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DETERMINANTS OF CAR OWNERSHIP IN RURAL AND URBAN AREAS: A PSEUDO-PANEL ANALYSIS

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ABSTRACT

This paper examines the factors determining car ownership for households living in rural and urban areas. A dynamic car ownership model is estimated using a pseudo-panel approach, based on data from Family Expenditure Surveys in the UK for 1982 to 1995. The results show that rural households' car ownership is far less sensitive to motoring costs than that of their urban counterparts. The implication of these results is that general increases in the costs of car transport would pose a considerable economic burden for rural households, and that other area-specific transport measures may be more suitable, particularly from an equity point of view.

keywords: transport modelling, car ownership, demand elasticities, pseudo-panel, family expenditure survey data

INTRODUCTION

This paper utilises the repeated cross-section data from annual Family Expenditure Surveys in the UK to estimate a dynamic car ownership model. It is based on a 'pseudo-panel' approach[1] which entails grouping individuals or households into cohorts, which are defined on the basis of common shared characteristics, and tracing the cohorts over time[2]. By treating the averages for the cohorts as observations in a panel, a dynamic model is estimated on the basis of the pseudo-panel data set. Although the data are not a true panel, since the individuals included change from year to year, the individuals within each cohort have similar characteristics in each time period, so that the cohorts can be treated as if they were observations of the same individuals over time. Thus the term "pseudo-panel".

The model relates car ownership to income, the costs of car ownership and use, and the socio-demographic characteristics of the households. It is dynamically specified so that the effects on car ownership of changes in these factors can be analysed over time, providing estimates of both short- and long-run elasticities. The study follows earlier work using this methodology and data set for the analysis of car ownership (Dargay and Vythoulkas, 1999). This paper extends the work presented there by giving particular consideration to differences in car ownership – and its determining factors – for households living in rural, urban and 'other' areas. In addition, the data sample is extended to 1995.

The primary objective of the modelling work is to determine the effects of transport costs on car travel in different time perspectives – i.e. the various short- and long-run cost elasticities that are required for policy assessment. The magnitude of these elasticities will determine the extent to which motoring could be reduced by various price-related policy measures or the cost increase required to realise a desired reduction in car traffic. The extent to which the elasticities differ for different household groups will determine the distributional aspects of the cost increase. Given the greater 'car dependency' in rural areas, the possibility to adjust to increases in motoring costs will be more limited than in urban areas, and the elasticity will be smaller. This study provides empirical evidence of the differences in elasticities between these groups.

The outline of the paper is as follows. Firstly, the cohort data constructed from the UK Family Expenditure Surveys are illustrated and discussed, and the historical development of various costs likely to influence car ownership is described. The next section presents the car ownership models used for the analysis. The empirical results are presented in the following section, along with a discussion of the resulting price and income elasticities, and a comparison of the results with those of our earlier study. The paper ends with some concluding remarks

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[1] The use of 'pseudo-panel' data was introduced by Deaton (1985) for the analysis of consumer demand systems. The paper shows that under certain conditions, repeated cross-section data can be treated as panel data, and discusses the estimation of econometric models on the basis of such data.

[2] The use of 'pseudo' panels can be found in the demographic approach to mobility and car ownership (see, for example, Madre, 1990, Gallez, 1994). Jansson (1989) uses cohort data and regression analysis to model the determinants of car ownership entry and exit. Van den Broecke (1988) applies a cohort model for car ownership and licence holding.

THE DATA

Car ownership is modelled on the basis of a pseudo-panel data set constructed primarily from annual UK Family Expenditure Surveys (FES). This Survey has been carried out annually since the 1960s and provides a random sample of over 7,000 households per year. The variables of interest in the current study are household car ownership, income, household composition and rural/urban nature of the area of residence. We are limited to the surveys from 1982 onwards, since information on area of residence by population density is missing from the earlier data sets.

The FES, however, contains no information on prices. These data must therefore be obtained from other sources, and in the absence of more detailed price information, we are forced to resort to national price indices, which are assumed to be identical for all households. The data used for the analysis are described below.

The cohort data

The cohorts are formed by grouping households on the basis of shared characteristics. A two-way classification is used: one relating to 'generation' and one to residential location. Generation is defined by the year of birth of the household head, while residential location groups households into those living in urban, rural and 'other' areas[3]. The cohorts are traced over time in each of the annual surveys, and the cohort observations for car ownership, income and household composition are constructed as the average values for the households included in each year-of-birth/area group. In order to ensure that the cohort means of the variables based on the sample are reasonable estimates of the population cohort variables, 5-year bands are used for defining the generations and only those cohorts containing at least 100 households are included in the statistical analysis.

