quality-of-service regulation in place.
Entry regulation and level of application fees	Positive effect of entry regulation on application fees to obtain a hackney carriage licence	Removal of entry restriction is associated with lower application fees to obtain a hackney carriage licence

Source: OXERA analysis.

4. Modelling the Level of Fares

As reported in 'Taxi Markets Literature Review', the level of fares has been identified in the available literature as one of the key determinants of consumer welfare in taxi markets. Hence, it is of paramount importance to identify and quantify the links between the regulatory environment and the level of actual fares.

In the dataset used for the modelling, the possibility of capturing the full impact of different regulatory environments on the actual level of fares is partly limited by the fact that hackney carriage fares are regulated in all LAs, which implies that hackney carriage service providers cannot raise fares above the cap set by the LA. On the other hand, some variability in the data is ensured by the fact that actual hackney carriage fares are allowed to fall below the cap and PHV fares are able to respond to changes in the regulatory environment, given that they are not subject to regulation.

Perceived fare, as defined in section 2.3, was used instead of the regulated fare for the following three reasons:

- perceived fare is a blended fare of PHV and hackney carriage fares, and captures the interaction between the two markets;
- in some areas, the regulated fare is not a prescribed, standard fare, but a maximum, and consumers may be able to barter an alternative arrangement;
- regulated fares may well be a result of the negotiating process between the taxi lobby and the LA.

The interaction between actual regulated fares and other forms of regulation is examined in section 3.

The rest of this section is structured as follows: section 4.1 presents the results of the modelling at the LA level, while section 4.2 presents the econometric results of the modelling of individual data. Finally, section 4.3 concludes.

4.1 Modelling daytime perceived fares at the LA level

This modelling exercise aims to capture the impact of the regulatory environment, namely entry and quality-of-service regulation, on the level of perceived fares. The theoretical framework highlighted in 'Taxi Markets Literature Review' suggests that entry deregulation can put downward pressure on fares if it spurs price competition, while upward pressure is also a possible outcome if entry deregulation leads to higher costs due to lower occupancy rates. Hence, the theoretical framework highlights that an empirical investigation is required to quantify the forces at work and disentangle the offsetting effects.

In relation to the impact of quality-of-service regulation on the level of perceived fare, the underlying economic theory suggests that stringent quality-of-service regulation is likely to lead to higher fares, as it represents an additional cost in the provision of hackney carriage service. On the other hand, quality-of-service regulation is generally more stringent for hackney carriages than for PHVs. Given that hackney carriage fares are regulated, whether stringent quality-of-service regulation leads to higher regulated fares also depends on the negotiating process determining the setting of the fares.

To identify the impact of entry and quality-of-service regulation on the level of perceived fares, it is necessary to control in the modelling for all other variables that can affect the level of fares, such as the rural factor, the level of the economic activity, and the concentration ratio in the taxi markets.

The methodology used for the modelling is general-to-specific. A general model is initially specified which encompasses all the factors that could, in theory, have a potential impact on the level of fares. The variables that are not found to have a significant impact on the level of fares are dropped out of the regression until a specific model including only the variables significantly affecting level of fares is identified. (General-to-specific modelling is described in detail in Appendix 3.) The remainder of this section presents the specification of the general model and the results of the specific model.

4.1.1 General model

On the basis of the hypothesis highlighted above, the following explanatory variables have been tested for inclusion in the general model on the basis of their economic relevance:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_Hackvhd*, *ln_Phvhd*);
- quality-of-service regulation (*Disabledaccess*, *Test*, *Testdiff*, *Age*, *Blackcabonly*, *Qualityreg*);
- way to obtain a taxi (*Rank_LA*, *Street_LA*)
- time of the day (*Time_11pm3am_LA*, *Time_7am12am_LA*, *Time_12am6pm_*LA, *Time_6pm11pm_LA* and *Time_11pm3am_LA*);
- economic activity (*Precoact* and *Prunemp*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

4.1.2 Specific model

The specific model reported in Table 4.1 shows that both entry regulation and quality-of-service regulation exercise upward pressure on level of fares, although the proxy for entry regulation is only significant at the 6% significance level. The level of economic activity has the expected sign, with the level of regulated fares being higher, the lower the proportion of unemployed population. The concentration ratio (*Mktshare*) is significant, but the effect on the level of fares is close to zero. The model fails the omitted variable (RESET) test. Appendix 3 provides a detailed description of the summary output and diagnostic tests reported in Table 4.1.

Table 4.1: Specific model, perceived fare at LA level

Ln_Threemiletrip_LA	**Coefficient**	**Standard error**	**t-value**	**P-value**
Ln_phvhack (Halcrow unmet demand studies)	0.079	0.379	2.08	0.060
Disabledaccess	0.361	0.102	3.54	0.004
Prunemp	–0.120	0.039	–3.07	0.010
Mktshare	0.004	0.001	2.59	0.023
Constant	6.375	0.146	43.67	0.000
Number of observations	17.000			
F(4,12)	6.03			
Probability > F	0.007			
R-squared	0.668			
Adjusted R-squared	0.557			
Root MSE	0.137			
		Value	**Probability**	
RESET F(3,9)		6.89	0.011	
Heteroscedasticity		0.19	0.660	
Skewness/kurtosis		1.14	0.566	

Source: OXERA analysis.

4.2 Modelling perceived fares at the individual level

As well as modelling the data at the LA level, OXERA has sought to determine the key factors that influence the level of fares using the data in disaggregated form—ie, using each individual's response. The advantage of modelling the level of perceived fares at the individual level arises from more variability in the data and a larger dataset. To capture the effect of regulation (which arises at the LA rather than the individual level), the appropriate regulation variables related to the relevant LA are attached to the individual responses to the Halcrow survey.

4.2.1 General model

The general model for perceived fares includes the variables specified at the LA level and an additional variable controlling for the purpose of the trip. Hence, the following explanatory variables have been tested for inclusion in the general model on the basis of their economic relevance:

- entry regulation variables matched with the year of Halcrow consumer survey (*ln_Phvhack*, *ln_Hackvhd*, *ln_Phvhd*);
- economic activity (*Precoact* and *Prunemp*);
- rural versus urban areas (*Rural* and *Density*);
- way to obtain a taxi (*Street_IND*, *Telephone_IND*)
- time of the day (*Time_11pm3am_IND*, *Time_7am12am_IND*, *Time_12am 6pm_IND*, *Time_6pm11pm_IND* and *Time_11pm3am_IND*);
- market share (*Mktshare*);
- quality-of-service regulation (*Disabledaccess*, *Test*, *Testdiff*, *Age*, *Blackcabonly*, *Qualityreg*);
- business purpose of the trip (*Business*).

4.2.2 Specific model

The results of the modelling at the individual level are similar to those at the LA level. In particular, as with the modelling at the LA level, entry and quality-of-service regulation are shown to have a positive impact on level of fares. The quality-of-service regulation index (*Qualityreg*) is the indicator of quality-of-service regulation, which is significant in this model specification, while the provision of wheelchair access was identified as the only form of quality-of-service regulation having an impact on fares in the modelling at LA level.

The effect of the control variables is also similar, with economic activity having a positive impact on the level of perceived fares and the concentration ratio a negligible effect. In this model specification, the rural factor, which was not significant in the modelling at the LA level, is shown to have a negative effect on the level of perceived fares. This effect can be explained by the fact that the reduced congestion characterising rural areas shortens journey times and, hence, reduces the level of fares.

The modelling fails the omitted variable and the normality test. This implies that the standard errors—and hence confidence in the significance of the results—are diminished. However, this should not have a material impact on the point estimates of the coefficients.

Table 4.2: Specific model, perceived fare at individual level

Ln_Threemiletrip_IND	Coefficient	Standard error	t-value	P-value
Ln_Phvhack (Halcrow, unmet demand studies)	0.099	0.006	15.79	0.000
Qualityreg	0.070	0.028	2.52	0.012
Rural	–0.228	0.302	–7.55	0.000
Precoact	0.049	0.003	18.81	0.000
Mktshare	–0.001	0.000	–2.88	0.004
Constant	3.072	0.141	21.78	0.000
Number of observations	3,017			
F(5,3011)	151.09			
Probability > F	0.000			
R-squared	0.201			
Adjusted R-squared	0.199			
Root MSE	0.315			
		Value	**Probability**	
RESET F(3,3008)		81.27	0.000	
Heteroscedasticity		1.91	0.167	
Skewness/kurtosis		67.29	0.000	

Source: OXERA analysis.

4.3 Conclusions

The modelling of the perceived fare yields significant results on the impact of entry and quality-of-service regulation on the level of fares, summarised in Table 4.3. In general, the identified links between regulatory environment and the level of fares are consistent between the two models.

Table 4.3: Effect of entry and quality-of-service regulation on the level of perceived fares—summary

	Indicator	Effect on level of fares	Implied effect of deregulation on level of perceived fares
Entry regulation			
LA level	Ratio of PHVs to hackney carriages	Positive	3.9% fall in daytime fares for a 3mile trip
Individual level	Ratio of PHVs to hackney carriages	Positive	4.9% fall in daytime fares for a 3 mile trip
Quality-of-service regulation			
LA level	Provision of wheelchair access (*Disabledaccess*)	Positive	1p increase in fare per journey associated with provision of wheelchair access
Individual level	Quality-of-service regulation index (*Qualityreg*)	Positive	1.48p increase in fare per journey associated with stringent quality-of-service regulation

Source: OXERA analysis.

Entry regulation, whose theoretical link with level of fares is ambiguous, is found in both of the modelling exercises to have a positive impact on level of fares. This implies that, following entry deregulation, the increase in price competition outweighs the increase in cost due to lower occupancy rate, and leads to a fall in the level of fares. The ratio of PHVs to hackney carriages is the indicator of entry regulation identified as significant in the modelling of perceived fares. The modelling suggests that deregulating entry would lead to a fall in the level of daytime fares for a 3-mile trip of between 3.9% and 4.9%. This estimated value is based on the hypothesis that deregulating entry leads to a 49% fall in the ratio of PHVs to hackney carriages, which is based on the results of the equality mean tests reported in section 4. Hence, an elasticity of level of fares with respect to the ratio of PHVs to hackney carriages equal to 0.079 (0.099), as identified in the modelling at LA (individual) level, implies that, following entry deregulation, a 49% reduction in the ratio of PHVs to hackney would lead to a 3.9% (4.9%) reduction in the level of fares. This result is formed from cross-sectional observations on the difference in mean values between entry-regulated and non-entry-regulated LAs. A more accurate assessment of the effect of deregulation might be obtained if time-series data were available on the number of PHVs per hackney carriage, before and after deregulation.

As expected, quality-of-service regulation is shown in both models to have a positive impact on the level of fares. In particular, the models at the LA level show that when taxis have to make special provision for wheelchair access, the level of fares increases by 1p per journey. Similarly, the models at the individual level show that stringent quality-of-service regulation is associated with a 1.48p increase in fare per journey.

5. Modelling Waiting Time

Expected passenger waiting time is generally considered to be of high value to the quality of the services received by passengers. This section follows the OXERA literature survey and the results of the RP study, where 86% of respondents rated waiting time in the 'high' importance category. The modelling here attempts to show which factors, particularly those relating to regulation, have a significant impact on consumers' waiting time.

Waiting times are not only significant welfare factors by themselves, but also play an important role in determining the level of demand and the resulting equilibrium in the market.

Waiting time depends on supply in the market, which is in turn a function of the occupancy rates of taxis, the number in service, and the equilibrium demand for taxi services. Hence, unless there is an oversupply of taxis, there will be a negative externality, as one consumer's demand will increase waiting time for all other consumers, reducing the utility that they receive from the service if the market is capacity-constrained in any way. This may in turn influence the level of demand, since an increase in waiting times will reduce the demand of potential consumers.[4]

Drawing on the results of the literature survey, the modelling sets out to test whether entry regulation significantly increases the amount of time consumers wait for a taxi. Control variables account for the circumstances in which the taxi is caught, such as time of day and whether it was booked by phone or hailed in the street, and the local socio-demographics (economic activity, market share and population density).

