The Impact of Transport Policy on Residential Location

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Abstract The objectives of this chapter are to assess the extent to which transport impacts on residential location decisions and hence on housing occupancy rates and house prices and to assess the extent to which transport policy decisions (such as road user charging, changes to fuel duties or the provision of light rapid transit systems) affect housing markets. This was achieved by undertaking two Stated Preference (SP) experiments in the Greater Oxford area. The aim of these experiments was to determine the key transport and location factors that householders take into account when determining their residential location. These surveys suggested that householders place high values on transport times and costs but also value low density developments, access to high quality schools, low noise levels and developments in small towns/rural areas. Stated Preference data was used to develop a hedonic pricing (HP) model which suggested much lower impacts of travel time to work, housing density and school quality on house prices than the SP choice model. Nonetheless, validation tests indicated that the HP model provided more reliable forecasts of house prices than the SP model. The HP model was used to provide preliminary forecasts of the impact of transport improvements on house prices in the Greater Oxford area.

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1 Introduction

It has been long recognized that transport factors have significant impacts on residential location. Although there is also an extensive literature on the influence of transport on residential location and on house prices, most of the previous studies have been based on revealed preference data. Thus these studies could only show the changes of transport behavior and impacts on housing markets after provision of new transport system or implementation of a new transport policy. Such studies are of significance in terms of evaluation of transport policies in the particular study region. However, the results of such studies have limitations to be directly applied to other regions due to differences of transport behavior, spatial patterns and so on in each region.

In this study, we analyze the trade-off effects between transport factors and housing price using stated preference data collected from 96 recently moved households in the Greater Oxford region in the UK. The estimation results of a bid-choice model and an hedonic model are then applied to examine the impact of different transport policies (such as a road user charge, changes of fuel duty, and a new public transport system) on housing markets. This study attempts to reveal not only the characteristics of consumer's behavior on residential location choice but also provides a framework to estimate the scope of funding transport improvements through various transport policies.

This study is novel in both its methodology, using an advanced discrete choice approach to calibrate a bid choice model of residential location, and its practical application, which permits detailed analysis of the impact of changes to the transport system on the housing markets. This study analyses three major topics as follows: firstly, individual behavior of residential location choice in terms of the trade-offs between transport factors and the others is analyzed using a discrete choice model. Secondly, the impact of transport accessibility on housing price is investigated through estimations of a bid-choice model and a hedonic price model. Finally, based on the housing price estimates, the impact of various exogenous transport policies on housing value is forecasted through a preliminary simulation method. The models are validated by comparing the forecast housing values with actual housing prices. It is then applied to examine the impact of different transport policies on housing markets in general and on property values in particular. The scope of funding transport improvement is investigated as this could provide an important long-term solution to transport funding problems.

The structure of this paper is as follows. In the rest of this section, a brief review of some recent relevant literature as well as the empirical framework are provided. In Section 2, the empirical models are specified and calibrated. In Section 3, the simulation models are applied with respect to the introduction of a road user charge, a fuel duty increase, a fuel duty decrease and the introduction of a new public transport system, Guided Transit Express. In Section 4, important findings and policy implications are summarized.

1.1 Review of Previous Study

There is an extensive literature on the influence of transport on residential location and therefore on house prices. Much of it is reviewed in Pagliara and Preston (2002a). Subsequently the Royal Institution of Chartered Surveyors and the Office of the Deputy Prime Minister (RICS Policy Unit 2002) have published the results of their study on the relationships between land use, land value and public transport. This involved a review of about 150 references. The main aim was to identify and analyze how occupier demand expressed through land values and investment yields (capital value) varied according to transport provision. In addition, ways in which better understandings of the impact of transport on property values could be used in cost benefit appraisal of transport proposals were explored. Similarly, the ways in which the impacts of transport on property values could be used in appraising land use planning and urban regeneration proposals were investigated.

Key references reviewed included Walmsley and Perrett (1992) who studied and reviewed the effects of 14 rapid transit systems in the UK, France, USA and Canada. They found that in Washington D.C. homes near stations appreciated at a faster rate than similar homes further away. Similarly, the Tyne and Wear Metro (TRL 1993) was found to have a localized effect on the housing market in a few areas, where the attractiveness of housing increased and some redevelopment took place. In general, properties near the Metro gained and maintained a slightly higher value compared with properties further away. Cervero and Landis (1995) reported that evidence from California reveals some degree of capitalization benefits, which over the long run could be expected to induce clustering around rail stations. However these impacts cannot be easily generalised. Ingram (1998) reports results of experience with new subways in Montreal, San Francisco, Toronto and Washington D.C. He found a very modest effect on metropolitan development patterns. There was also some evidence of development around stations (Toronto and Washington). Similarly, there is some evidence of CBD development impacts of high-speed rail. Banister and Berechman (2000) reviewed impacts of high-speed rail in Japan. Impacts were found at both the network and local levels. Network effects relate to the substantial increase in accessibility to key national and international markets. Another interesting study is the evaluation of the impacts that the London congestion charge had on property prices both inside and outside the zone (Zhang and Shing 2006). The congestion charge was introduced in February 2003 to reduce traffic levels in the centre of London. Postcode sector level property prices for sectors are investigated under the premise that the benefits of transport innovation can be captured by property prices. If housing markets are efficient, residential property prices should capture all the benefits and costs to commuters that a location offers. It is found that the gap between property price inside and outside the zone has actually reduced as a result of congestion charging. Also, after the implementation of congestion charge, the sensitivity of house prices with respect to distance from the boundary has fallen for sectors inside the zone relative to sectors outside the zone. An hedonic pricing model is estimated in the work of Debrezion et al. (2006) with the aim of analyzing the impact of railways on house prices in terms of distance to railway station, frequency of railway services and distance to the railway line. It has found out that dwellings very close to a station are on average about 25% more expensive than dwellings at a distance of 15 km or more. A doubling of frequency leads to an increase of house values of about 2.5% ranging from 3.5% for houses close to the station to 1.3% for houses further away. In the study by Hess and Almeida (2007) the impact of proximity to light rail transit stations on residential property values in Buffalo, New York is assessed, where light rail has been in service for 20 years, but population is declining and ridership is decreasing. Hedonic models are constructed of assessed value for residential properties within half a mile of 14 light rail stations and independent variables are included that describe property characteristics, neighborhood characteristics and locational amenities. The model suggests that, for homes located in the study area, every foot closer to a light rail station increases average property values by $2.31 (using geographical straight-line distance) and $0.99 (using network distance). Consequently, a home located within one-quarter of a mile radius of a light rail station can earn a premium of $1,300–3,000, or 2.5% of the city's median home value.