The data on car ownership for some of the cohorts are illustrated in Figure 1. The horizontal axis gives the age of the household head, and the vertical axis shows the average number of cars owned or used per household. The lines represent the different cohorts - solid for rural households and dashed for urban - with the birth-year bands given adjacently. For clarity, only every second age-group cohort is shown, and households living in 'other' areas are not shown.[4] The initial data point for each cohort is obtained from the first survey in which an observation for the cohort containing at least 100 households is available (1982 for most cohorts), and the final data point is obtained from the last survey containing a comparable observation (generally 1995).

As expected, car ownership is higher for rural than for urban households for all birth-year cohorts. On average, rural households have about 0.3 more cars than do comparable urban households. Both 'life-cycle' and 'generation' trends are apparent for cohorts in each of the areas. Although individual cohorts are followed for only a part of the life cycle, a general

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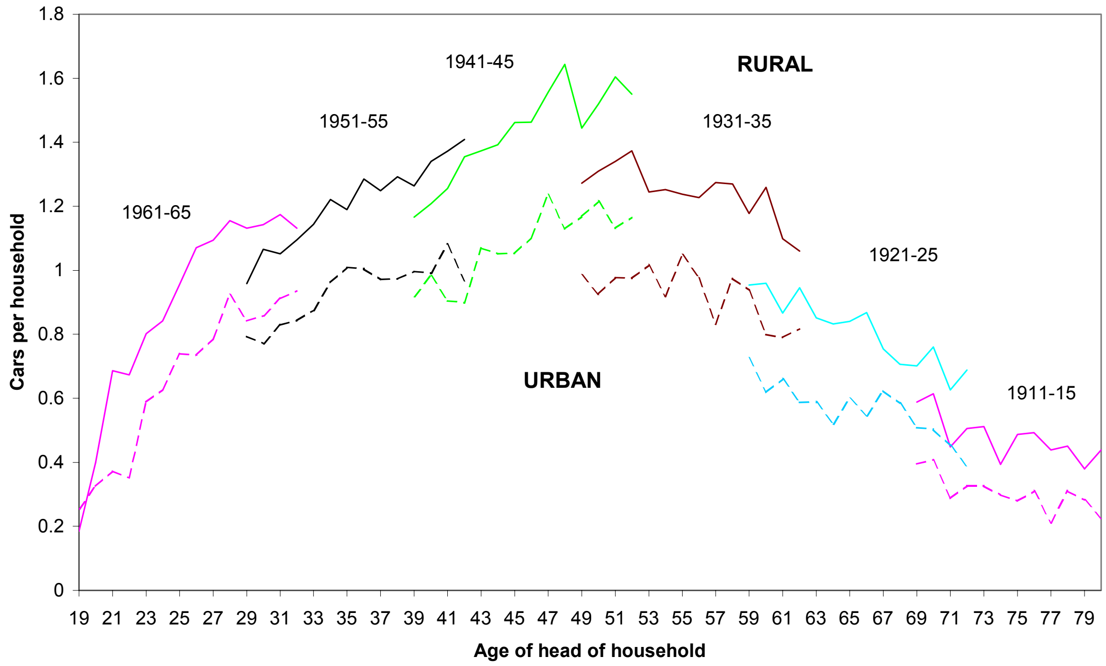
[3] Urban is defined as Greater London and former Metropolitan Counties in England (Greater Manchester, Merseyside, West and South Yorkshire, Tyne and Wear and West Midlands) and the Central Clydeside Conurbation in Scotland). Other and Rural are defined as non-Metropolitan districts with 7.9 or more persons per hectare, and less than 7.9 persons per hectare, respectively. These groupings are not ideal, but are the only ones provided in the FES.

[4] Car ownership for 'other' households lies in between that for rural and urban households for all cohorts.

pattern emerges: car ownership begins at a relatively low level, increases rapidly as the age of the household head increases, reaches a maximum at the age of around 50, and thereafter slowly declines. The generation effect is seen by comparing car ownership for cohorts in a common area and of the same age group, but with different years-of-birth. Here we see that car ownership at each age is higher for more recent generations than for previous ones.