5.1 Modelling waiting time results

5.1.1 Modelling waiting time at the LA level

The dependent variable is waiting time for all methods of obtaining a taxi (from a rank, in the street, or by telephone). This includes time spent walking to the rank as well as waiting at the rank, and any time deviation from the expected time when booking a taxi by telephone.

General model

The following explanatory variables have been included in the general model to explain waiting times on the basis of their economic relevance:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_hackvhd*, *ln_phvhd*);
- the method used to obtain a taxi (*Street_LA* and *Telephone_LA*);
- economic activity (*Precoact* and *Prunemp*);

[4] This is discussed in 'Taxi Market Literature Review', section 2.2.

- time of the day (*Time_7am12am_LA*, *Time_12am6pm_LA*, *Time_6pm11pm_LA* and *Time_11pm3am_LA*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

Specific model

The model of waiting times was estimated using the Tobit model to account for the truncated nature of the data (see Table 5.1). The preferred model does not include the proxy for entry, as it is has fallen out due to being insignificant. When it is included in the regression (see Table 5.2), it displays a positive sign, indicating that, although not significant at the 5% confidence level, restricting entry can lead to longer waiting times.

Table 5.1: Specific Tobit model, waiting time at LA level

ln_Waitingtime_LA	Coefficient	Standard error	t-value	P-value
Telephone_LA	–0.010	0.004	–2.56	0.018
Street_LA	0.013	0.006	2.25	0.035
Time_7am12am_LA	–0.017	0.013	–1.34	0.194
Time_12am6pm_LA	–0.028	0.014	–2.00	0.058
Time_6pm11pm_La	–0.021	0.014	–1.55	0.134
Time_11pm3am_LA	0.000	0.013	–0.04	0.972
Constant	3.491	1.353	2.58	0.017
Number of observations	28.000			
Number of censored observations	0.000			
LR chi2(7)	50.07			
Prob > chi2	0.000			
Link test	fails			
Pseudo R-squared	1.4053			

Source: OXERA analysis.

Table 5.2: Specific Tobit model, waiting time at LA level (with entry regulation)

ln_Waitingtime_LA	Coefficient	Standard error	t-value	P-value
ln_phvhack (Halcrow unmet demand studies*)*	0.036	0.036	1.01	0.328[5]
Telephone_LA	–0.010	0.004	–2.28	0.037
Street_LA	0.013	0.007	1.78	0.094
time_7am12am_LA	–0.023	0.015	–1.57	0.137
time_12am6pm_LA	–0.037	0.017	–2.19	0.044
time_6pm11pm_LA	–0.026	0.016	–1.63	0.123
time_11pm3am_LA	–0.006	0.015	–0.40	0.695
Constant	4.043	1.527	2.65	0.018
Number of observations	23			
Number of censored observations	0.000			
LR chi2(7)	40.54			
Prob > chi2	0.000			
Link test	fails			
Pseudo R-squared	1.363			

Source: OXERA analysis.

5.1.2 Modelling waiting time at rank at LA level

Alternative dependent variables to measure waiting time were used in the form of excess demand and average passenger delay from Halcrow unmet-demand studies. Excess demand is defined as the proportion of ranks with two or more people waiting at them in any given hour. By definition, this variable is only available for those catching taxis from ranks.

General model

The following explanatory variables have been included in the general model:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_hackvhd*, *ln_phvhd*);
- the method used to obtain a taxi (*Rank_LA*);
- economic activity (*Precoact*, *Prunemp*);
- time of the day (*Time_11pm3am_LA*, *Time_7am12am_LA*, *Time_12am6pm_LA*, *Time_6pm11pm_LA and Time_11pm3am_L*A);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

[5] Not significant at the 5% level, but included to indicate the direction of the effect of entry regulation.

Specific model

The specific model for waiting times has a significant entry regulation proxy in the form of the number of hackney carriages per head of population. More hackney carriages lead to lower waiting times, indicating that when the number of hackney carriages is restricted, waiting times increase. The dummy variable for rural versus urban was also significant, showing that waiting times are lower in rural areas, possibly due to lower demand and less congestion.

Table 5.3: Specific Tobit model, waiting time at rank (8am–2am)

Excessdemand	**Coefficient**	**Standard error**	**t-value**	**P-value**
ln_hackvhd (Halcrow unmet demand studies*)*	–0.17382	0.05174	–3.36	0.003
Rural	–0.37337	0.07455	–5.01	0.000
Constant	0.47704	0.04522	10.55	0.000
Number of observations	26			
Number of censored observations	1			
LR chi2(2)	19.18			
Prob > chi2	0.000			
Link test	Pass			
Pseudo R-squared	0.082			

Source: OXERA analysis.

Tables 5.4 and 5.5 show that similar results were found when examining peak and off-peak markets separately.

Table 5.4: Specific Tobit model, waiting time at rank—peak (6pm—2am)

Excessdemand_peak	**Coefficient**	**Standard error**	**t-value**	**P-value**
Ln_Hackvhd (Halcrow unmet demand studies*)*	–0.24369	0.04924	–4.95	0.000
Rural	–0.36371	0.07089	–5.13	0.000
Constant	0.46022	0.04274	10.77	0.000
Number of observations	26			
Number of censored observations	1			
LR chi2(2)	23.46			
Prob > chi2	0.000			
Link test	Pass			
Pseudo R-squared	0.100			

Source: OXERA analysis.

Table 5.5: Specific Tobit model, waiting time at rank—off-peak (8am–6pm)

Excessdemand_offpeak	**Coefficient**	**Standard error**	**t-value**	**P-value**
Ln_Hackvhd (Halcrow unmet demand studies*)*	–0.10818	0.07854	–1.38	0.181
Rural	–0.33078	0.011342	–2.92	0.008
Constant	0.33796	0.06895	4.90	0.000
Number of observations	26			
Number of censored observations	1			
LR chi2(2)	7.26			
Prob > chi2	0.027			
Link test	Pass			
Pseudo R-squared	0.033			

Source: OXERA analysis.

5.1.3 Modelling waiting time at rank using average passenger delay

Data on average passenger waiting time was available from the Halcrow unmet-demand studies. The model was run with (the log of) average passenger delay as a dependent variable to proxy waiting time. This data is only available for those waiting at ranks.

General model

The following explanatory variables have been included in the general model:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_hackvhd*, *ln_phvhd*);
- the method used to obtain a taxi (*Rank*);
- economic activity (*Precoact*, *Prunemp*);
- time of the day (*Time_7am12am_LA*, *Time_12am6pm_LA*, *Time_6pm11pm_LA* and *Time_11pm3am_LA*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

Specific model

Only the rural dummy variable is significant in modelling average passenger delay, highlighting that waiting times in rural areas are lower than in urban areas.

Table 5.6: Specific OLS model—average passenger delay

Ln_avpassdelay	**Coefficient**	**Standard error**	**t-value**	**P-value**
Rural	–1.169	0.341	–3.43	0.002
Constant	0.221	0.232	0.95	0.350
Number of observations	26			
F(1,24) =	11.75			
Probability > F	0.002			
R-squared =	0.329			
Adjusted R-squared	0.301			
Root MSE =	0.867			
		Value	**Probability**	
Heteroscedasticity		1.39	0.238	
Skewness/kurtosis		0.89	0.640	

Source: OXERA analysis.

Modelling the data in peak and off-peak markets leads to the same result as when modelling the day as a whole (see Tables 5.7 and 5.8).

Table 5.7: Specific OLS model—average peak passenger delay (6pm–2am)

Ln_avpassdelay_peak	**Coefficient**	**Standard error**	**t-value**	**P-value**
Rural	–1.012	0.419	–2.42	0.024
Constant	0.568	0.278	2.05	0.052
Number of observations	25			
F(1,23) =	5.85			
Probability > F	0.024			
R-squared =	0.202			
Adjusted R-squared	0.168			
Root MSE =	1.039			
		Value	**Probability**	
Heteroscedasticity		0.09	0.763	
Skewness/kurtosis		4.38	0.112	

Source: OXERA analysis.

Table 5.8: Specific OLS model—average passenger delay (off-peak, 8am–6pm)

Ln_avpassdelay_offpeak	**Coefficient**	**Standard error**	**t-value**	**P-value**
Rural	–1.124	0.551	–2.04	0.053
Constant	–0.743	0.382	–1.94	0.064
Number of observations	25			
F(1,24) =	4.16			
Probability > F	0.053			
R-squared =	0.153			
Adjusted R-squared	0.116			
Root MSE =	1.377			
		Value	**Probability**	
Heteroscedasticity		1.17	0.278	
Skewness/kurtosis		6.48	0.039	

Source: OXERA analysis.

5.1.4 Modelling waiting time at the individual level

OXERA was able to construct a total waiting time variable for each respondent to the Halcrow surveys, whether they obtained their taxi in the street, at a rank, or booked it by phone. Modelling at the individual level allows much more detail to be gained on actual waiting times and journeys. However, the regulation variables are common to all respondents in an LA.

General model

The following explanatory variables have been included in the general model:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_hackvhd*, *ln_phvhd*);
- the method used to obtain a taxi (*Street_IND* and *Telephone_IND*);
- economic activity (*Precoact* and *Prunemp*);
- time of the day (*Time_7am12am_IND*, *Time_12am6pm_IND*, *Time_6pm11pm_IND* and *Time_11pm3am_IND*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*);
- business trip (*Business*).

Specific model

The specific model of waiting time for individuals (see Table 5.9) shows that the proxy for entry regulation (*ln_phvhack*—the number of PHVs per hackney carriage) has a positive impact on waiting times. Where entry regulation is more stringent for hackney carriages, there is likely to be a higher ratio of PHVs to hackney carriages.

Business users appear to be more time-sensitive than non-business users, possibly investigating alternative modes of transport more quickly than non-business users who may be prepared to wait.

Table 5.9: Specific OLS model—waiting time at individual level

ln_waiting time_IND	**Coefficient**	**Standard error**	**t-value**	**P-value**
ln_phvhack (Halcrow unmet demand studies*)*	0.053	0.021	2.48	0.013
business	–0.339	0.079	–4.29	0.000
time_7am12am_IND	–0.021	0.008	–2.57	0.010
time_12am6pm_IND	–0.030	0.009	–3.49	0.001
time_6pm11pm_IND	–0.020	0.008	–2.47	0.013
time_11pm3am_IND	–0.017	0.008	–2.20	0.028
Constant	4.064	0.710	5.73	0.000
Number of observations	1,631			
F(6,1624) =	5.82			
Probability > F	0.000			
R-squared =	0.021			
Adjusted R-squared	0.017			
Root MSE =	0.914			
		Value	**Probability**	
RESET F(3,1624)		1.270	0.282	
Heteroscedasticity		2.68	0.101	
Skewness/kurtosis		13.750	0.001	

Source: OXERA analysis.

5.2 Conclusions of waiting time modelling

The individual models of waiting time have been estimated in section 5.1. The preferred specification was that which used waiting times at the individual level, as this gave the most observations and greatest variation, while still taking into account waiting times from all three methods of obtaining a taxi.

Where entry regulation is more stringent for hackney carriages there is likely to be a higher ratio of PHVs to hackney carriages. The model indicates that, as entry regulation is tightened and the ratio of PHVs to hackney carriages rises, waiting times get longer.

Business users appear to be more time-sensitive than non-business users, possibly investigating alternative modes of transport more quickly than non-business users who may be prepared to wait or possibly choosing the mode of obtaining a taxi that minimises waiting time.

Table 5.10 summarises the effects on waiting times of entry regulation.

Table 5.10: Waiting time modelling results—summary

Dependent variable	Entry proxy	Coefficient	t-statistic	Implied effect of no entry regulation (%)
Waiting time for individuals (preferred model)	PHV per hackney carriage	0.05	2.48	–2.4
Waiting time (averaged across LAs)	PHV per hackney carriage	0.04[6]	1.01	–1.7
Excess demand—total	Hackney carriage per head	–0.17	–3.36	–6.9
Excess demand—peak	Hackney carriage per head	–0.24	–4.95	–9.6
Excess demand—off-peak	Hackney carriage per head	–0.11	–1.38	–4.3

Note: The implied effect is calculated by multiplying the percentage difference between limited and unlimited areas, see Table 5.1, by the coefficient value (see Appendix 4). For a discussion on the indicators of entry regulation, see section 3.
Source: OXERA analysis.