1.2 Empirical Framework

Traditional location theory examines the role of accessibility on house prices. It states that housing and accessibility to employment centers are jointly purchased in that those paying higher prices are compensated by the lower costs of commuting to the central business district (CBD) (So et al. 1996). This is the bid rent approach that has its origins with Alonso (1964).

An alternative choice approach, particularly associated with Anas (1982), examines the probability of an individual choosing a particular property as a function of the characteristics of that property, the characteristics of the individual/household and characteristics of the neighborhood in which the property is located, including accessibility. A stated preference (SP) model of this type has been calibrated and is detailed in Pagliara and Preston (2002b) and Pagliara et al. (2002a). Our empirical framework is to develop a bid choice model, which is a combination of the choice model and bid rent approaches. More specifically, we intend to follow the approach developed by Martinez (2000). That is, we intended to start by estimating the choice probability that house type v in zone i is bought by individual/household h, as given by (1):

$$P_{vi/h} = \frac{\exp \mu'(WP_{hvi} - r_{vi})}{\sum\limits_{v'i' \in \Omega} \exp \mu'(WP_{hv'i'} - r_{v'i'})} \tag{1}$$

with WP = Willingness to Pay, r = house price (rent).

The bid probability of house type v in zone i being bought by individual household h is then given by (2):

$$P_{h/vi} = \frac{\exp(\mu B_{hvi})}{\sum_{h'=H} \exp(\mu B_{h'vi})} = \exp \mu(WP_{hvi} - w_h - r_{vi} + \gamma), \tag{2}$$

where B is the bid, γ is the Euler's constant and w is the bidder's surplus, which in a perfectly competitive model will approximate to zero.

The potential terms in the WP function can be represented as:

$$WP_{hvi} = b^0 + b_h^1 + b_{vi}^2 + b_{hvi}^3. \tag{3}$$

Notice that, with the choice probability equation, it is impossible to calibrate constant WPs terms or those associated with attributes that depend only on (i.e. are constant across) households (b^0, b^1). Conversely, with the bid probability equation, constant parameters and linear terms on locations attributes (b^0, b^2) cannot be calibrated. Thus in both cases one can only calibrate truncated WP functions. In the case of bid probability equation (2), we complement the calibration by adding the rent equation (4):

$$r_{vi} = E\left[\underset{h \in H}{Max} \left(B_{hvi} + \varepsilon_{hi} \right) \right] = \frac{1}{\mu} \ln \sum_{h \in H} \exp[\mu(WP_{hvi} - w_h)] + \frac{\gamma}{\mu}. \tag{4}$$

Equation (4) allows us to calibrate the terms b^0 and b^2 in (3). This approach has been developed in Santiago, Chile, by Martinez (2000) by calibrating (2) and (4) jointly by several methods (sequential and simultaneous). However, the problem we encountered in Oxfordshire was that data were only readily available in a highly aggregate form. For example, our SP surveys only contained sufficient data for four household types (high/low income, work in city/elsewhere), two household locations (city/suburb) and two house types (detached/non detached). Similarly, house price data was only readily available at the postcode district level (e.g. OX1). As a result, an alternative approach based on hedonic pricing has been applied.

2 Model Calibration and Validation

2.1 Model Specification and Calibration

The starting point was the combination of the two utility functions of two different SP experiments (one considering access to work, the other considering access to shops) and then recalibration of the coefficients. The second step was that of converting the choice model into the bid-choice model in order to get a model, which can forecast the property chosen by households. All the attributes considered in the two SP experiments were important for the understanding of the choices made by residents in Oxfordshire (Pagliara et al. 2002b; Pagliara and Preston 2002a). However each experiment, used on its own, provided just limited information, thus a combination of the two was made. This might be thought of as a form of integrated choice experiment (Van de Vijvere et al. 1997).

The two different data sets were combined considering respectively the attributes in the second experiment held constant when calibrating the first experiment and the attributes of the first experiment held constant when estimating the second experiment. The specification of the SP choice model was as follows:

$$P_{vi/h} = \frac{\exp \mu(WP^*{}_{hvi} - r_{vi})}{\sum_j \exp\mu(WP^*{}_{hvj} - r_{vj})}, \tag{5}$$

where $P_{vi/h}$ is the probability of household h choosing property v in zone i, $WP^*{}_{hvi}$ is the truncated willingness-to-pay of household h for a property v in zone i.

The independent variables used for the empirical estimation of (5) are defined and explained in Table 1.