As illustrated in Dargay and Vythoulkas (1999), the life-cycle effect predominantly reflects differences in income and household size and composition over the life cycle. Both real income (as measured by total weekly expenditures in constant prices) and the number of adults (of driving age) increase over the life cycle until the head reaches his/her early 50s and declines thereafter - a similar trend as that noted for car ownership. In like manner, the generation effect is partially explained by the rising incomes over the past decades - at the same age, incomes are generally higher for more recent than for older generations.

Figure 1. Cars per household for households living in rural (solid lines) and urban (dashed lines) areas *



* Every second cohort is shown with year of birth bands for head of household. The observation period is 1982-1995.

Transport costs

Car ownership is also influenced by costs – not only the purchase prices of cars, but also the costs of car use and fares of alternative transport modes. Since information on the prices relevant to individual households is not available, it is necessary to use national average price data.

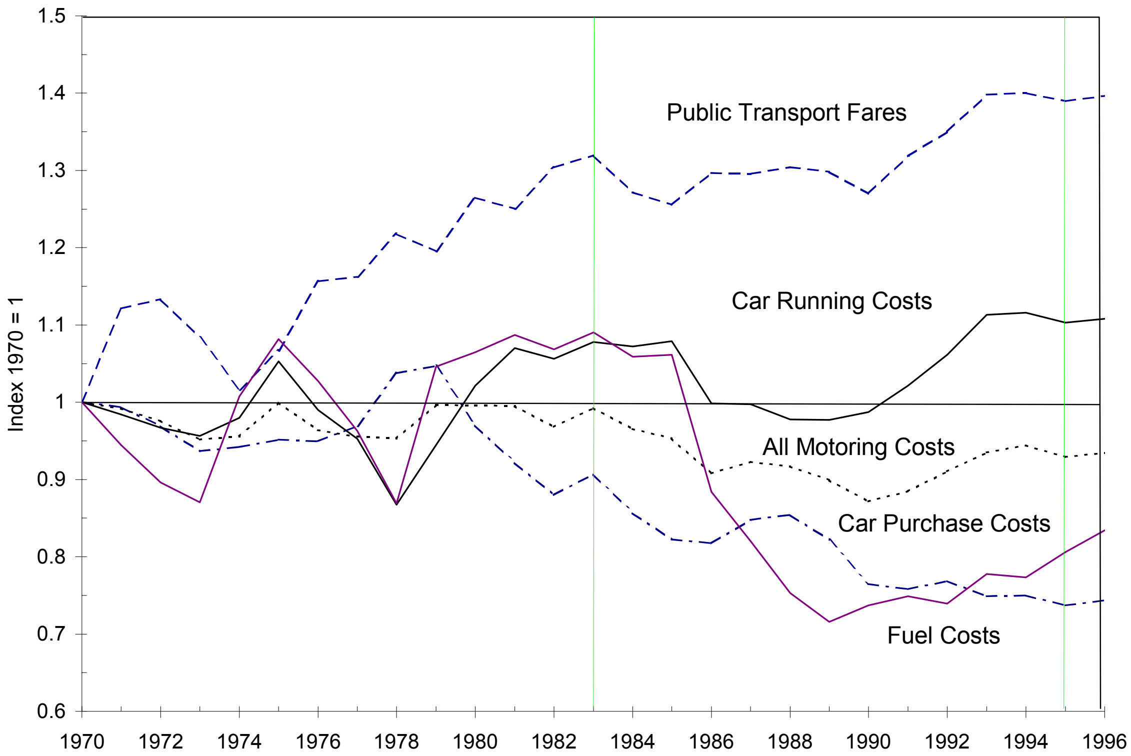
Relevant price data are shown in Figure 2 for the years 1970 to 1996. Although our study concerns car ownership for the period 1983 to 1995, pre-1983 costs are shown since the longevity of the vehicle stock implies that current car ownership is dependent on past as well as current costs. Post-1995 costs, however, are shown only for comparison.

All prices are converted into real terms using the retail price index and shown in index form with the prices for 1970 set equal to 1. Car purchase costs are calculated as a sales-weighted average of new and second-hand car prices. Running costs include maintenance, parts, tyres, petrol and oil, road tax, tolls, parking and insurance. Total motoring costs are comprised of both purchase and running costs. Fuel costs are calculated in per-kilometre terms as a weighted average of the prices of petrol and diesel and information on average vehicle fuel efficiencies. Public transport fares are a weighted average of rail and bus fares. All data were provided by the UK Department of the Environment, Transport and Regions.