Modelling waiting times using several different dependent variables has shown that waiting times are slightly longer in LAs with higher numbers of PHVs per hackney carriage, which are more likely to have entry restriction in place. Similarly, when looking at ranks, waiting times fall when there are more hackney carriages per head. The modelling suggests that waiting times will fall by around 2% and excess demand will fall by around 7% when entry restrictions are lifted.[7] Entry regulation appears to have a greater effect on excess demand at peak times than off-peak times—the highest elasticity of 9.6% was achieved when examining peak periods only. In the preferred model, removing entry restrictions would lead to a 2.4% reduction in an individual's average waiting time.

Waiting times are lower in rural areas, possibly due to the greater use of telephone booking and lower congestion levels. People travelling for business purposes are likely to wait less time for a taxi, possibly because they are less price-sensitive and are likely to search for alternative modes sooner. As expected, waiting time is longest between 11pm and 3am.

The other controlling variables behave as expected. Booking a taxi by telephone leads to a lower waiting time than waiting at the rank, whereas hailing one in the street takes longer than at a rank.

As noted above, waiting times vary according to the interaction between supply and demand. Therefore, without knowledge of both demand and supply elasticities, it is not possible to predict with certainty the relationship between the level of demand and

[6] The coefficient is insignificant.
[7] Although the implied effect of regulation on waiting times was 1.7% using data at the LA level, this estimate was not statistically significant.

waiting times. However, provided that supply is not fully elastic with respect to demand, waiting times can be expected to increase as demand increases. The time variables also behave according to these expectations; the peak hours for taxis are after 11pm and, in the specific model above, this is associated with the longest waiting times.

6. Modelling Quality of Service

The modelling of quality of service aims to identify the impact of the regulatory environment on quality of service. The theoretical framework highlighted in ‘Taxi Markets Literature Review’ suggests that quality-of-service regulation should have a positive impact on quality of service. The literature review also suggests that entry regulation may have a positive impact on quality of service, as the barrier to entry enables licence-holders to compete on non-price grounds. However, the overall effect is unclear, as entry regulation may protect the existing market and reduce the need to invest in quality of service. Quality-of-service regulation is likely to have a positive impact on actual quality of service, by setting a minimum required level.

To identify the effect of entry and quality-of-service regulation on the level of quality of service, all other factors that could have an impact on quality of service need to be identified and included in the general model. As for the modelling of perceived fares and waiting time, the characteristics of the LAs that have been identified as potentially affecting quality of service are the level of economic activity, the rural factor, and market concentration.

The remainder of this section presents the results of the modelling of quality of service at the LA level (section 6.1) and the individual level (section 6.2).

6.1 Modelling quality of service at the LA level

6.1.1 General model

The following explanatory variables have been tested for inclusion in the general model on the basis of their economic relevance:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack*, *ln_Hackvhd*, *ln_Phvhd*);
- quality-of-service regulation (*Disabledaccess*, *Test*, *Testdiff*, *Age*, *Blackcabonly*, *Qualityreg*);
- economic activity (*Precoact* and *Prunemp*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*).

6.1.2 Specific model

The model has been estimated by using a Tobit model for limited distributions. While both *Quality_LA* and *Quality_dv_LA* have been modelled, only the modelling of *Quality_LA* yields significant results (reported in Table 6.1).[8] All the indicators of entry and quality-of-service regulation were not significant and have dropped out of the regression. Hence, the modelling at the LA level does not allow the identified theoretical

[8] No explanatory variables were found to have a significant effect on overall customer satisfaction with the hackney carriage service variable, *Quality_LA*.

relations between entry and quality-of-service regulation and quality of service to be tested. The only factor identified as significant is the market concentration index, which has a negative impact on quality of service. This result could be explained by the inefficiencies associated with the lack of competition, which can sometimes characterise highly concentrated markets. The model fails the link test for model specification.

Table 6.1: Specific Tobit model, quality of service at LA level

Quality_dv_LA	Coefficient	Standard error	t-value	P-value
Mktshare	–0.263	0.102	2.57	0.019
Constant	2. 986	4.402	0.68	0.506
Observations	20.000			
LR chi2(1)	5.720			
Prob > chi2	0.017			
Pseudo R2	0.035			

Source: OXERA analysis.

6.2 Modelling quality of service at the individual level

6.2.1 General model

All the variables included in the general model at the LA level have also been included in the general model at the individual level. Whether the trip was taken for business purposes is an additional individual-specific variable, which has been included in the general model, given that satisfaction with quality of service may vary by customer type, with business users having a different perception of quality of service.

The following explanatory variables have therefore been included in the general model on the basis of their economic relevance:

- entry regulation variables matched with the year of the Halcrow consumer survey (*ln_Phvhack, ln_Hackvhd, ln_Phvhd*);
- economic activity (*Precoact* and *Prunemp*);
- rural versus urban areas (*Rural* and *Density*);
- market share (*Mktshare*);
- quality-of-service regulation (*Disabledaccess, Test, Testdiff, Age, Blackcabonly, Qualityreg*);
- business purpose of the trip (*Business*).

6.2.2 Specific model

The model at the individual level has been estimated using a logit model, given the binary nature of the dependent variable *Quality_dv*, which is equal to 1 if respondents are satisfied with the current quality of their driver and car, and 0 otherwise. Table 6.2 shows that quality of service is higher in LAs with a higher ratio of PHVs per 1,000 head of population, which characterises LAs with limited entry. This empirical finding is that a regulatory environment characterised by entry restrictions is likely to be associated with a higher level of satisfaction with quality of service.

The hypothesis related to the effect of quality-of-service regulation on actual quality could not be tested, as all the indicators of quality-of-service regulation were not significant and dropped out of the regression.

Two control factors were found to be significant: the concentration ratio, which is shown to have a negative impact on quality of service, and *Density*, the effect of which on satisfaction is close to zero.

Table 6.2: Specific logit model, quality of service at individual level

Quality_dv_IND	**Coefficient**	**Standard error**	**Z**	**P>|z|**
Phvhd (Halcrow unmet demand studies)	0.370	0.061	6.06	0.000
Precoact	0.110	0.020	5.41	0.000
Mktshare	–0.009	0.002	–3.84	0.000
Density	–0.011	0.006	–1.78	0.074
Constant	–4.709	1.338	–3.52	0.000
Number of observations	4,282			
LR chi2(3)	74.35			
Prob > chi2	0.000			
Pseudo R2	0.033			

Source: OXERA analysis.

6.3 Summary

The modelling of quality of service has tested the impact of the regulatory environment on quality of service. Only the hypothesis that entry regulation has a positive impact on quality of service was supported by the data. Quality-of-service regulation was not found to be significant and its impact on quality of service could not be estimated.

This may be a result of the relatively weak dependent variable specification that had to be used due to the paucity of alternatives. In particular, the survey question that underpinned the dependent variable was ill-suited to the modelling purposes, as it was not sufficiently specific about the service characteristics that respondents were considering, and the options for dissatisfaction included fares and waiting time.

An alternative explanation for this result would be that consumers do not value as ‘quality of service’ the forms of quality of service imposed on the market by regulation. This would imply that regulation of quality of service, as currently specified, raises fares, but does not deliver the appropriate benefits to consumers.

7. Conclusions: Drawing the Results Together

OXERA has investigated the impact of entry and quality-of-service regulation on the key factors that influence consumer welfare in the taxi markets. OXERA's literature review and RP study have identified level of fares, waiting time and quality of service as the three most important factors affecting consumer welfare. Hence, OXERA has modelled the effect of entry and quality-of-service regulation on each of these three factors. The modelling of perceived fares and waiting time cover both the hackney carriage and PHV markets, while actual quality of service has been modelled only for the hackney carriage market, due to lack of information on consumer satisfaction regarding the quality of the service provided by PHVs.

The results of the modelling, presented in Table 7.1, are briefly summarised below.

Table 7.1: Impact of regulation on consumer welfare—summary

	Perceived fare	Waiting time	Actual quality of drivers and vehicles provided by hackney carriage services	Overall effect on consumer welfare
Entry regulation	Positive —entry regulation is associated with a 3.9–4.9% increase in fare	Positive—entry regulation is associated with a 2.4% increase in waiting time and a 7% increase in excess demand	Positive	Ambiguous
Quality-of-service regulation	Positive	Not relevant	No impact	Negative

Source: OXERA analysis.

The 'Taxi Markets Literature Review' paper highlighted that, in theory, the effect of entry regulation on the level of fares is ambiguous, depending on whether entry regulation leads to more price competition, which would cause a fall in the level of fare, or to an increase in cost, due to lower occupancy rates, which could be reflected in higher fares. OXERA's modelling found that entry regulation has a positive impact on perceived fares, which implies that, following entry deregulation, the prevailing effect is the increase in price competition, resulting in downward pressure on the level of fares.

The estimated fall in level of fares following deregulation is around 4%. This is a relatively low price effect. It could be explained by the fact that all fares in the sample were regulated, which results in considerably dampened price movements that may not reflect standard market forces. This relationship was not found when examining regulated fares. This may be because regulated fares only represent part of the market, with PHVs having varying rates and not all hackney carriage drivers charging the maximum fare. Furthermore, the setting of regulated fares is a bargaining process and is difficult to model.

Entry regulation is found to increase waiting time. The literature survey suggested that deregulating entry would lead to lower waiting time, although this may be mitigated, but not removed if demand also falls. The estimated fall in waiting time following deregulation is 2% and a 7% fall in the measure of excess demand, which is associated with the modelling of waiting time at ranks. Removing entry restrictions is also found to lead to a 9% fall in excess demand at ranks at peak time.

Although the theoretical relationship is ambiguous, entry regulation is found to have a positive impact on actual quality of service.

Given that the overall impact on consumer welfare depends on how customers weight the level of fares, waiting time and quality of service, the impact of entry regulation on welfare is ambiguous. The effect is only likely to be positive if consumers place a high value on quality of service relative to perceived fares and waiting time.

As expected, quality-of-service regulation is shown to have a positive impact on the level of fares and no effect on waiting time. Prices increase by only 1.5 pence per journey for general quality-of-service regulation, and 1 pence per journey for disabled access. This would seem very low compared with the costs of providing these forms of quality-of-service improvements, and may also be the result of fare regulation that causes prices to be sticky (ie, they adjust very slowly).

While the effects of quality-of-service regulation on fares and waiting time are in line with the theoretical relationship, there is no empirical evidence that quality-of-service regulation positively affects actual quality, contrary to expectations. This may be a result of the relatively weak dependent variable specification that had to be used due to the paucity of alternatives. In particular, the survey question that underpinned the dependent variable was ill-suited to the modelling purposes, as it was not sufficiently specific about the service characteristics that respondents were considering, and the options for dissatisfaction included fares and waiting time.

An alternative explanation for this result could be that consumers do not value as ‘quality of service’ the forms of quality of service imposed on the market by regulation. This would imply that regulation of quality of service, as currently specified, raises fares but does not deliver the appropriate benefits to consumers.

The overall effect of quality-of-service regulation on consumer welfare is negative, given that the only way in which quality-of-service regulation affects consumer welfare is through higher level of fares.

Overall, despite a number of difficulties with the dataset resulting from the fact that the Halcrow studies had been generated for a different purpose from this modelling exercise, the results support most of the expected outcomes identified from the literature, and suggest that the key factors that influence consumer welfare could be increased by deregulation in the taxi markets. In order to determine whether the taxi markets should indeed be deregulated, it would be necessary to determine the balance between the benefits to consumers and the costs of deregulating. OXERA’s SP survey contributes to the understanding of the amount of benefit that consumers could derive from changes in the variables that determine consumer welfare.

Appendix 1: Description of the datasets

The Appendix presents a description of the datasets used in the econometric modelling, namely Halcrow consumer surveys (section A1.1), Halcrow unmet-demand studies (section A1.2) and the OFT LA survey (section A1.3).