2.2 Estimation Results and Validation

The estimation results are reported in Table 2 for the full data set. All the attributes are significant and of the expected sign. House price, travel time and cost to work appear to be important factors influencing residential location choice. The negative value of the housing density dummy is justified by the fact that people prefer to live in areas where there is much open land. The negative value of the location dummy CITY means that the preference is for living away from the city i.e. in country towns and rural areas – we refer to these locations below as SUBURBAN areas. Another important factor is travel cost to shops, which is negative and significant, i.e. people prefer to live close to shopping centers. The positive and highly

Table 1 Variable definition

Variable	Definition
HPrice	The current market value of the house (in pounds)
TTWork	The total time (in minutes) spent making a single trip from the house to the workplace
TCWork	The total cost (in pence) spent making a single trip from the house to the workplace
DENS	A dummy equal to 1 if the house is in an area with no open land, 0 otherwise
CITY	The location within the boundary of Oxford City (OX1, OX2, OX3, OX4)
TCShop	The total cost (in pence) spent making a single trip from the house to a large supermarket
QSCH	A dummy, equal to 1 if the house is in an area with good schools, 0 otherwise
NOISE	A dummy equal to 1 if the house is in a noisy area, 0 otherwise
DETACH	A dummy equal to 1 if the house is detached, 0 otherwise

Table 2 Stated preference choice model estimation results

Variable	Coefficient (t-value)
HPrice	−0.328-E05 (−2.620)
TTWork	−0.449-E01 (−9.033)
TCWork	−0.660-E02 (−5.125)
DENS	−0.498 (−7.593)
CITY	−0.291 (−4.027)
TCShop	−0.321-E02 (−2.790)
QSCH	0.727 (12.849)
NOISE	−0.877 (−14.015)
DETACH	0.323 (3.653)
No. of observations	3,072
L(*)	−2,928
L(0)	−3,374
ρ^2	0.132

Table 3 Probabilities computation for persons working in city

Income	House Type	Residence	Estimated probability	Actual probability
High	Detached	City	0.33894	7.89E-02
		Suburban area	0.24377	0.28947
	Non-detached	City	0.24654	0.39474
		Suburban area	0.17074	0.23684
Low	Detached	City	–	–
		Suburban area	0.13166	6.67E-02
	Non-detached	City	0.46091	0.48889
		Suburban area	0.40744	0.44444

significant value of the quality of school dummy means that people prefer to live in areas with good schools. The negative and significant value of the noise dummy means that the choice of residence is strongly influenced by the noise level of a given area. The preference is to live in quiet areas. The positive and significant value of the detached dummy means that people prefer, all other things being equal, to live in detached houses.

Households are grouped according to household income and workplace location. Household income categories (two levels) are low (in our sample less than/equal £42.50 K per year) and high (greater than £42.50 K per year). Workplace locations are CITY, i.e. within the boundary of Oxford city (OX1, OX2, OX3, OX4) and SUBURBAN area (the remaining part), i.e. outside Oxford city (two levels). Therefore, four categories of households have been identified. Residential zones are again CITY and SUBURBAN area (two levels) and whether households live in a detached house or not (two levels). Again four categories have been identified. Therefore 16 (= 4 × 4) different segments have been identified and the estimated and actual probabilities are reported in Tables 3 and 4. The estimated probabilities were obtained by operationalising (5) with the coefficient values in Table 2. The actual probabilities came directly from our surveys.

Table 4 Probabilities computation for persons working in suburban area

Income	House type	Residence	Estimated probability	Actual probability
High	Detached	City	–	–
		Suburban area	0.28989	0.42857
	Non-detached	City	0.15119	0.28571
		Suburban area	0.55892	0.28571
Low	Detached	City	–	–
		Suburban area	0.71049	0.16667
	Non-detached	City	4.51E-02	0.16667
		Suburban area	0.19879	0.66667

For people working in the CITY (Table 3) and choosing a detached house, the actual probability of residing in a SUBURBAN area is higher for those in the high income group compared to those in the low income group. The former, thanks to their budget, can choose to live in a detached house with higher prices. Conversely, the actual probability of choosing a non-detached house and residing in a SUBURBAN area is higher for those in the low income group. For people working in the SUBURBAN area (Table 4), the actual probability of residing in the SUBURBAN area and choosing a detached house is higher for those in the high income group (although our model's forecasts do not replicate this). High income group can move to the CITY. The probability of living in the CITY and choosing a non-detached house is also higher for the high income group, reflecting their ability to afford more expensive properties.

2.3 Comparison Between Actual and Estimated Probabilities

The estimated probabilities in Tables 3 and 4 fail to take into account supply side constraints. For example, the stock of detached houses is limited, particularly in the CITY. Therefore, in order to derive a bid-rent model from our SP choice model the following procedure was developed, to reflect the aggregate nature of our data. The willingness-to-pay is related to utility by the following relation: $U_{hvi} = \mu (WP_{hvi} - r_{vi})$ and given that the log sum is the appropriate measure of expected maximum utility the following expression can be computed (for a model calibrated at the individual level):

$$b_i = \frac{1}{\theta\mu} \ln \sum_h H_h S_{hi} \exp(\theta\mu WP_{hi}), \tag{6}$$

where:

I	is the zone index,
H	is the household type (high/low income, work in city/suburban area),
H_h	is the number of households of type h,
S_{hi}	is the density of households of type h in zone i,
$\theta\mu$	are parameters to be estimated.

Given that the parameter μ has been estimated in the SP choice model the re-scaling parameter θ may be estimated from aggregate data, based on the Berkson-Theil method as follows:

$$\ln\left(\frac{P_{h/vi}}{1-P_{h/vi}}\right) = \theta\left(U_{h/vi} - U_{h/vj}\right), \tag{7}$$

where:

$P_{h/vi}$	is the probability house and location type vi is chosen by individual h,
$U_{h/vi}$	is the utility of the chosen alternative for individual h and house and type location type vi,
θ	is the parameter to be estimated.