Since the 1970s public transport fares have increased by 40% in real terms, far more substantially than any of the prices relating to private motoring. Of motoring costs, car-running costs have increased by around 10% while car purchase costs have declined by around 25%. The fluctuations in car running costs in the 1970s and the decline in the mid-80s reflect the variations in fuel prices resulting from the of oil price shocks of 1974 and 1979 and the price collapse of 1986, while the increase in the 1990s is mainly a result of escalating taxation on motor fuels. It is interesting to note that there has been an increase in car running costs (which include fuel costs) over the entire period, despite the fact that petrol prices in 1996 were about at the same level in real terms as they were in 1970. The reason for this is a large increase in insurance and car maintenance costs. Most significantly, it is apparent that car transport has become more economical overall in comparison to public transport over the period. Since 1970, public transport fares have risen by nearly 40% in real terms while total motoring costs have fallen by about 7%. This is likely to have had a significant impact on both car ownership and use, as well as on public transport use. The increase in the relative advantage of motoring is most evident during the 1970s, when public transport fares increased substantially while motoring costs remained more-or-less constant. In the period we are mainly concerned with in our study - 1982 to 1995 - fares rose by 7%, while total motoring costs declined by 4%.

The figures on car running costs and total motoring costs do not take into account improvements in vehicle fuel efficiency. In per-kilometre terms, car running costs have increased less and total motoring costs have decreased more than indicated in the figure. The measure of fuel costs shown in the figure, however, is adjusted for efficiency improvements. Fuel costs per kilometre have decreased by 20% over the period, with the greatest decline in the late 1980s.

Figure 2. Real transport prices, 1970-1996*



* 1970 = 1.0, observation period for current study demarcated by vertical dotted lines

In the econometric work we assume that the national average prices hold for all households in all areas. For motoring costs, this should not pose a problem, since these do not differ significantly in the broad areas used in the study. The assumption of common prices is a poorer one for public transport fares, however, as these are generally higher in rural than in urban areas, and the development over time has not been identical in all areas.[5] Because of this, and the lack of data on service provision, the effects of alternative transport modes are not considered in this study.

As mentioned above, the efficiency-adjusted fuel costs are a better measure of car use costs than the available data on total running costs. For this reason, in addition car purchase costs, fuel costs are used instead of total running costs to represent the costs of car use.

SPECIFICATION OF THE CAR OWNERSHIP MODEL

As in our earlier studies, a partial adjustment model is used to specify the dynamics of car ownership. We begin by assuming that desired long-run car ownership, $C^*_{i,r,t}$, for cohort of generation *i* in region *r* at year *t* can be expressed as:

[5] The variation in the level and development of bus fares in Great Britain is discussed in Dargay and Hanly (1999). Although data on bus fares exist on a county level for part of the time period concerned in this study, it has not been possible to construct fares for the rural-urban distinction used.

$$C^*_{i,r,t} = f(Y_{i,r,t}, A_{i,r,t}, K_{i,r,t}, P_t, G_i) \quad (1)$$

where $Y_{i,r,t}$, $A_{i,r,t}$, and $K_{i,r,t}$ are total household expenditures (used a proxy for income), the number of adults of driving age and the number of children per household included in cohort i in region r at period t. P_t are real prices relating to car ownership and use, which vary over time, but are assumed to be identical for all households. G_i is a cohort-specific generation effect, assumed to be the same for all regions and constant over time for each year-of-birth cohort.[6] Two specifications of the generation effect are tested. One is the normal fixed-effects model (FEM) that contains a time-invariant year-of-birth cohort-specific intercept term. The other is a "Generation" model (GEN). In this case, the generation effect is specified as the cohort number (which is based on the year of birth of the household head), and a constant term, assumed to be equal for all households.[7]

The partial adjustment model is based on the notion that households do not fully adjust to changes in circumstances or costs instantaneously, or within one time period. Instead, only a proportion θ of their desired adjustment is achieved during the first year,

$$C_{i,r,t} - C_{i,r,t-1} = \theta(C^*_{i,r,t} - C_{i,r,t-1}) \quad (2)$$

while adjustment in following years declines geometrically, finally to become negligible over time. Substituting desired car ownership (1) into (2) and rearranging terms results in the familiar lagged dependent variable model, where car ownership, $C_{i,r,t}$ for cohort of generation i in region r at year t is expressed as:

$$C_{i,r,t} = \theta\, f(Y_{i,r,t}, A_{i,r,t}, K_{i,r,t}, P_t, G_i) + (1-\theta)C_{i,r,t-1} + u_{i,r,t} \quad (3)$$

where $C_{i,r,t-1}$ is car ownership in period *t-1*. Other differences in car ownership between cohorts are assumed to be randomly distributed and subsumed in the error term $u_{i,r,t}$.