A1.1 Halcrow consumer surveys

Halcrow has conducted consumer surveys on the taxi markets across 39 LAs over the 1998–2002 period. For some LAs more than one survey is available. Where this is the case, the survey with the higher response rate on perceived fare and time of the trip has been chosen. If response rates were similar for all surveys, the most recent survey was selected. The table reports the selected survey for each LA where more than one survey is available—for example, the 1998 survey in Carrick was selected for the modelling, given that the question on perceived fares had only one response in the 2002 survey; similarly, the 2002 survey in Exeter was included in the modelling instead of the 1999 survey, where no respondents answered the question on perceived fares.

The following nine LAs have also been excluded from the econometric modelling because they are not been included in the OFT LA survey: Bournemouth; Dundee; Eastbourne; Leeds; Sheffield; Southampton; Stratford upon Avon; Wolverhampton; Worcester. The final list of LAs included in the modelling (with the corresponding year of study) is reported in Table 2.2 above.

Table A1.1 lists, for each Halcrow consumer survey, average perceived fare for a daytime three-mile trip (*Threemiletrip*), the percentage of respondents taking the taxi at the rank (*Rank*), hailing it in the street (*Street_LA*) and taking it between 6pm and 3am (*Time_6pm3am_LA*). The data shows that, in some LAs, the percentage of respondents who hailed a taxi in the street in their last taxi journey is particularly low or even equal to zero—for example, in Torridge and North Devon, nobody reported having hailed a taxi in the street the last time they took a taxi.

Table A1.1: Summary of Halcrow data

	LAs included in Halcrow consumer survey	Included in OFT LA survey	Included in OXERA modelling	Year of Halcrow survey	Obs. (No.)	Variables			
						Time_ 6pm3am_LA (%)	*Threemile trip_LA* (p)	*Rank_LA* (%)	*Street_LA* (%)
1	Blackpool	Yes	Yes	1998	520	54.7	434.1	29.2	4.6
2	Bournemouth	No	No	2001	201	47.8	559.8	31.3	19.9
2	Bournemouth	No	No	1998	203	47.7	562.2	33.0	10.8
3	Bradford	Yes	Yes	2002	281	56.9	Note [1]	41.3	12.5
4	Brighton and Hove	Yes	Yes	2002	316	62.6	Note [1]	38.9	18.0
5	Bristol	Yes	Yes	2002	283	54.8	637.1	33.6	23.7
6	Burnley	Yes	Yes	1998	230	24.3	437.5	17.4	7.8
7	Calderdale	Yes	Yes	2000	469	45.6	401.1	22.2	5.8
8	Cambridge	Yes	Yes	1999	170	45.0	501.9	26.5	9.4
8	Cambridge	Yes	No	1997	167	42.8	476.5	34.7	13.8
9	Cardiff	Yes	Yes	2001	447	50.1	532.3	19.2	18.6
10	Carrick	Yes	Yes	2002	156	30.1	390.3	45.5	12.8
10	Carrick	Yes	No	1998	148	50.7	100.0[2]	38.5	8.1
11	Castle Point	Yes	Yes	2000	186	Note [1]	458.1	19.9	12.9
12	Cherwell	Yes	Yes	2001	192	75.5	795.3	75.0	3.6
13	Congleton	Yes	Yes	1999	117	32.8	465.7	15.4	8.5
14	Dundee	No	No	1999	330	32.7	373.7	42.1	18.8
14	Dundee	No	No	2002	299	46.0	449.8	34.1	16.1
15	Eastbourne	No	No	1999	159	35.0	334.9	34.0	3.8
16	Edinburgh	Yes	Yes	2001	649	56.4	609.5	34.4	35.1
17	Ellesmere	Yes	Yes	2001	158	32.3	367.2	20.9	1.3
18	Exeter	Yes	No	1999	255	53.5	Note [1]	38.4	3.5
18	Exeter	Yes	Yes	2002	212	52.9	439.4	47.6	11.3
19	Forest Heath	Yes	Yes	1997	319	31.4	361.2	31.0	1.9
20	Hull	Yes	Yes	1999	308	42.2	474.5	23.1	14.0
21	Leeds	No	No	2000	542	48.8	489.5	25.3	13.3
22	Leicester	Yes	Yes	2000/01	194	48.9	520.9	23.2	18.0
23	Manchester	Yes	No	2000	296	31.7	427.7	27.4	14.2
23	Manchester	Yes	No	1997	296	1[(2)]	714.7	57.1	25.3
23	Manchester	Yes	Yes	2001	142	39.1	485.7	35.9	15.5
24	North Devon	Yes	Yes	1998	85	40.3	314.9	28.2	0[3]
25	Nottingham	Yes	Yes	1997/98	619	54.9	458.9	27.8	15.3
26	Peterborough	Yes	Yes	1999	215	42.0	477.2	37.2	5.1
27	Sefton	Yes	Yes	2000	670	Note [1]	430.3	13.4	13.1
28	Selby	Yes	Yes	1999	138	63.6	403.3	37.7	0.7
29	Sheffield	No	No	1998	158	43.9	500.8	33.5	7.0
30	South Ribble	Yes	Yes	2000	314	55.2	416.3	18.8	11.5
31	Southampton	No	No	1999	179	48.0	529.9	41.9	13.4
32	Stratford Upon Avon	No	No	1998	144	43.4	434.0	31.3	6.3
33	Sunderland	Yes	Yes	1998	195	31.9	356.2	16.4	9.2

	LAs included in Halcrow consumer survey	Included in OFT LA survey	Included in OXERA modelling	Year of Halcrow survey	Obs. (No.)	Variables			
						Time_ 6pm3am_LA (%)	*Threemile trip_LA* (p)	*Rank_LA* (%)	*Street_LA* (%)
33	Sunderland[5]	Yes	No	1998	271	48.5	446.2	24.0	2.6
34	Thurrock	Yes	Yes	2000	353	0[2]	415.8	26.9	2.3
35	Torridge	Yes	Yes	2001	120	47.4	408.7	38.3	0[4]
36	Wansbeck	Yes	Yes	1998	211	46.5	407.2	23.2	2.4
37	Wigan	Yes	Yes	2002	325	52.9	436.1	32.0	17.5
38	Wolverhampton	No	No	1999	206	34.6	597.7	14.1	5.3
39	Worcester	No	No	2001	168	42.8	476.5	34.5	13.7

Note: [1] Only missing observations. [2] Only one observation.[3] 23 missing observations (out of 85). [4] Only three missing observations (out of 120). [5] Washington results.
Source: OXERA analysis.

The complete Halcrow database (ie, for the 39 LAs) has 30,441 observations. However, only 41% of the respondents reported having undertaken a taxi journey in the last month (Table A1.1). More than half of the respondents reporting on their last taxi journey booked the taxi by telephone (Table A1.2). 37% of the respondents who made a taxi trip in the last month are full-time employed (Table A1.3), while 39% are economically inactive (students, retired or housewife/husband), see Table A1.4. Table A1.5 shows that the taxi journeys are evenly spread over the day, with 13% of the respondents not reporting the time of the trip.

Table A1.2: Halcrow data: 'Have you made a trip by taxi in the last month?'

	Frequency	Percentage (%)
Yes	12,521	41.13
No	17,825	58.56
Missing	95	0.31
Total	**30,441**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.3: Halcrow data: 'How was the taxi obtained?'

	Frequency	Percentage (%)
At rank	3,798	30.33
Waved down in the street	1,561	12.47
By telephone	6,971	55.67
Missing	191	1.53
Total	**12,521**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.4: Halcrow data, by status

	Total sample		Respondents who made a taxi journey in the last month	
	Frequency	**Percentage (%)**	**Frequency**	**Percentage (%)**
N/a	704	2.32	272	2.18
Full-time employed	10,203	33.6	4,709	37.70
Part-time employed	3,997	13.16	1,730	13.85
Unemployed	2,022	6.66	706	5.65
Student/pupil	3,805	12.53	2,045	16.37
Retired	6,125	20.17	1,750	14.01
Housewife/husband	2,957	9.74	1,081	8.65
Other	556	1.83	199	1.59
Total	**30,369**	**100.00**	**12,492**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.5: Halcrow data, by time of the last trip

Time of the trip	Frequency	Percentage (%)
Don't Know	1,668	13.32
03:01–07:00	450	16.92
07:01–12:00	2,760	22.04
12:01–18:00	2,509	20.04
18:01–23:00	2,712	21.66
23:01–03:00	2,401	19.18
Missing	21	0.17
Total	**12,521**	**100.00**

Source: OXERA analysis of Halcrow data.

Given that only a sub-sample of the Halcrow database has been used for the econometric modelling, summary statistics are also reported in the Tables A1.6 to A1.9 for the reduced dataset of 30 surveys. The total number of observations for the reduced sample is 8,591. The statistics for the reduced sample are close to those reported for the complete database, implying that there is no bias determining the selection of the 30 LAs that have been included in the modelling.

Table A1.6: Halcrow reduced sample— ‘Have you made a trip by taxi in the last month?’

	Frequency	Percentage (%)
Yes	8,510	40.5
No	12,423	59.12
Missing	81	0.39
Total	**21,014**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.7: Halcrow reduced sample: 'How was the taxi obtained?'

	Frequency	Percentage (%)
At rank	2,449	28.78
Waved down in the street	1,065	12.51
By telephone	4,842	56.90
Missing	154	1.81
Total	**8,510**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.8: Halcrow reduced sample, by status

	Respondents who made a taxi journey in the last month	
	Frequency	**Percentage (%)**
N/a	242	2.84
Full-time employed	3,224	37.88
Part-time employed	1,104	12.97
Unemployed	447	5.25
Student/pupil	1,388	16.31
Retired	1,198	14.08
Housewife/husband	760	8.93
Other	147	1.73
Total	**8,510**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.9: Halcrow reduced sample: by time of the last trip

Time of the trip	Frequency	Percentage (%)
Don't know	1,338	15.72
03:01–07:00	323	3.80
07:01–12:00	1,765	20.74
12:01–18:00	1,566	18.40
18:01–23:00	1,841	21.63
23:01–03:00	1,677	19.71
Total	**8,510**	**100.00**

Source: OXERA analysis of Halcrow data.

Table A1.10 reports the breakdown of the time of the trip by LA, showing that the peak time for taxi journey appears to vary to a significant extent across LAs.

Table A1.10: Time of the trip—by LA

	Local authority	3:00–7:00	7:00–12:00	12:00–18:00	18:00–23:00	23:00–3:00
1	Blackpool B.C.	3.4	25.0	16.8	27.0	27.8
2	Bradford M.D.C.	4.6	13.9	24.6	24.6	30.2
3	Brighton & Hove	3.8	17.9	15.7	29.4	33.2
4	Bristol City Council	8.5	18.1	18.5	29.5	25.3
5	Burnley B.C.	13.7	31.4	30.5	15.9	8.4
6	Calderdalem B.C.	0.6	24.1	29.7	25.4	20.2
7	Cambridge City	5.3	29.0	20.7	29.6	15.4
8	Cardiff C.C.	5.7	26.5	17.7	25.2	24.9
9	Carrick D.C.	2.6	40.5	26.8	19.0	11.1
10	Castle Point Borough	n/a	n/a	n/a	n/a	n/a
11	Cherwell D.C.	3.6	14.6	6.3	6.3	69.3
12	Congleton B.C.	3.5	47.8	15.7	14.8	18.3
13	Edinburgh City Council	6.0	22.3	15.3	38.7	17.7
14	Ellesmere Port & Neston	3.8	36.1	27.8	29.7	2.5
15	Exeter City Council	0.5	20.2	26.4	19.7	33.2
16	Forest Heath D.C	1.7	35.6	31.4	20.5	10.9
17	Hull City Council	8.6	25.7	23.4	19.5	22.8
18	Leicester City Council	5.8	20.5	24.7	22.1	26.8
19	Manchester City	3.6	25.4	31.9	15.9	23.2
20	North Devon D.C.	8.1	32.3	19.4	37.1	3.2
21	Nottingham City Council	6.3	18.6	20.3	20.1	34.8
22	Peterborough C. C.	2.4	23.7	31.8	25.1	17.1
23	Sefton M.B.C.	n/a	n/a	n/a	n/a	n/a
24	Selby D.C.	2.3	15.9	18.2	25.0	38.6
25	South Ribble B.C.	2.3	26.3	16.2	30.2	25.0
26	Sunderland City Council	6.9	40.4	20.7	22.9	9.0
27	Thurrock Council	0.0	100.0	0.0	0.0	0.0
28	Torridge D. C.	1.7	19.0	31.9	27.6	19.8
29	Wansbeck District Cnl	2.0	32.5	19.0	37.0	9.5
30	Wigan Council	2.5	19.1	25.5	30.8	16.3

Note: n/a, not available.
Source: OXERA analysis.