From (7), the θ coefficient has been obtained as 0.464 with a t-statistic of 4.244. Hayashi and Doi (1989) found values for a bid MNL (Multinomial Logit) scale parameter of about one third of the choice MNL scale parameter. This result is comparable to what we have obtained. From Table 2 we can estimate the willingness to pay as equal to:

$$\begin{aligned} WP_{hvi} = (&-0.449\text{-}E01\ TTWork - 0.660\text{-}E02\ TCWork - 0.498\ DENS \\ &- 0.291\ CITY - 0.321\ TCShop + 0.727\ QSCH - 0.877\ NOISE \\ &+ 0.323\ DETACH)/0.328 - E05 \end{aligned}$$

where 0.328-E05 is the parameter value of the house price attribute. Operational models recognise that the estimation of utility or willingness-to-pay functions is subject to inaccuracy in terms of fully describing actual behavior, and best defined as a stochastic variable. Let us assume that bids are given by $B_{hvi} = B_{hvi} + \varepsilon_{hvi}$ where $B_{hvi} = WP_{hvi} - w_h$ is the deterministic component, ε_{hvi} is a random error term and w_h is the speculative term that has to be equal for all location options to make sure that the consumer is indifferent to any option where he or she is the best bidder. A family of location models can be proposed by assuming different distributions of the random term. One of the most applied is the Gumbel distribution (Martinez 2000). Assuming the stochastic terms as independent and identically distributed Gumbel (IIG) with a scale parameter θ, we obtained the following expression for the expected maximum bid, which directly represents the expected rent at location (vi):

$$r_{vi} = E[MAX(B_{hvi} + \varepsilon_{hi}] = \frac{1}{\theta\mu}\ln\sum_{h\in H}\exp[\theta\mu(WP_{hvi} - w_h)] + \frac{\gamma}{\theta\mu}, \tag{8}$$

where γ is the Euler's constant (approximately 0.577) and we assume $w_h = 0$.

By applying appropriate weighting parameters (H_h and S_{hi}), house price forecasts for our aggregate categories are shown in Table 5. However, the forecasts systematically under predicted actual prices, with this being particularly evident for suburban non-detached properties. Moreover, the bid-choice prices that result are very sensitive to the weighting parameters used. However, it is important to note that our SP data was collected in April 2002 whilst our actual data was provided

Table 5 Comparison between bid-choice prices and actual prices (unit: £)

Residential area	House type	Bid-choice prices	Actual prices	% Change
City	Detach	362,790	385,000	−5.8
City	Non-detach	213,152	255,532	−16.6
Suburban	Detach	296,722	293,750	−1.0
Suburban	Non-detach	66,227	174,065	−62.0

Table 6 Estimation results of Hedonic Price Model

Attribute	β	t-statistic
Constant	83.072	5.296
NBEDROOMS	29.457	11.064
TTWork	−1.264	−8.482
TCWork	−3.631	−1.975
DENS	−16.345	−4.047
TCShop	−3.749	−0.921
QSCH	12.567	3.882
NOISE	20.531	4.634
DETACH	105.979	14.137
CITY	29.302	13.023
HIGH_INCOME	54.952	13.023
WORKCITY	14.462	2.295
R^2 : 0.276		

from the Land Registry for the period July to September 2002 (from www.proviser.com). There will have been some increases in house prices between these two dates. Between mid 2000 and mid 2001 house prices in Oxford rose by 19%, whilst between mid 2001 and mid 2002 house prices rose by 37%. This suggests that land prices in our study area could have risen by as much as 12% in the period between our surveys (in April, 2002) and the mid-term date of the Land Registry data used (August, 2002). In order to reconcile results, a hedonic pricing (HP) regression has been undertaken (Rosen 1974). This assumes that house prices are some implicit (hedonic) function of a bundle of attributes. The data set used is that collected in the stated preference exercise (3,072 observations) but includes data on the existing property as well as the two hypothetical properties presented in each scenario and the option of staying with the existing property is modelled in addition to choosing the hypothetical properties. An element of revealed preference data is therefore included in the HP model. The advantages of HP methods include their links with market data and their widespread application. Disadvantages include assumptions of identical incomes and preferences for all consumers, no transaction costs and fixed supply (Tinch 2002).

A linear model was specified, with the explained variable being house price (in thousands of pounds) and the explanatory variables being the other attributes in the SP experiment but in addition the number of bedrooms was added as an attribute. Table 6 reports the estimation results of the hedonic model. Note that TCWork and TCShop are expressed in pounds rather than pence. Most parameter values are significant at the 5% level (but note the repeat observations problem will be at play here), although the TCWork parameter value is only just significant and

Table 7 Values (in £) in terms of house price of a unit change in attributes

Attribute	SP		HP	
	Attribute values	t-statistics	Attribute values	t-statistics
TTWork	−13,680	(2.67)	−11,264	(8.48)
TCWork	−2,011	(2.37)	−36.31	(1.98)
DENS	−151,868	(2.42)	−16,345	(4.05)
TCShop	−978	(2.11)	−37.49	(0.92)
QSCH	221,650	(2.47)	12,567	(3.88)
NOISE	−267,406	(2.50)	20,531	(4.63)
DETACH	98,538	(2.28)	105,979	(14.14)
CITY	−88,807	(2.31)	29,302	(5.64)

the TCShop parameter value is insignificant. The goodness of fit is only modest, suggesting this model may be affected by multicollinearity. This is a common problem with HP models and might also explain the implausible sign of the NOISE parameter value, although this could also reflect model mis-specification. For example, our model only includes local accessibility measures but locations close to motorway junctions, although having high noise levels, may also have good long distance accessibility.