It remains to specify a functional form for the long-run relationship between car ownership and the independent variables. In addition to the linear and logarithmic models typically used, two other specifications are estimated which allow for saturation of car ownership. The four models are described below.

Model M1 - Linear model:

$$C_{i,r,t} = G_i + \theta\beta_{Y,r}Y_{i,r,t} + \theta\beta_{A,r}A_{i,r,t} + \theta\beta_{K,r}K_{i,r,t} + \theta\beta_{P,r}P_t + (1-\theta)\,C_{i,r,t-1} + u_{i,t,t} \quad (4)$$

In this model, the elasticities increase with car ownership and decrease with the level of the

6 Since the number of households in each cohort is not the same in every year, G will actually vary over time. However, as long as the number of households in each cohort is large, the variation will be small and can be ignored. See Deaton (1985) or Dargay and Vythoulkas (1999).

7 See Dargay and Vythoulkas (1999) for a derivation of this model.

independent variables. It is the specification used in Dargay and Vythoulkas (1999).

Model M2 - Semi-log model:

$$C_{i,r,t} = \theta G_i + \theta\beta_{Y,r} LnY_{i,r,t} + \theta\beta_{A,r} A_{i,r,t} + \theta\beta_{K,r} K_{i,r,t} + \theta\beta_{P,r} P_t + (1-\theta)\ C_{i,r,t-1} + u_{i,r,t} \tag{5}$$

In this model, there is a linear relationship between car ownership and all variables except income. Car ownership is a function of the log of income, so that the income elasticity decreases with increasing car ownership. This is the specification used in Dargay (2001).

The next two models assume that adjustment is in terms of the logs, rather than the levels, of car ownership, i.e. the Cs in equations (2) and (3) are replaced by *LnC*.

Model M3 - Double-log model:

$$LnC_{i,r,t} = \theta G_i + \theta\beta_{Y,r} LnY_{i,r,t} + \theta\beta_{A,r} LnA_{i,r,t} + \theta\beta_{K,r} LnK_{i,r,t} + \theta\beta_{P,r} LnP_t + (1-\theta)\ LnC_{i,r,t-1} + u_{i,r,t} \tag{6}$$

This is the commonly used constant elasticity model.

Model M4 - Log-inverse model:

$$LnC_{i,r,t} = \theta G_i + \theta\beta_{Y,r} / Y_{i,r,t} + \theta\beta_{A,r} LnA_{i,r,t} + \theta\beta_{K,r} LnK_{i,r,t} + \theta\beta_{P,r} LnP_t + (1-\theta)\ LnC_{i,r,t-1} + u_{i,r,t} \tag{7}$$

This model implies a constant elasticity for all variables except income. The log of car ownership is related to the inverse of income (1/Y), so that the income elasticity declines with increasing income.

The short-run elasticities are determined by the coefficients of the independent variables, the θβs, while the long-run elasticities are equal to the parameters of the long-run demand function, i.e. the βs. These are obtained by dividing the estimated coefficients by 1 minus the coefficient of the lagged dependent variable, i.e. by θ.

EMPIRICAL RESULTS

The fixed-effects (FEM) and the generation (GEN) versions of the functional specifications M1 to M4 in equations (4) to (7) are estimated from the year-of-birth and area cohort data described above. The estimation is based on data pooled cross-section time-series data for 41 cohorts - 13 rural, 15 other and 13 urban. These are shown in Table 1, along with the mean number of households in the sample comprising each cohort and the number of yearly observations available for each cohort. Each cohort contains between 100 and 300 households per year and information for the majority of cohorts is available for the entire 1983 to 1995 time period[8]. In all, we have a total of 445 observations.