A1.2 Halcrow unmet-demand studies

Data on the unmet demand in several LAs was available for a variety of years by each hour. This data does not correspond to the years in which the Halcrow surveys were carried out. The variables available by hour were;

- number of hackney carriages;
- number of PHVs;
- passenger throughput (rank/week);
- average passenger delay (minutes);

- average taxi delay (minutes);
- excess demand (%);
- proportion waiting at ranks.

Table A1.11 lists the LAs available and the year in which the unmet-demand study took place.

Table A1.11: Unmet-demand data available

LA	Year	LA	Year
Wigan	2002	Bradford	2000
Exeter	2002	Peterborough	2000
Bradford	2002	Calderdale	2000
Bristol	2002	Manchester	2000
Blackpool	2002	Edinburgh	2000
Dartford	2002	Wolverhampton	1999
Carrick	2002	Calderdale	1999
Cardiff	2001	Hull	1999
Bournemouth	2001	Eastbourne	1999
Ellesmere Port	2001	Dundee	1999
Worcester	2001	Exeter	1999
Cherwell	2001	Selby	1999
Torridge	2001	Cambridge	1999
Manchester	2001	Southampton	1999
Edinburgh	2001	Sunderland	1998
Leeds	2000	North Devon	1998
Castle Point	2000	Burnley	1998
South Ribble	2000	Stratford-upon-Avon	1998
Thurrock	2000	Carrick	1998
Sefton	2000	Blackpool	1998
Southend	2000	Bournemouth	1998
Leicester	2000	Wansbeck	1998

Source: OXERA analysis.

A1.3 OFT database

The OFT LA survey contains information on the regulatory environment in place in the taxi markets across 253 LAs. Information on the following types of regulation is available from the OFT database for the year 2002:

- fare regulation;
- entry regulation;
- quality-of-service regulation.

Table A1.12 shows that only 12 LAs have deregulated taxi fares and all of them also have deregulated entry. The interaction between various forms of regulation in place in the taxi markets across the LAs sampled by the OFT is presented in section 6.

Table A1.12: OFT LA survey: interaction of entry and fare regulation

		Entry		Total
		Unlimited	**Limited**	
Fares	Regulated	119 (90.8%)	118 (100%)	**237**
	Unregulated	12 (9.2%)	0 (0%)	**12**
Total		**131**	**118**	**249**

Note: The percentages within brackets are calculated over the total number of LAs with unlimited and limited regulation
Source: OXERA analysis.

Appendix 2: Description of Data used in the Modelling

Table A2.1 shows the variables used in the econometric modelling, the level of aggregation and the source at the LA and individual level, respectively. Tables A2.2 and A2.3 contain summary statistics for the variables, including mean, standard deviation and the range.

Table A2.1: Description of variables included in the econometric modelling

Variable	Description of the variable	Aggregation	Source
Fares			
Fr_t1_2m	Regulated day tariff for a 2-mile journey for 1 person (2002)	LA	OFT
Fr_t2_2m	Regulated night tariff for a 2-mile journey for 1 person (2002)	LA	OFT
Threemiletrip_IND	Perceived fare for a 3-mile taxi journey at daytime	Individual	Halcrow, CS
Threemiletrip_LA	Perceived fare for a 3-mile journey at daytime (mean)	LA	Halcrow, CS
Threemiletripmd_LA	Perceived fare for a 3-mile journey at daytime (median)	LA	Halcrow, CS
Waiting time			
Waitingtime_IND	Waiting time[1]	Individual	Halcrow, CS
Waitingtime_LA	Waiting time (mean)	LA	Halcrow, CS
Excessdemand	Average excess demand at rank between 8am - 2am	LA	Halcrow, UD
Excessdemand_peak	Excess demand at rank between 6pm –2 am	LA	Halcrow, UD
Excessdemand_offpeak	Excess demand at rank between 8am and 6pm	LA	Halcrow, UD
Avepassdelay	Average passenger delay (minutes) at rank	LA	Halcrow, UD
Avepassdelay_peak	Average passenger delay at rank between 6pm –2 am	LA	Halcrow, UD
Avepassdelay _offpeak	Average passenger delay at rank between 8am and 6pm	LA	Halcrow, UD
Quality of service			
Quality_IND	Dummy variable equal 1 if respondents are satisfied with the hackney carriage service	Individual	Halcrow, CS
Quality_dv_IND	Dummy variable equal 1 if respondents are satisfied with quality of the drivers and vehicles provided by the hackney carriage service	Individual	Halcrow, CS
Quality_LA	Respondents satisfied with the black cab service (%)[2]	LA	Halcrow, CS
Quality_dv_LA	Respondents satisfied with the quality of the drivers and vehicles provided by the hackney carriage service (%)[2]	LA	Halcrow, CS
Entry regulation			
Hackvhd	Number of hackney carriage vehicles per 1,000 head of population	LA	Halcrow, UD and OFT
Phvhd	Number of PHVs per 1,000 head of population	LA	Halcrow, UD and OFT[9]
Phvhack	Ratio of PHVs to hackney carriage vehicles	LA	Halcrow, UD and OFT
Entryreg	Dummy variable equal to 1 if LA has entry regulation	LA	OFT

[9] OFT data is for 2002, while Halcrow unmet-demand studies data matches the year of the consumer surveys.

Table A2.1: Description of variables included in the econometric modelling (cont'd)

Variable	Description of the variable	Aggregation	Source
Entry regulation (cont'd)			
Rankspop	Number of rank spaces per head of population[3]	LA	OFT
Quality-of-service regulation			
Test	Dummy variable equal to 1 if drivers need to pass knowledge test	LA	OFT
Testdiff	Estimated time required to pass knowledge test (1=Less than 1 month, 2= 1–3 month, 3= 3–6 months, 4=6–12 months, 5=more than one year)	LA	OFT
Disabledaccess	Dummy variable equal to 1 if hackney carriages have to make special provision for wheelchair access	LA	OFT
Blackcabonly	Dummy variable equal to 1 if only black cabs are allowed as types of vehicles	LA	OFT
Age	Dummy variable equal to 1 if there is a maximum age for a vehicle used as a hackney	LA	OFT
Qualityreg	Dummy variable equal to 1 if the LA has at least 3 of the following quality dummies equal to 1: Age, Disabledaccess, Test and Blackcabonly	LA	OFT
Characteristics of LAs			
Rural	Dummy variable equal to 1 if the survey respondent defines the LA as either a mix of rural and urban areas, or a rural area.	LA	OFT
Density	Number of people per hectare	LA	ONS
Mktshare	Concentration ratio—sum of market share of the three largest taxi operators	LA	OFT
Way to obtain a taxi			
Rank_IND	Dummy variable equal to 1 if respondent took taxi at the rank	Individual	Halcrow, CS
Street_IND	Dummy variable equal to 1 if respondent waved down taxi in the street	Individual	Halcrow, CS
Telephone_IND	Dummy variable equal to 1 if respondent hired taxi by telephone	Individual	Halcrow, CS
Rank_LA	Respondents catching the cab at the rank (%)[2]	LA	Halcrow, CS
Street_LA	Respondents hailing cab in the street (%)[2]	La	Halcrow, CS
Telephone_LA	Respondents calling cab by telephone (%)[2]	LA	Halcrow, CS
Time of the trip			
Time_3am7am_IND	Dummy variable equal to 1 if respondent took cab between 3pm and 7am	Individual	Halcrow, CS
Time_7am12am_IND	Dummy variable equal to 1 if respondent took cab between 7am and 12am	Individual	Halcrow, CS
Time_12am6pm_IND	Dummy variable equal to 1 if respondent took cab between 12am and 6pm	Individual	Halcrow, CS
Time_6pm11pm_IND	Dummy variable equal to 1 if respondent took cab between 6pm and 11pm	Individual	Halcrow, CS
Time_11pm3am_IND	Dummy variable equal to 1 if respondent took cab between 11pm and 3am	Individual	Halcrow, CS
Time_6pm3am_IND	Dummy variable equal to 1 if respondent took cab between 6pm and 3am	Individual	Halcrow, CS
Time_3am7am_LA	Respondents taking cab between 3am and 7am (%)[2]	LA	Halcrow, CS
Time_7am12am_LA	Respondents taking cab between 7am and 12am (%)[2]	LA	Halcrow, CS
Time_12am6pm_LA	Respondents taking cab between 12am and 6pm (%)[2]	LA	Halcrow, CS
Time_6pm11pm_LA	Respondents taking cab between 6pm and 11pm (%)[2]	LA	Halcrow, CS
Time_11pm3am_LA	Respondents taking cab between 11pm and 3am (%)[2]	LA	Halcrow, CS
Time_6pm3am_LA	Respondents taking cab between 6pm and 3am (%)[2]	LA	Halcrow, CS

Table A2.1: Description of variables included in the econometric modelling (cont'd)

Variable	Description of the variable	Aggregation	Source
Economic activity			
Precoact	Population economically active (% of total population)	LA	ONS
Prunemp	Unemployed population (% of total population)	LA	ONS

Note: [1] Total waiting time includes both time walking to the rank and time waiting at the rank for respondents taking the taxi at a rank. [2] The percentage of total respondents that have taken a taxi journey in the last month. [3] Includes rank spaces at railway stations and airports.
Source: Halcrow, CS (consumer survey) and UD (unmet-demand) studies OFT, ONS and OXERA calculations.

Table A2.2: Summary statistics—LA level

Variable	Obs.	Mean	Std. dev.	Min	Max
Fares					
Fr_t1_2m (£, 2002 prices)	30	3.800	0.471	2.800	5.000
Fr_t2_2m (£, 2002 prices)	30	4.587	0.729	3.400	6.000
Threemiletrip_LA (p)	28	478.720	95.111	327.664	811.244
Threemiletripmd_LA (p)	28	503.303	94.869	353.877	827.469
Waiting time					
*Waitingtime_LA (*minutes)	30	4.674	2.579	1.490	15.764
Waitingtime_LA (m)—excluding Cherwell	29	4.292	1.532	1.490	7.886
Excessdemand (%)	27	34.425	23.044	0	92.245
Excessdemand_peak (%)	27	34.675	23.964	0	93.084
Excessdemand_offpeak (%)	27	22.490	26.656	0	90.100
Avepassdelay (minutes)	27	1.129	1.058	0.064	4.456
Avepassdelay_peak (minutes)	27	1.778	1.823	0	8.921
Avepassdelay_offpeak (minutes)	27	0.583	0.743	0	3.246
Quality of service					
Quality_LA (%)	30	37.487	15.084	13.714	64.666
Quality_dv_LA (%)	30	88.268	16.012	27.848	98.587
Entry regulation					
Hackvhd (no. per 1,000 head) (OFT, 2002)	30	1.068	0.679	0.340	2.700
Phvhd (no. per 1,000 head) (OFT, 2002)	29	2.132	1.360	0.210	5.850
Phvhack (OFT, 2002)	29	2.884	2.198	0.147	8.342
Hackvhd (no. per 1,000 head) (Halcrow UD)	27	1.060	0.871	0.248	3.943
Phvhd (no. per 1,000 head) (Halcrow UD)	27	1.872	1.264	0.179	5.352
Phvhack (Halcrow UD)	25	2.853	2.270	0.045	7.143
Entryreg (dummy)	30	0.867	0.346	0.000	1.000
Rankspop (no. per head)	17	0.001	0.001	0.000	0.003