Table 7 reports some marked differences in attribute values obtained from the SP and HP approaches. The SP valuations of TTWork, QSCH, and DETACH are more than 10 times greater than the values from the HP model, whilst the SP valuation of DENS is over 9 times greater than that of the HP model. Moreover, the valuations of TCWork and TCShop are even more substantially higher in the SP model than the HP model. This leads to a high value of time estimated in the HP model of almost 35 pence per minute compared to the much more plausible 8 pence per minute in the SP experiment.

The Department for Transport's Transport Economic Note (http://www.roads.dft.gov.uk/roadnetwork/heta/highway/04.htm) suggests a market price value of working time for car drivers of 35.1 pence per minute (23.3 pence per minute for all modes) and 7.5 pence per minute for non-working time (all at 1998 prices). This suggests that the HP model's values of time are broadly consistent with values of working time and the SP model's values are broadly consistent with values of non-working time. Around 13% of distance traveled and around 5% of all trips by car are in the course of work (Source: http://www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm#012 <Accessed 27 February 2007), and hence we would expect the "true" average values to be closer to the SP than the HP results, although the HP results may reflect marginal values.

It is also noteworthy that the CITY dummy variable has a negative impact on house prices in the SP model but a positive influence on house prices in the HP model. This may suggest that those living in the CITY are less likely to move than those living in rural areas or country towns. Similarly, the NOISE parameter has a strong negative effect on house prices in the SP model but a modest positive effect in the HP model.

The comparisons in Table 7 suggest that the values from the SP model may have serious upward biases. These are corrected in the HP model by better representing

Table 8 Comparison between hedonic prices and actual prices (unit: £)

Residential area	House type	Hedonic prices	Actual prices	% Change
City	Detach	357,662	385,000	−7.10
City	Non-detach	216,976	255,532	−15.08
Suburban	Detach	293,652	293,750	−0.03
Suburban	Non-detach	187,673	174,065	7.81

housing characteristics by including a parameter for the number of bedrooms and thus reducing specification error. It is interesting to note that the one valuation that was similar in the SP and HP models was the DETACH dummy variable. Furthermore, the inclusion of the choice of the current property may have led to a better representation of budget and other constraints and thus reduced non-commitment bias.

Table 8 presents the resultant forecast prices from the HP model. Compared to Table 5, there is no longer a systematic under valuation of prices. The main advantage of the HP approach appears to be the more accurate forecasts of suburban non-detached housing.

2.4 Application of the Hedonic Price Model to the Study Area

The final stage of the study has involved the application of the model to assess the impact of transport policy changes on residential location preferences and the resultant prices. The area under study is the corridor Kidlington–Oxford–Abingdon.

The first step has been that of applying the HP model to the relevant post code districts, computing the resultant house prices and comparing them with the house prices in the Land Registry database (www.proviser.com). The aggregate nature of this analysis should be reiterated. These computations have given the following results shown by Tables 9 and 10. The sensitivity tests provided by Table 10 involved adjusting the HP model so that the values of time are in line with those obtained in the SP model. This was done by increasing (in absolute terms) the parameter values of travel costs to work and to shop to –18.5 from –3.631 and –3.749 respectively.

The unweighted HP model slightly underestimates house prices on average, as might be expected given the recent rapid increases (estimated as being as much as 12% between April and August 2002). The last column shows the percentage change of house prices since 2002.

The re-weighted model underestimates house prices to a greater extent as might be expected as the impact of transport cost has been increased somewhat artificially. Both models are reasonably accurate in aggregate, but both versions of the model have a problem in capturing the premium attached to OX2 (North Oxford) addresses by people working at the University of Oxford.

Table 9 (Unweighted) Comparison between hedonic prices and actual prices

Area	House type	Hedonic prices (£)	Land registry prices (£) (2002)	Δ% (2002)	Land registry prices (£) (2008)	Δ% Land registry prices (2002–2008)
OX1	Detach	307,670	297,125	3.55	529,272	43,861
	Non-detach	178,524	163,571	9.14	266,428	38,605
OX2	Detach	355,240	506,549	−29.87	543,881	68,640
	Non-detach	226,093	292,953	−22.82	327,603	10,576
OX4	Detach	284,196	307,500	−7.58	426,059	27,826
	Non-detach	153,277	148,686	2.96	197,594	24,751
OX5	Detach	280,293	300,083	−6.59	426,906	29,707
	Non-detach	157,653	145,666	8.23	169,499	14,060
OX13	Detach	238,246	279,286	14.69	525,800	46,883
	Non-detach	172,211	164,055	4.97	155,000	−5,841
OX14	Detach	239,772	240,740	−0.40	356,135	32,402
	Non-detach	173,737	155,369	11.82	171,189	92,412
Average		230,576	250,147	−3.44	341,280	23,245

Table 10 (Weighted) Comparison between hedonic prices and actual prices

Area	House type	Hedonic prices (£)	Land registry prices (£) (2002)	Δ% (2002)
OX1	Detach	289,990	297,125	−2.40
	Non-detach	160,844	163,571	−1.67
OX2	Detach	340,789	506,549	−32.72
	Non-detach	215,643	292,953	−26.39
OX4	Detach	275,014	307,500	−10.56
	Non-detach	146,604	148,686	−1.40
OX5	Detach	274,280	300,083	−8.60
	Non-detach	147,556	145,666	1.30
OX13	Detach	225,907	279,286	−19.11
	Non-detach	169,330	164,055	3.22
OX14	Detach	215,974	240,740	−10.29
	Non-detach	169,397	155,369	9.03
Average		219,277	250,132	−8.30

3 Model Application and Policy Simulation

The model has been applied by examining the impact of some transport policy scenarios on the housing market and in particular on house prices. Further details are given in Pagliara et al. (2002b). Actual travel times and costs to/from each of the postcode districts have been computed for both car and bus, whilst journey to work movements have been obtained from the 1991 Census.