Table 1. Cohorts included in the estimation, mean number of households per cohort and annual observations per cohort

		Mean number of Households per year			Number of annual observations		
Cohort	Date of birth of head	Rural	Other	Urban	Rural	Other	Urban
1	1901-1905		104			1	
2	1906-1910	115	148	134	3	8	6
3	1911-1915	126	179	158	8	11	13
4	1916-1920	127	209	161	11	13	13
5	1921-1925	147	260	196	13	13	13
6	1926-1930	134	234	178	13	13	13
7	1931-1935	127	220	163	13	13	13
8	1936-1940	130	223	181	12	13	13
9	1941-1945	149	259	183	13	13	13
10	1946-1950	179	315	226	13	13	13
11	1951-1955	152	290	222	13	13	13
12	1956-1960	147	283	236	12	13	13
13	1961-1965	139	272	221	8	11	11
14	1966-1970	113	195	165	2	7	7
15	1971-1975		129			2	
	All	142	239	190	134	159	152

In order to explore possible variation in elasticities for households in different areas, separate coefficients for most variables are estimated for each of rural, urban and 'other' cohorts, while the adjustment coefficient, θ, and the generation effects in the FEM and GEN models are assumed to be the same for all three areas. Two dummy variables, one set equal to 1 for rural areas and 0 otherwise, and one set equal to 1 for urban areas and 0 otherwise, are included to account for any differences in car ownership between the areas not accounted for by the other explanatory variables. Since the numbers of households in each cohort/time period are not the same, all variables are weighted by the square root of the number of households in the respective cohort to correct for the resulting heteroskedasticity. All models were estimated using Maximum Likelihood methods.

Initially, both the fixed-effects (FEM) and the generation (GEN) variations of models M1 to M4 were estimated. However, likelihood ratio tests for the restrictions imposed by the GEN model reject this formulation in preference to the fixed-effects model for all functional specifications.[9] This result differs from that found in Dargay and Vythoulkas (1999) using a

[8] The first observation, in most cases 1982, for each cohort is lost to allow for the lagged dependent variable.

[9] The χ^2 values with 14 degrees of freedom are 44.4, 51.1, 105.2 and 68.4 for models M1-M4 respectively, so

slightly different model and only year-of-birth cohort data for a shorter time period, where the generation model was not rejected. This appears to be due to the greater disaggregation and more recent data used in the current study. Particularly, the generation model assumes a linear increase in car ownership for each new generation, and this appears not to hold for the most recent generations, which make up a greater part of the extended sample used in the present study.

Tests for functional specification (models M1 - M4) are based on the preferred FEM models. These are shown in Table 2. For the linear and semilog models (M1 and M2) and the log and log inverse models (M2 and M3), we compare the Log-Likelihood values. The linear model (M1) is rejected in favour of the semi-log (M2) and the log model (M3) is rejected in favour of the log-inverse (M4). Since the dependent variables in models M1 and M2 are not the same as those in M3 and M4, comparison between groups cannot be done on the basis of the Likelihood values. Instead, we use the PE test[10], which involves re-estimating each of the models including the differences in predictions obtained from the initial estimation and testing for the significance of the prediction term. If the term is significant the model can be rejected. The results in the table show that M1 is rejected in favour of M3 and M2 is rejected in favour of M4. Since M3 was already rejected in favour of M4, M4 is the preferred model.[11]

Table 2. Tests for functional specification of the Fixed Effects Model.

Models	Test	Test statistics	Result
1 vs 2	Log likelihood values (LL)	LL(2) = 667.7 > LL(1) = 658.7	Reject model 1
3 vs 4	Log likelihood values (LL)	LL(4) = 592.5 > LL(3) = 574.2	Reject model 3
1 vs 3	PE-test: t-statistic and (p-value)	t(1) = 3.2 (0.00)	Reject model 1
		t(3) = 1.62 (0.11)	
2 vs 4	PE-test: t-statistic and (p-value)	t(2) = 3.3 (0.00)	Reject model 2
		t(4) = 0.13 (0.90)	

The results of the fixed-effects version of model M4 are presented in the first three columns of Table 3, each row showing the estimated coefficients for the given variable, followed by standard errors and probability values. The final three columns (restricted model) show the results for the same model, constraining the coefficients of all variables to be the same for all areas.

All the estimated parameters are of the expected signs and generally significant. Car ownership increases with income (since it decreases with the inverse of income), and the number of adults and children in the household, while car ownership decreases with increasing costs. The coefficient of the lagged dependent variable is significant and of a

that the GEN model is rejected at the 99% level in all cases.

[10] See MacKinnon, White and Davidson (1983).