Table A2.2: Summary statistics—LA level (cont'd)

Variable	Obs.	Mean	Std. dev.	Min	Max
Quality-of-service regulation					
Test (dummy)	30	0.700	0.466	0.000	1.000
Testdiff	21	1.952	0.973	1.000	4.000
Disabledaccess (dummy)	30	0.267	0.450	0.000	1.000
Blackcabonly (dummy)	30	0.333	0.479	0.000	1.000
Age (dummy)	27	0.556	0.506	0.000	1.000
Qualityreg (dummy)	24	0.458	0.509	0.000	1.000
Characteristics of LAs					
Rural (dummy)	29	0.448	0.506	0.000	1.000
Density	30	16.354	12.953	0.599	40.74
Mktshare	20	32.438	29.983	2.948	100.000
Method of obtaining taxi					
Rank_LA (%)	30	30.460	12.631	13.433	75.000
Street_LA (%)	30	10.466	8.022	0.000	35.131
Telephone_LA (%)	30	57.585	14.012	21.354	77.215
Time of the trip					
Time_3am7am_LA (%)	28	4.295	3.072	0.000	14.155
Time_7am12am_LA (%)	28	28.605	16.366	13.879	100.000
Time_12am6pm_LA (%)	28	21.655	7.696	0.000	31.897
Time_6pm11pm_LA (%)	28	23.934	8.693	0.000	38.705
Time_11pm3am_LA (%)	28	21.267	13.857	0.000	69.271
Time_6pm3am_LA (%)	28	45.445	14.706	0.000	75.521
Economic activity					
Precoact (%)	29	65.391	4.529	55.835	75.384
Prunemp (%)	29	3.505	1.086	1.873	6.228

Source: OXERA analysis.

Table A2.3: Summary statistics—individual level

Variable	Obs.	Mean	Std. dev.	Min	Max
Fares					
Threemiletrip_IND (p)	7,609	464.156	182.007	100	3,000
Waiting time					
Waitingtime_IND (minutes)	8,464	4.854	8.845	0	120
Quality of service					
*Quality_IND (*dummy)	8,109	0.349	0.477	0	1
Quality_dv_IND (dummy)	8,325	0.886	0.317	0	1
Way to obtain a taxi					
Rank_IND (dummy)	8,510	0.288	0.453	0	1
Street_IND (dummy)	8,510	0.125	0.331	0	1
Telephone_IND (dummy)	8,510	0.569	0.495	0	1
Time of the trip					
Time_3am7am_IND (dummy)	7,193	0.045	0.207	0	1
Time_7am12am_IND (dummy)	7,193	0.245	0.430	0	1
Time_12am6pm_IND (dummy)	7,193	0.218	0.413	0	1
Time_6pm11pm_IND (dummy)	7,193	0.256	0.436	0	1
Time_11pm3am_IND (dummy)	7,193	0.233	0.423	0	1
Time_6pm3am_IND (dummy)	7,193	0.492	0.500	0	1

Source: OXERA analysis.

A2.1 Correlation analysis

Table A2.4 presents the correlation matrix for the key variables considered for the econometric modelling. The correlations are reported for the variables at the LA level. The main findings of the correlation analysis are reported below.

- Daytime and night-time regulated fares are positively correlated (correlation = 0.338), suggesting that higher daytime regulated fares are associated with higher night-time regulated fares. Figure A2.1 reports the scatterplot of daytime and night-times regulated fares, confirming the positive relationship between the two variables.

- Daytime perceived and regulated fares are also positively correlated (correlation = 0.186), although the correlation is quite low. The low correlation could be due to the fact that perceived fares are a blend of regulated fares and unregulated PHV fares.

- *Rural* and *Entryreg* are negatively correlated (correlation = –0.323), suggesting the rural areas are more likely to have deregulated entry in the taxi markets.

- The negative correlation between *Rural* and *Qualityreg* (correlation = –0.652) implies that rural areas also have less stringent quality-of-service regulation in place.

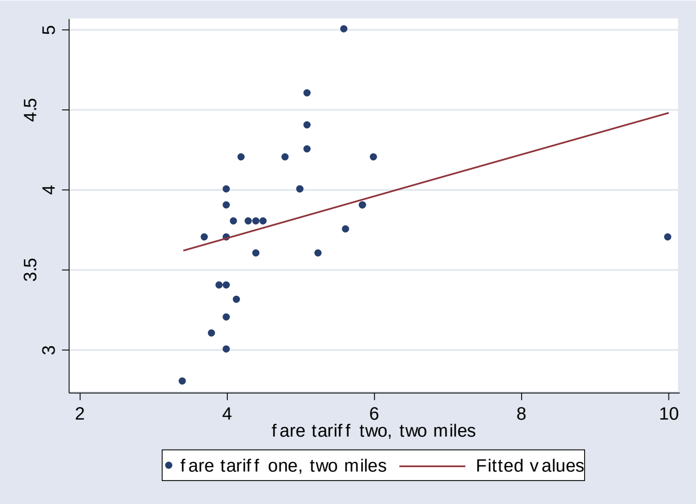
Table A2.4: Correlation table

	Fr_t1_2m	Fr_t2_2m	Threemiletrip_LA	Waitingtime_LA	Quality_dv_LA	Taxivhd (OFT)	Phvhd (OFT)	Phvhack (OFT)	Entryreg	Rankspop
Fr_t1_2m	1.000									
Fr_t2_2m	0.338	1.000								
Threemiletrip_LA	0.186	–0.188	1.000							
Waitingtime_LA	0.284	–0.054	0.812	1.000						
Quality_dv_LA	0.318	–0.005	–0.267	–0.027	1.000					
Hackvhd (OFT)	0.443	–0.024	0.256	0.069	0.008	1.000				
Phvhd (OFT)	–0.167	–0.270	0.233	0.021	0.004	0.115	1.000			
Phvhack (OFT)	–0.493	–0.226	–0.055	–0.021	–0.108	–0.601	0.543	1.000		
Entryreg	–0.077	0.086	0.161	0.125	–0.028	–0.211	0.165	0.191	1.000	
Rankspop	–0.076	–0.074	–0.037	–0.298	0.036	0.423	0.530	–0.041	0.126	1.000
Test	0.354	0.019	0.347	0.322	–0.138	0.220	0.473	0.057	–0.098	0.307
Disabledaccess	0.001	–0.290	0.318	0.065	0.189	0.249	0.411	0.080	0.067	0.183
Blackcabonly	–0.106	–0.275	0.183	–0.089	–0.173	0.204	0.237	0.148	–0.063	0.264
Age	–0.101	–0.001	0.038	–0.011	–0.183	–0.170	0.312	0.348	–0.043	–0.317
Rural	–0.090	–0.047	–0.196	0.051	–0.016	–0.251	–0.362	–0.058	–0.323	–0.449
Qualityreg	0.089	–0.357	0.265	0.092	–0.172	0.217	0.446	0.242	–0.037	0.133
Mktshare	0.348	–0.057	0.317	0.439	–0.499	0.124	–0.237	–0.274	0.244	0.114
Street_LA	0.258	0.129	0.462	0.303	–0.038	0.447	0.422	0.078	0.260	0.025
Telephone_LA	–0.494	–0.143	–0.699	–0.722	0.138	–0.292	0.007	0.233	–0.154	0.064
Time_6pm11pm	0.066	0.110	–0.248	–0.251	–0.050	0.319	–0.200	–0.176	–0.212	–0.013
Time_11pm3am	0.266	–0.138	0.712	0.819	–0.077	–0.002	0.118	–0.050	0.288	–0.068
Precoact	0.025	0.068	0.100	0.285	–0.042	–0.145	–0.625	–0.156	–0.204	–0.481
Prunemp	–0.058	–0.243	–0.110	–0.167	–0.127	–0.011	0.525	0.220	0.339	0.389

	Test	Disabled access	Black cabonly	Age	Rural	Qualityreg	Mktshare	Street_LA	Telephone_LA	Time_ 6pm11pm_LA	Time_ 11pm3am_LA	Precoact	Prunemp
Test	1.000												
Disabledaccess	0.395	1.000											
Blackcabonly	0.309	0.533	1.000										
Age	0.158	0.120	0.189	1.000									
Rural	–0.445	–0.401	–0.362	–0.389	1.000								
Qualityreg	0.650	0.769	0.842	0.510	–0.652	1.000							
Mktshare	0.089	–0.387	–0.068	–0.216	–0.084	–0.136	1.000						
Street	0.393	0.433	0.382	0.291	–0.450	0.601	–0.186	1.000					
Telephone	–0.310	–0.185	–0.045	0.131	0.056	–0.179	–0.229	–0.478	1.000				
Time_6pm11pm	0.005	0.087	0.125	0.139	–0.169	0.150	0.067	0.226	0.019	1.000			
Time_11pm3am	0.165	0.004	–0.159	0.038	0.121	0.004	0.508	0.156	–0.630	–0.227	1.000		
Precoact	–0.290	–0.322	–0.136	–0.418	0.589	–0.416	0.320	–0.424	–0.086	–0.226	0.196	1.000	
Prunemp	0.280	0.489	0.138	0.326	–0.443	0.452	–0.061	0.249	0.104	0.073	–0.116	–0.702	1.000

Source: OXERA analysis.

Figure A2.1: Scatterplot of daytime and night-time regulated fares, Fr_t1_2m and Fr_t2_2m (£)



Source: OXERA analysis.

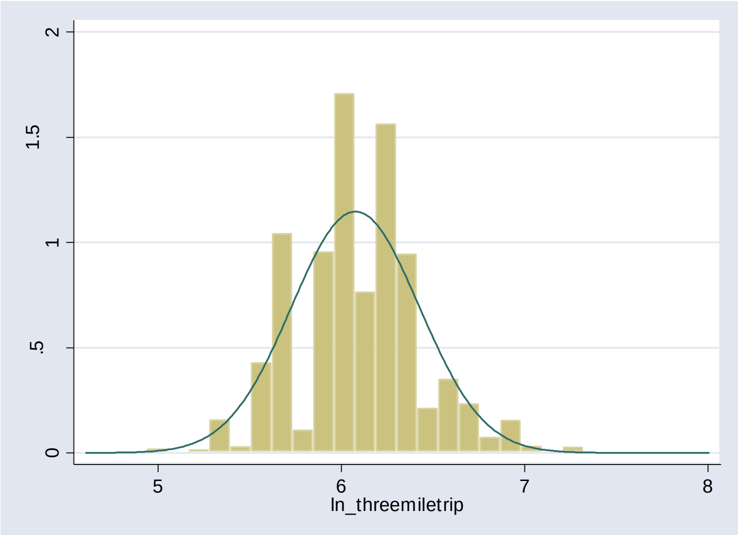
A2.2 Distribution of variables

The factors influencing consumer welfare which are considered in this study are fares, waiting times and quality of service. The distributions of potential variables to capture these are shown in the following section.

Fare

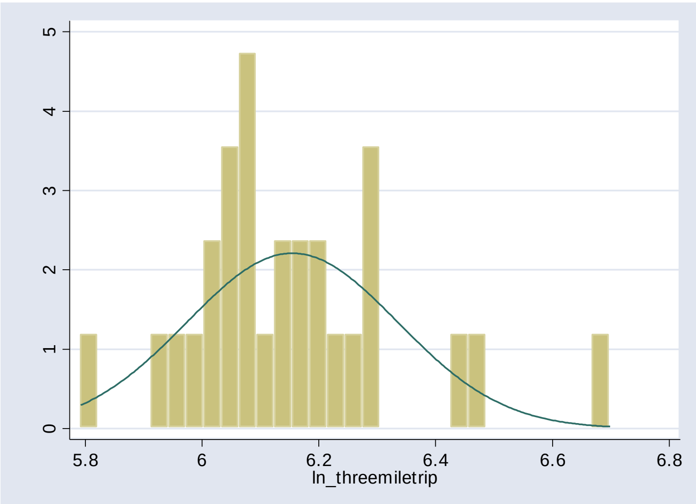
Given that the sample of LAs is nominal data over time, with the year of the survey spanning the period 1997–2002, perceived fares have been adjusted for inflation and converted to 2002 prices. To correct for potential measurement errors, the distribution of the perceived fare has been truncated at £30, which is likely to be the upper limit price for a three-mile journey. Both mean and median level of perceived fares (*Threemiletrip* and *Threemiletripmd*, respectively) have been considered for the modelling exercise, given that the high dispersion of *Threemiletrip* values at the individual level may hinder the reliability of the mean as estimator of the average LA fare level. Figure A2.2 presents the distribution of the perceived fares for a daytime three-mile trip at the individual level, while Figures A2.3 and A2.4 present the distribution of the mean and median perceived fare for a three-mile trip.