In order to evaluate the effect of transport policy changes on residential location preferences the incremental logit model (Kumar 1980; Preston 1991) has been applied to calculate the mode shares of travel in the before and after situation. For the simple two mode situation, the formulation is as follows:

$$P'_C = \frac{P_C \exp(U'_C - U_C)}{P_C \exp(U'_C - U_C) + P_{PT} \exp(U'_{PT} - U_{PT})}, \tag{9}$$

where:

$P'_C(P_C)$	is the proportion of people choosing car in the after (before) situation,
$U'_C(U_C)$	is the utility measure of car in the after (before) situation,
P_{PT}	is the proportion of people choosing public transport in the before situation,
$U'_{PT}(U_{PT})$	is the utility measure of public transport in the after (before) situation.

Four different scenarios have been examined for illustrative purposes. These are (1) Road User Charge, (2) Fuel Duty Increase, (3) Fuel Duty Decrease and (4) Introduction of the GTE system.

In order to calculate the proportions in the after situation with the provision of the new mode of transport (Scenario 4), the extended logit model formulation has been applied. This has the following formulation:

$$P'_{PT} = \frac{P_{PT}\,[exp(U'_{NT} - U_{XT}) + exp(U'_{NT} - U_{XT})]^{\phi}}{P_C\, exp(U'_C - U_C) + P_{PT}\,[exp(U'_{NT} - U_{XT}) + exp(U'_{NT} - U_{XT})]^{\phi}}, \tag{10}$$

where

$_{XT}$ = Existing Public Transport mode (Bus),

$_{NT}$ = New Public Transport Mode (Guided Transit Express),

ϕ = Expected Maximum Utility Parameter Value.

The utility of travel in the before situation is therefore:

$$U^* = \ln(\exp U_C + \phi \exp U_{XT}). \tag{11}$$

This can been divided through by the cost parameter in order to derive a generalised cost measure. Similarly in the after situation, the utility of travel can be determined as:

$$U'^* = \ln[\exp U'_C + \phi(\ln(\exp U'_{XT} + \exp U'_{NT}))]. \tag{12}$$

A problem with such composite utility terms is that they cannot easily be split into time and cost changes. Naïve averaging of times and costs will give implausible results. For example suppose a new public transport mode such as Guided Transit Express is introduced and which on average has the same speeds as other modes (but will be faster for some passengers) but fares are slightly higher than the bus. Averaging would indicate that overall the generalized costs of travel have gone up and overall travel demand has gone down. However, this is not plausible. Barring congestion effects, a new transport mode cannot reduce demand, at worst it can have no effect. The solution to this was to use the proportionate change in generalized costs (and its component time and cost elements) derived from (11) and (12) to adjust both travel time and travel cost. Ideally, our HP model would include the composite utility terms as explanatory variables but this was not possible with the data sets used in this project.

Equations (9) and (10) thus determine the impact on modal shares of transport policy changes. The impacts on travel times and costs are then computed from (11) and (12) and these are then fed into the HP model (Table 6) to determine the impact on house prices.

3.1 Road User Charge

In the first scenario, a cordon toll of £1 per day is introduced for those traveling into or through the city centre (specified as OX1 and OX2). This is similar to the level of road user charging being considered at the time in cities such as Bristol. It is supposed that in the city centre there is an increase in speeds equivalent to a decrease of 5 min of travel time. Tables 11 and 12 report the resultant prices in the two situations, reflecting a value of time of 35 pence per minute and 7 pence per minute respectively.

The charge of £1 to enter the central area (OX1 and OX2) from OX4, OX5, OX13, and OX14 has caused a decrease in house prices in the outer areas of between 2% and 18%, with this decrease in house price being more marked in the (re)weighted model as expected given the increase in the cost parameter value. The slight increase in house prices in OX1 and OX2 of between 1% and 6% is due to the forecast reductions of travel time in those areas. Overall, the unweighted HP model suggests an average housing price decrease of 1.7%. However, this is composed of an average 1.8% increase in house prices in the charged area and a 3.4% decrease in the non charged area. A similar pattern has recently been forecast, using a different methodology, in work in Greater Manchester undertaken as part of a parallel New Horizons project (David Simmonds Consultancy 2003).

Table 11 (Unweighted) Prices in Scenario 1 (£)

Area	House type	Before	After	% Change
OX1	Detach	307,670	311,591	1.26
	Non-detach	178,524	181,445	1.61
OX2	Detach	355,240	361,250	1.66
	Non-detach	226,093	232,218	2.64
OX4	Detach	284,196	277,080	−2.57
	Non-detach	153,277	146,110	−4.91
OX5	Detach	280,293	273,953	−2.31
	Non-detach	157,653	151,009	−4.40
OX13	Detach	238,246	232,122	−2.64
	Non-detach	172,211	165,311	−4.17
OX14	Detach	239,772	233,001	−2.91
	Non-detach	173,737	167,882	−3.49
Average		230,576	227,748	−1.69

Table 12 (Weighted) Prices in Scenario 1 (£)