[11] Similar tests were carried out in Dargay (2001) using only year-of-birth cohort data. M2 was the preferred model, but M4 was not considered.

reasonable order of magnitude. The value of (1-θ), estimated to be about 0.3 in the unrestricted model, implies that 70% of the adjustment of car ownership to changes in the independent variables occurs within one year, while full adjustment (99%) takes around 4 years. The speed of adjustment is substantially quicker than that indicated in Dargay and Vythoulkas (1999) using solely year-of-birth cohorts (40% occurring within one year and 99% within 10 years). The more rapid adjustment found within areas is reasonable since it does not include longer-term 'adjustment' by changing area of residence.

The dummy variables for rural and urban households are not significantly different from zero in the unrestricted model, but are highly so in the restricted model. This indicates that the differences in car ownership between rural, urban and other households are fully explained by the differences in the coefficients between areas in the unrestricted model. Constraining these coefficients to be the same for all areas (the restricted model) leaves a significant difference in car ownership between areas, which can only be 'explained' by the inclusion of area dummies. The estimated coefficients of the dummy variables in the restricted model are, as would be expected, indicative of a higher car ownership in rural areas and a lower ownership in urban areas, as compared to other areas.

Otherwise the coefficients of the two models are very similar, with those of income, costs and the number of adults estimated in he constrained model lying within the intervals of the coefficients of the unrestricted model. The number of children in the household is not significant in either of the models; in the specification shown the coefficient is restricted to be the same in all areas.

From the R^2 values, we see that both models fit the data extremely well. However, from the likelihood ratio test shown in the last row, we find that the hypothesis of equal coefficients for the three areas imposed by the restricted model is strongly rejected.

The estimated fixed effects for each year-of-birth are also shown the table. These can be interpreted as 'generation' effects, which cannot be explained by the included explanatory variables. Although the generation effect is generally increasing, indicating an increasing car ownership for more recent generations, it appears to fall for the most recent generations. The majority of these are not significant, particularly in the unrestricted model, and due to the large standard errors, most are not significantly different from each other. However, as is shown in the Likelihood Ratio tests at the bottom of the table, restricting all G_is to be the same is strongly rejected in both cases, so the fixed effects are not excluded from the model. It is clear that there is not a linear relationship between the generation effect and the cohort number, as is assumed in the generation model. It is thus not surprising that this latter model was rejected in favour of the fixed-effects model. However, given the large standard errors, no firm conclusions can be drawn concerning the generation effects.

Table 3. Estimated Log-Inverse model, dynamic specification

	Unrestricted Model			Restricted Model		
Variable	Coefficient	Std. Error	p-value	Coefficient	Std. Error	p-value
Cars per household (-1)	0.27	0.03	0.00	0.31	0.03	0.00
1/Income				-87.17	7.69	0.00
Urban	-90.15	7.71	0.00			
Other	-81.72	9.45	0.00			
Rural	-61.37	11.35	0.00			
Fuel costs				-0.05	0.03	0.11
Urban	-0.10	0.05	0.03			
Other	-0.05	0.04	0.27			
Rural	-0.06	0.06	0.33			
Car purchase costs				-0.32	0.07	0.00
Urban	-0.44	0.12	0.00			
Other	-0.40	0.10	0.00			
Rural	-0.23	0.14	0.11			
Adults per household				0.42	0.08	0.00
Rural	0.41	0.10	0.00			
Other	0.58	0.11	0.00			
Urban	0.55	0.12	0.00			
Children	0.02	0.02	0.14	0.01	0.02	0.49
Rural household	0.01	0.11	0.96	0.08	0.01	0.00
Urban household	0.02	0.09	0.84	-0.13	0.01	0.00
G1	-0.40	0.15	0.01	-0.23	0.13	0.09
G2	-0.32	0.12	0.01	-0.15	0.09	0.10
G3	-0.24	0.11	0.03	-0.07	0.09	0.40
G4	-0.14	0.11	0.21	0.02	0.08	0.85
G5	-0.09	0.11	0.40	0.06	0.08	0.49
G6	-0.06	0.11	0.60	0.08	0.08	0.30
G7	-0.01	0.11	0.93	0.13	0.08	0.13
G8	0.00	0.11	0.98	0.14	0.09	0.11
G9	0.03	0.11	0.79	0.17	0.09	0.05
G10	0.04	0.11	0.74	0.17	0.08	0.04
G11	0.03	0.11	0.77	0.17	0.08	0.04
G12	0.02	0.10	0.85	0.16	0.08	0.04
G13	-0.01	0.10	0.95	0.13	0.08	0.08
G14	-0.04	0.10	0.68	0.10	0.08	0.17
G15	-0.18	0.12	0.13	-0.03	0.10	0.76
Log-Likelihood		592.47			577.02	
Observations		445			445	
Estimated Parameters		31			23	
R^2		0.977			0.976	
LR-test for restrictions χ^2 (probability)						
G_I = C for all i =1 to 15		81.74 (0.000)			69.32	(0.000)
Restricted vs unrestricted					51.06	(0.000)