Figure A2.2: Log of perceived fare for a daytime three-mile trip (p), individual level (*ln_Threemiletrip*)



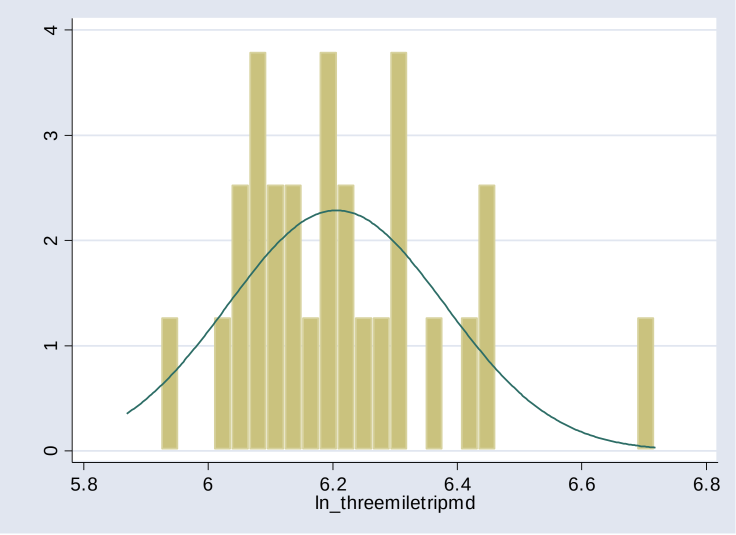
Source: OXERA analysis.

Figure A2.3: Log of mean perceived fare for a daytime three-mile trip (p), LA level (*ln_Threemiletrip*)



Source: OXERA analysis.

Figure A2.4: Log of median perceived fare for a daytime three-mile trip (p), LA level (*ln_Threemiletripmd*)

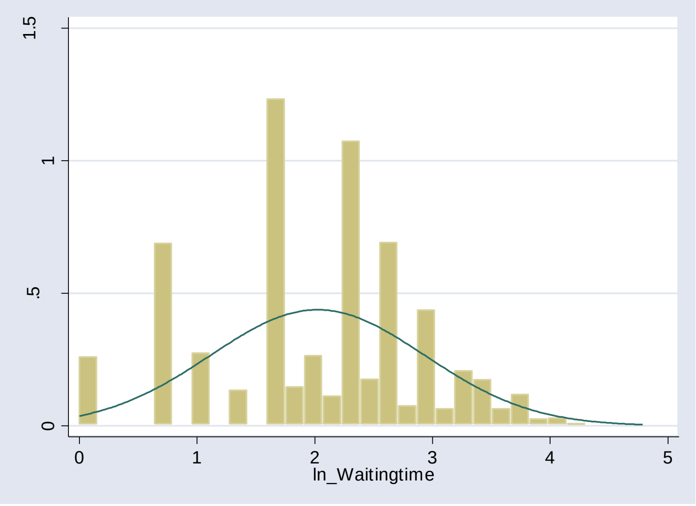


Source: OXERA analysis.

Waiting time

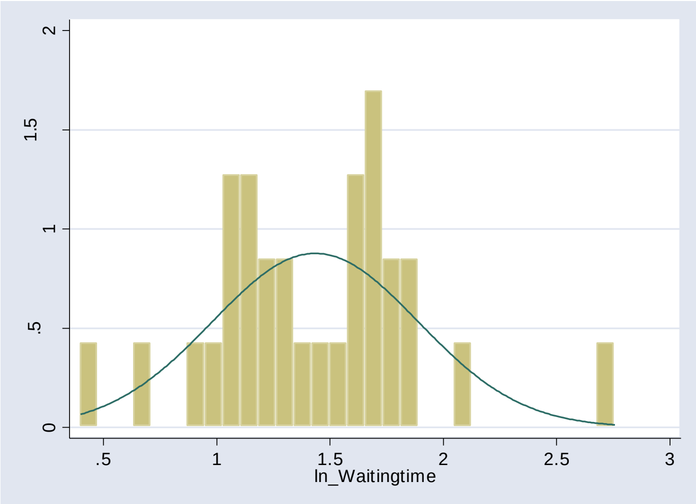
The most accurate measure of waiting time available is drawn from the Halcrow consumer surveys, where respondents were asked to report the waiting time for the taxi journey made in the last month. The methodology used to construct a measure of average waiting time from individual data is discussed in section 2.3 of this report. Figures A2.5 shows the distribution of *Waitingtime_IND* (in logarithm). Figure A2.6 shows the distribution of the logarithm of *Waitingtime_LA*, which demonstrates a particularly high value for waiting time (close to 15 minutes) in Cherwell. The econometric modelling has therefore been run with and without Cherwell, to check any statistically significant difference in the results. Figure A2.7 reports the distribution of the log of *Waitingtime_LA* excluding Cherwell.

Figure A2.5: Log of waiting time, individual level (*ln_Waitingtime_IND*)



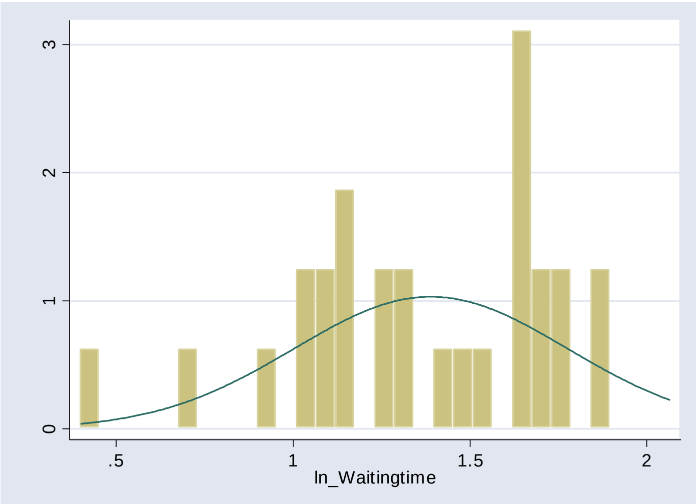
Source: OXERA analysis

Figure A2.6: Log of mean waiting time, LA level (*ln_Waitingtime*)



Source: OXERA analysis.

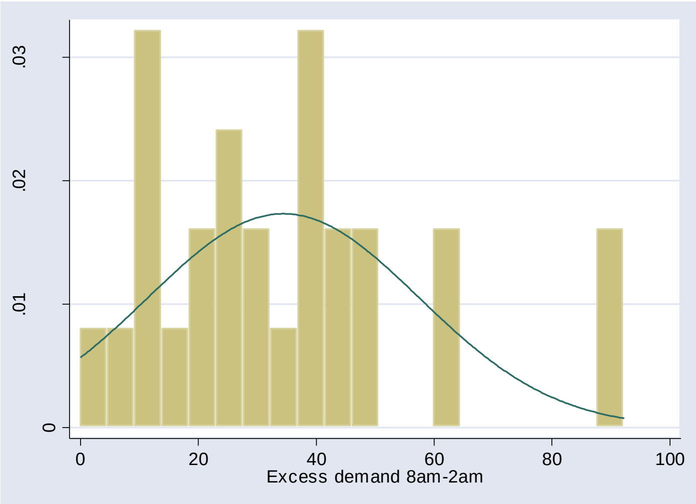
Figure A2.7: Log of mean waiting time, LA level excluding Cherwell (*ln_Waitingtime_LA*)



Source: OXERA analysis.

A specific indicator of waiting time at ranks is provided by the information collected in Halcrow unmet-demand studies on excess demand, defined as the proportion of ranks where there are two or more passengers waiting at any time in an hour of the day. As explained in section 3, *Excessdemand* has been defined by OXERA as the average of excess demand in each hour of the day, weighted by the corresponding average passenger delay in that hour. Weighting excess demand by passenger delay allows the length of time that passengers wait at a rank to be accounted for: for a given level of excess demand, higher weights are attached to hours characterised by longer passenger delays. Average peak and off-peak excess demand have also been constructed to assess whether entry and quality-of-service regulation have a different impact on waiting time at peak and off-peak periods. The advantage of using the excess demand indicator rests on its high reliability, given that the data for unmet-demand studies has been collected through third-party observations. Hence, this indicator is less likely to be subject to measurement errors than customers' perception of waiting time collected through the customer survey. On the other hand, the excess demand studies capture waiting time at rank only, while *Waitingtime_IND* (*Waitingtime_LA* at the LA level) provides an average measure of waiting time for the three methods of obtaining a taxi: hailed in the street, caught at a rank, or booked by telephone. Both measures are used in the modelling of waiting times in section 7. Figure A2.8 shows the distribution of *Excessdemand*.

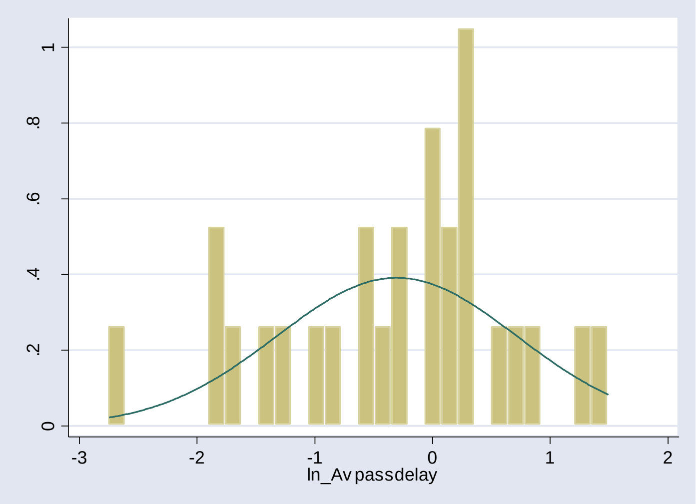
Figure A2.8: Average excess demand between 8am and 2am (*Excessdemand*)



Source: OXERA analysis.

Average passenger delay, defined as the average waiting time at a rank (minutes) between 8am and 2am, has also been used as dependent variable in the waiting time regression (as well as peak and off-peak average passenger delay). Figure A2.9 shows the distribution of the variable in logarithm. As for excess demand, a peak and off-peak measure of average passenger delays has been constructed to test whether entry and quality-of-service regulation has a different impact on peak and off-peak time.

Figure A2.9 Log of average passenger delay (*Ln_Avepassdelay*)

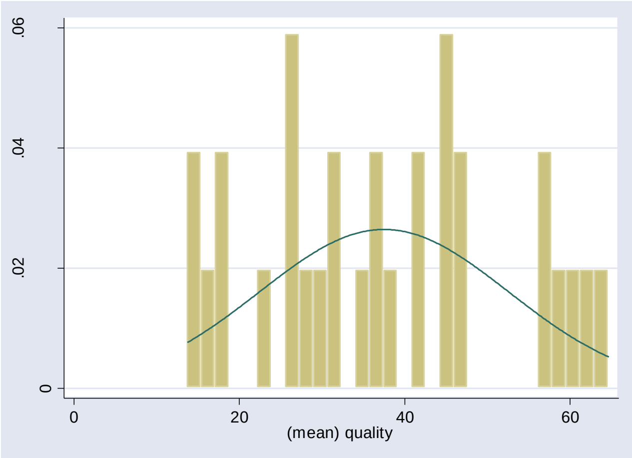


Source: OXERA analysis.