Area	House type	Before	After	% Change
OX1	Detach	289,990	297,123	2.40
	Non-detach	160,844	166,444	3.36
OX2	Detach	340,789	348,122	2.11
	Non-detach	215,643	229,163	5.90
OX4	Detach	275,014	232,175	−18.45
	Non-detach	146,604	125,001	−17.28
OX5	Detach	274,280	241,745	−13.46
	Non-detach	147,556	127,122	−16.07
OX13	Detach	225,907	198,122	−14.02
	Non-detach	169,330	146,145	−15.86
OX14	Detach	215,974	188,412	−14.63
	Non-detach	169,397	207,146	18.22
Average		219,277	208,893	−6.48

It should be noted that the HP model does not take into account relative accessibility (in contrast to the bid rent and bid choice approaches) and hence might understate the differential between charged and non-charged areas. On the other hand, we have assumed that the revenue raised from road user charging is not hypothecated into, for example, improvements to local public transport or bettering the local urban environment. Such hypothecation could reduce the impact on property prices in the outer area (David Simmonds Consultancy 2003).

3.2 Fuel Duty Increase

Scenario 2 considers an increase of 10% in fuel duty assuming that the petrol cost is equal to 70 pence/l and that the fuel duty is equal to 60 pence. Tables 13 and 14 show the prices after this increase. As expected, such an increase has brought a reduction of house prices everywhere, in this case of between 2% and 13%. Again this is more marked in the reweighed model. Overall, the unweighted model suggests an average house price reduction of 3.4%.

3.3 Fuel Duty Decrease

Scenario 3 considers a decrease of 10% in fuel duty, again assuming that the petrol cost is equal to 70 pence/l and that the fuel duty is equal to 60 pence. Tables 15 and 16 show the resultant house prices after this decrease. In this scenario, house prices increase everywhere as expected by between 2% and 9%. Overall, the unweighted model suggests an average house price increase of 3.2%. However, in comparison with a fuel duty increase, some interesting asymmetries are revealed. This reflects the non-linear nature of the incremental logit models used to forecast the impact of fuel duty on mode choice and hence on overall travel times and costs.

Table 13 (Unweighted) Prices in Scenario 2 (£)

Area	House type	Before	After	% Change
OX1	Detach	307,670	300,712	−2.31
	Non-detach	178,524	173,204	−3.07
OX2	Detach	355,240	346,041	−2.66
	Non-detach	226,093	216,895	−4.24
OX4	Detach	284,196	276,686	−2.71
	Non-detach	153,277	146,488	−4.63
OX5	Detach	280,293	272,544	−2.84
	Non-detach	157,653	152,268	−3.54
OX13	Detach	238,246	230,620	−3.31
	Non-detach	172,211	164,585	−4.63
OX14	Detach	239,772	230,828	−3.87
	Non-detach	173,737	169,793	−2.32
Average		230,576	223,389	−3.35

Table 14 (Weighted) Prices in Scenario 2 (£)

Area	House type	Before	After	% Change
OX1	Detach	289,990	272,063	−6.59
	Non-detach	160,844	153,144	−5.03
OX2	Detach	340,789	330,122	−3.23
	Non-detach	215,643	201,075	−7.25
OX4	Detach	275,014	248,126	−10.84
	Non-detach	146,604	132,122	−10.96
OX5	Detach	274,280	259,122	−5.85
	Non-detach	147,556	137,896	−7.01
OX13	Detach	225,907	199,889	−13.02
	Non-detach	169,330	158,015	−7.16
OX14	Detach	215,974	203,166	−6.30
	Non-detach	169,397	158,126	−7.13
Average		219,277	204,406	−7.53

Table 15 (Unweighted) Prices in Scenario 3 (£)

Area	House type	Before	After	% Change
OX1	Detach	307,670	314,467	2.16
	Non-detach	178,524	185,110	3.56
OX2	Detach	355,240	364,179	2.45
	Non-detach	226,093	235,033	3.80
OX4	Detach	284,196	296,722	4.22
	Non-detach	153,277	160,445	4.47
OX5	Detach	280,293	286,299	2.10
	Non-detach	157,653	161,978	2.67
OX13	Detach	238,246	249,191	4.39
	Non-detach	172,211	176,156	2.24
OX14	Detach	239,772	249,376	3.85
	Non-detach	173,737	178,341	2.58
Average		230,576	238,108	3.21

Table 16 (Weighted) Prices in Scenario 3 (£)

Area	House type	Before	After	% Change
OX1	Detach	289,990	310,122	6.49
	Non-detach	160,844	175,369	8.28
OX2	Detach	340,789	358,889	5.04
	Non-detach	215,643	236,728	8.91
OX4	Detach	275,014	299,125	8.06
	Non-detach	146,604	159,223	7.93
OX5	Detach	274,280	289,693	5.32
	Non-detach	147,556	156,478	5.70
OX13	Detach	225,907	240,102	5.91
	Non-detach	169,330	178,690	5.24
OX14	Detach	215,974	233,489	7.50
	Non-detach	169,397	179,236	5.49
Average		219,277	232,179	6.66

3.4 Introduction of the GTE System

Another scenario considered is the provision of the Guided Transit Express (GTE) system. This system will serve the Kidlington–Oxford–Abingdon corridor studied for the other scenarios. The aim of our model is to estimate the impact of the system on house prices. Oxford GTE is a proposal for a guided bus way to allow an express bus network to connect the city centre to key Park and Ride sites and surrounding towns. The GTE route involves sections of off-highway (on a guide way) and on-highway alignment. The concept of a guided bus scheme to link Park and Ride sites to the north and south of Oxford with the City centre was first proposed in 1994 by the Oxford Bus Company. At that time, the project was being considered as a public– private partnership involving the County and City Councils and key private sector organizations including Oxford's bus companies, national construction companies and local business and education establishments.

The intention of the GTE is to provide fast, reliable and congestion free routes for public transport into the city centre of Oxford from country towns and villages. The scheme will enable public transport operators to provide a more effective network of routes and interchange points to serve Oxfordshire County and Oxford City (CJ Associates 2001). It will help to ease congestion by removing cars from the roads and routing some existing bus services from the roads into the guide way. This will also help to improve the quality of the city centre in terms of both air quality and pedestrian amenity. In addition, by providing additional public transport services the stress on existing networks will be reduced.

The provision of the GTE will change travel times and costs. It is supposed that this system will have fares around 10% higher than competing bus services and will reduce travel times between the areas directly served by the route. Tables 15 and 16 show the forecast house prices after the introduction of the new system.

With the provision of the GTE prices go up everywhere. The increase in house prices varies between 1% and 7%. This is not surprising since the new system brings reductions in travel times and makes all areas more accessible. The more accessible

Table 17 (Unweighted) Prices in Scenario 4 (£)

Area	House type	Before	After	% Change
OX1	Detach	307,670	320,348	3.96
	Non-detach	178,524	191,200	6.63
OX2	Detach	355,240	363,100	2.16
	Non-detach	226,093	233,299	3.09
OX4	Detach	284,196	290,602	2.20
	Non-detach	153,277	156,430	2.02
OX5	Detach	280,293	286,739	2.25
	Non-detach	157,653	164,510	4.17
OX13	Detach	238,246	246,113	3.20
	Non-detach	172,211	180,078	4.37
OX14	Detach	239,772	245,750	2.43
	Non-detach	173,737	179,660	3.30
Average		230,576	238,152	3.32

Table 18 (Weighted) Prices in Scenario 4 (£)

Area	House type	Before	After	% Change
OX1	Detach	337,035	345,831	2.61
	Non-detach	207,889	215,683	3.75
OX2	Detach	393,457	399,396	1.51
	Non-detach	264,310	269,249	1.87
OX4	Detach	313,967	319,575	1.79
	Non-detach	184,728	188,379	1.98
OX5	Detach	276,222	282,439	2.25
	Non-detach	192,497	200,238	4.02
OX13	Detach	249,749	257,711	3.19
	Non-detach	203,172	211,577	4.14
OX14	Detach	250,507	256,131	2.24
	Non-detach	203,930	210,240	3.09
Average		256,455	263,037	2.70

is an area the higher are the price increases, with the biggest increases in central Oxford (OX1), Kidlington (OX5) and Abingdon (OX13 and OX14). The unweighted model suggests an average house price increase of 3.2%. This is broadly consistent with the recent RICS (2002) survey. It should be noted that the forecast increase in house prices is less in the weighted model because the GTE is more expensive but faster than existing public transport and the weighted model involves increasing the sensitivity of house prices to travel cost increases (Tables 17 and 18).

4 Conclusions

This study has had a number of findings as follows:

First, the literature review confirmed that the bid choice approach that combines bid rent and choice models of residential preferences was the most appropriate way forward.

Secondly, the SP models of residential choice confirmed the importance of attributes such as transport times and costs, quality of schools, housing densities and noise levels. These models produced plausible estimates of the value of non-working travel time (in relation to travel cost) but appeared to produce implausibly high valuations of attributes in relation to house costs. We may speculate that this was due to a combination of different types of bias. Specification bias may have arisen due to omitted variables, such as those related to house type. Instrument bias may have arisen due to the unrealistic manner in which some attributes were represented in the SP experiments. Non-commitment bias may have arisen, as respondents in SP experiments are not committed to behave in the way they state in the surveys. In particular, it is difficult to represent budget and other constraints and the transaction costs associated with residential relocation in a SP experiment.

Thirdly, we found that disaggregate data did not readily exist in our Greater Oxford case study area to develop a bid choice approach at a meaningful level of spatial resolution. We are aware that house price data is becoming available at the postcode sector level (e.g. OX13 – see for example www.upmystreet.com). This in combination with 2001 Census data and improved transport models offers the prospects of more disaggregate data in the near future, which we intend to investigate in follow-up research.

Fourthly, an HP model produced more plausible valuations of the impact of travel time, quality of schools, housing densities and noise levels on house prices. However, the impact of travel costs was implausible, although not particularly statistically robust.

Fifthly, application of the HP model suggests that transport policy changes appear to have relatively modest impacts on house prices, particularly if more plausible assessments of the valuation of travel costs are used. The unweighted HP model suggested road user charging might reduce house prices on average by around 2%, although this was made up of a reduction of house prices of on average 3% outside the charged area and an increase in house prices of 2% inside the charged area. A 10% change in fuel duty was found to have a similar overall effect, leading to an average change in house prices of around 3%, but with the direction of change being uniform throughout the study area. It was also found that introducing a new public transport system (Guided Transit Express, now Expressway Oxford) might increase house prices by around 3% on average, with the greatest increases being in central Oxford and the outer suburbs (Abingdon and Kidlington) These changes may be considered modest given the backdrop of an increase in house prices over the last year of over 30%.

We therefore conclude that transport policy has a small but significant impact on the housing market. For example, we estimate that our Kidlington–Oxford–Abingdon corridor has a population of over 190,000 and almost 80,000 residential dwellings. An average price increase of £7,000 as a result of the Guided Transit Express, would suggest a windfall gain in the residential property market of over £500 million. This suggests that there may be substantial scope for fiscal measures that capture such increases in land values, though it should be noted that such measures would themselves probably affect the behavior of households and hence of the market.

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