Quality of service

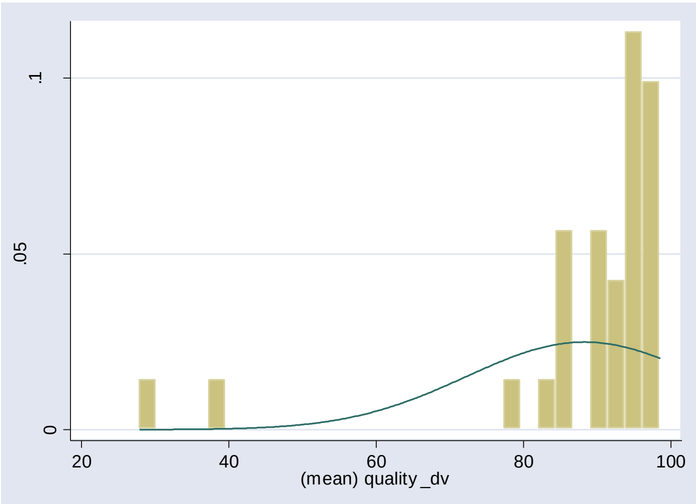
The only available evidence on customers' satisfaction with quality of service is drawn from Halcrow's customer surveys, where respondents are asked whether the hackney carriage service could be improved. The *quality_LA* variable is defined at the LA level as the percentage of respondents satisfied with the current level of service (see section 2.3 for an explanation of how this variable has been constructed). However, this variable is only an imperfect proxy for actual quality of service, given that overall satisfaction could be mainly related to the actual level of fares and number of hackney carriages. Ideally, only customers' perception on the level of quality of service should be included as an indicator of consumer welfare in the regression model of actual quality of service. To circumvent this problem, the *quality* variable has been restated by recoding as 'dissatisfied customers' only those respondents stating that 'better drivers' and 'better vehicles' are priority improvements for them, and all the other respondents as 'satisfied customers'. Although this is the only possible adjustment to be made to the available quality variable in order to obtain a better proxy for actual level of quality of service, this adjustment is imperfect, to the extent that respondents who did not state 'better drivers' and 'better vehicles' as priority improvements are also dissatisfied with the actual level of quality. For example, it may be that some respondents stated level of fares as a reason of dissatisfaction because this factor was the highest in their priority list, but they would have pointed out other aspects of service that could be improved, had they been given the opportunity. The modelling exercise for the quality of service has been run using both *quality_LA* (*quality_IND* at the individual level) and *quality_dv_IND (quality_dv_IND* at the individual level*)* as dependent variables, although the modelling of *Quality_LA* and *Quality_IND* did not yield any significant result. The results of the modelling are reported in section 8. Figures A2.10 and A2.11 show the distribution at the LA level of *quality_LA* and *quality_dv_LA*, respectively.

Figure A2.10: Overall satisfaction with hackney service, LA level (*quality_LA*)



Source: OXERA analysis.

Figure A2.11: Satisfaction with quality of drivers and vehicles of hackney service, LA level (*quality_dv_LA*)



Source: OXERA analysis.

Appendix 3: General-to-specific Methodology

OXERA has adopted a general-to-specific methodology in the estimation of the models. The stages of this methodology are the following:

- all potentially relevant explanatory variables, which seem to make sense a priori on economic grounds, have been considered for inclusion;
- a number of measurable and reasonably uncorrelated (or ‘orthogonal’) explanatory variables have been selected as the explanatory factors to be included in the ‘general model(s)’ to be estimated;
- statistical testing has then be employed to reduce the explanatory factors to a few key variables to produce a parsimonious model, with statistically insignificant variables being dropped out of the equation(s). The significance of each explanatory variable (ie, the extent to which the variable ‘explains’ the dependent variable) is signalled by the ‘t-ratio’ statistics;
- once the specific model has been identified, the most appropriate functional form have been tested statistically. The advantage of specifying the model in log terms is that the coefficients related to the explanatory variables (ie, the ‘b’ coefficients) can be interpreted directly as elasticities;
- *ex post* diagnostic testing has then be employed, to check that the relationships estimated are robust in statistical terms. A key aspect of any model evaluation is the extent to which the model fits the data—referred to as goodness-of-fit. One popular measure is the coefficient of determination, R^2, which refers to the proportion of the sample variability of the dependent variable that is explained by its linear relationship with the regressor set. F-test also provides a joint significance test of all the variables in the model and represents the multivariate version of the t-test. Additional diagnostic tests have also been conducted.

Appendix 4: Statistical Output and Diagnostic Tests

The **coefficient estimates** for each of the variables are displayed in the model summary tables. In addition, information is provided in order to ascertain the *statistical significance* of each of the coefficients (and therefore the validity of including the explanatory variables in the models).

- **Standard errors**—these provide measures of the statistical uncertainty surrounding each of the coefficient estimates (the higher, the more unreliable the estimate obtained).

- **t-statistic**—dividing the coefficient estimate by its standard error results in a 't-statistic'. These statistics may be compared with tabulated values. If the t-statistic for a particular coefficient falls below its tabulated critical value, the explanatory variable concerned is not viewed as 'statistically significant' and should be removed from the model. The critical values are dependent on the size of the dataset. However, as a rule of thumb, in large datasets an explanatory variable is statistically significant if its t-statistic exceeds 1.96 using a 5% significance level test. The 'significance level' is the theoretical probability of finding that a coefficient estimate is significantly different from zero when its 'true' value is indeed zero.

- **Probability value (p-value)**—these are provided in addition to the t-statistics, and refer to the lowest significance level at which the coefficient estimate obtained becomes statistically significant. Basically, low p-values (ie, less than 0.05) indicate high statistical significance—thus, a p-value of 0.025 indicates that the explanatory variable is significant at the 2.5% significance level. The model summary tables in this report also provide key summary statistics in relation to the overall model fit obtained.

- **Number of observations**, **N**, which refers to the number of observations used to fit the model.

- $\mathbf{R^2}$, which provides a measure of the 'explanatory power' or 'goodness of fit' of the model, or the extent to which the relationship posited fits the data.[10] An R^2 of 1 indicates a perfect fit, whereas an R^2 of 0 indicates no explanatory power.

- **Adjusted** $\mathbf{R^2}$ provides an adjusted measure of the goodness of fit of the model. The value of R^2 will always increase even if insignificant variables are added to the model. The adjusted R^2 adjusts the R^2 value by imposing a 'penalty' for any increase in the number of explanatory variables.

[10] More specifically, this refers to the proportion of the variability of the dependent variable (on the left-hand side) that is explained by the formulation described (on the right-hand side).

- **F-test** provides a joint significance test of all the variables in the model and represents the multivariate version of the t-test. In the table the **F(k, N – k – 1)** value—where k represents the number of explanatory factors in the model excluding the constant—provides the value of the statistic, while **Probability > F** provides the significance level of the test. As with the t-test, a **p-value** below 0.05 indicates that all the variables are jointly significant (at below the 5% level) in explaining the variation in the dependent variable.

- **Root MSE**, or 'root mean-squared error', is the standard error of the OLS error term. This provides a further indication of the overall performance of the model (the higher this standard error, the less reliable the model).

Since, theoretically, an R^2 of 0 would indicate no explanatory power and an R^2 of 1 would indicate a good fit, it would be tempting to dismiss a low R^2 value as representing a poor model fit. However, if a model is a 'unit' cost model (with the dependent variable divided by a key scale driver), the model will tend to have a low R^2.[11] For unit cost models, a poor R^2 is not necessarily indicative of poor model performance. A better indication is given by the **R^2 value of the unrestricted version of the model**.

Finally, the table provides some information on three 'diagnostic tests', conducted after the modelling has been undertaken. Basically, there are some assumptions regarding the behaviour of the error term upon which OLS estimation is based. When these assumptions break down, the results of the modelling can be invalidated. Diagnostic testing helps to ascertain whether these assumptions have broken down.

The three tests presented are for the following potential problems:

- **heteroscedasticity**—OLS assumes that the variance of the error term, u_i, is constant. If this is not the case then heteroscedasticity is said to exist, which may be tested using a 'Cook Weisberg' (CW) test; and

- **RESET**, incorrect functional form—OLS assumes that the true relationship is that specified in the regression model estimated (eg, a 'linear' or a 'log' relationship). If this is not the case, the functional form has been 'mis-specified', which may be tested using a 'Ramsey RESET' test;

- **skewness/kurtosis** is a test for the normality of the residuals. This is undertaken by examining the third and fourth moments of the distribution of the residuals—their skewness and kurtosis. These measure whether the distribution is symmetric or skewed to one side, and how fat the 'tails' of the distribution are. These measures are then compared with the expected values from a normal distribution. Normality of the

[11] This is because the variability of the left-hand-side variable is reduced somewhat by adopting the restriction implicit in the unit cost formulation—ie, that of no economies of scale with respect to population.

residuals is assumed for some of the statistical tests. The failure of this test is not as serious as if the above two tests fail, but could indicate the presence of outliers.

If these problems occur, the error term, u_i, will not be 'well behaved'. In turn, this makes interpreting the results from the regressions estimated problematic. In general, *high* p-values associated with these tests are desirable, as this means that it is possible to reject the hypothesis that heteroscedasticity exists, that the functional form has been mis-specified, or that the errors are not normally distributed.

The application of OLS requires the following assumptions to hold:

- the error term εi has a zero expected value (which will always be the case if a constant term is included);
- the error term has a constant variance and errors are unrelated to each other;
- errors are unrelated to explanatory factors;
- parameters are constant (this factor is generally of more relevance in time-series modelling, but could also be relevant in cross-sectional data); and
- the error term is distributed normally.

The most relevant diagnostic tests are for the following two potential breaches of the above assumptions: heteroscedasticity; and functional form mis-specification.

Heteroscedasticity occurs when the classic assumption of a *constant error variance* across observations does not hold. In particular, problems for statistical inference based on least-squares estimates tend to arise when this error variance is a function of the values of the explanatory variables. For example, heteroscedasticity might, hypothetically, occur in the R&T model if the size of the error term increases with the number of sources in each company. Although this should not affect the expected values of the coefficient estimates, β_1, β_2 and β_3, it would invalidate the standard errors associated with these coefficients. Consequently, heteroscedasticity would hamper the assessment of whether particular variables were statistically significant.

Tests for heteroscedasticity tend to consider whether the error variance (estimated by the squared residuals) is a function of the explanatory variables and their squares. This paper uses the CW test. Here, if the value of the test statistic obtained exceeds the relevant critical value in the χ^2 distribution, or equivalently that the p-value is *below 5%* (or 0.05), then the 'null hypothesis' (of no heteroscedasticity) is rejected.

Regression models also make an assumption that the dependent variable is related to the explanatory variables in the particular way chosen by the researcher. For example, the R&T model assumes that the relationship between unit costs and each of the explanatory variables is linear. However, hypothetically, the true relationship might be logarithmic (as in a number of Ofwat's other models), or a function of the squares of the explanatory variables might be included.

The Ramsey RESET test of functional form is a very general test and considers whether adding non-linearities into the model significantly adds explanatory power. The test examines whether squares and 'cross-products' of the explanatory variables should be included in the regression equation. If the value of the test statistic derived exceeds the relevant critical value in the *F*-distribution, or, equivalently, if the p-value is below 0.05, then the null hypothesis (of correct functional form) is rejected.

The diagnostic test used after Tobit modelling estimation is the link test, which performs a link test model for model specification error based on Pregibon.[12].

One kind of model specification error is that the dependent variable requires a transformation or link to relate it to the independent variables.

If a regression is well specified it should not be possible to find any additional variables that are significant. The link test adds an independent variable to the specification that is likely to be significant, such as predictions and squared predictions. If these variables are found to be significant it is possible that the dependent variable is not correctly specified to form a good fit with the independent variables.

To rectify a problem with the linkage either the dependent or the independent variables may be changed to adequately capture the nature of the relationship being modelled.

[12] Pregibon, D. (1979), 'Data Analytic Methods for Generalized Linear Models', PhD Dissertation, University of Toronto.