The short- and long-run elasticities results for both the unrestricted and restricted models are shown in the upper section of Table 4. The short-run income elasticity is calculated as $-\beta_Y$ /Y, while the short-run elasticities for the other variables are obtained directly as the estimated coefficients. The functional specification implies that the income elasticity declines with increasing income, thus allowing for the saturation of car ownership as income increases. Otherwise all elasticities are constant, and independent of car ownership and the level of the independent variables. The income elasticities shown in the table are calculated at an income of £250 per week (in 1989 prices) in all areas.

We see that the income and price elasticities increase with urbanisation level, while the effect of an increase in the number of adults declines. In most cases the difference in elasticity between rural and urban is areas is significant at at least the 90% confidence level. In all cases the income elasticity – even in the long run – is well below unity, indicating cars to be a necessary rather than a luxury good. At the same income level, the income elasticity is greater for urban households than for those in rural areas. This is logical; car ownership is higher in rural areas and closer to saturation and is more of a necessary good.

Table 4. Estimated short- (SR) and long-run (LR) elasticities*

	Unrestricted Model						Restricted Model	
	Urban		Other		Rural		All areas	
Dynamic Model								
	SR	LR	SR	LR	SR	LR	SR	LR
Income	0.36	0.50	0.33	0.45	0.25	0.34	0.35	0.51
Purchase costs	-0.44	-0.60	-0.40	-0.55	(-0.23)	(-0.31)	-0.32	-0.46
Fuel costs	-0.10	-0.14	(-0.05)	(-0.07)	(-0.06)	(-0.08)	(-0.05)	(-0.07)
Adults	0.41	0.57	0.58	0.80	0.55	0.76	0.42	0.60
Static Model**								
Income	0.47		0.43		0.32		0.49	
Purchase costs	-0.69		-0.64		-0.47		-0.59	
Fuel costs	-0.14		(-0.08)		(-0.06)		-0.07	
Adults	0.61		0.79		0.75		0.60	

*Values in parenthesis indicate elasticities are not significantly different from zero at the 95% level.
**Based upon estimates found in the Appendix

As expected, car ownership is more sensitive to changes in car purchase costs than to fuel costs, and the sensitivity to both costs increases with urbanisation. Car ownership in urban areas is twice as sensitive to car purchase costs as it is in rural areas – rural households are more car dependent and have little alternative transport possibilities, so that the cost matters less. In addition, while car ownership in urban households is mildly sensitive to fuel costs, rural and other households appear to be totally price insensitive.

An increase in the number of adults in the household has a greater impact on car ownership in rural areas than in urban areas. Again, this is in keeping with expectations, as multiple-car households are more prevalent in rural areas. Finally, as would be expected, the elasticities obtained from the restricted model lie within the intervals for the different areas in the unrestricted model.

For comparison, the lower section of Table 4 shows the elasticities obtained from the same models using a static specification, i.e., without the lagged car ownership term. These are based on the estimates presented in the Appendix. The overall pattern of the coefficients are very similar to those obtained in the dynamic specification, although they are generally of a greater order of magnitude. The conclusions concerning model choice are the same: the restricted model is rejected in favour of the unrestricted and the fixed-effects model is preferred to one with a single intercept term. However, the static model has a poorer explanatory power than the dynamic model, and as shown in the last row, the static model is clearly rejected in favour of the dynamic.

We see that the elasticities estimated on the basis of the static model are very similar to the long-run elasticities in the dynamic model, and that the differences in elasticities between rural and urban households support the conclusions based on the dynamic model. It appears that - in this case, at least - the static model captures long-run relationships. However, the disadvantage of using the static model is that it gives no indication of the short-run elasticities or of the time required for adjustment to changes in the factors determining car ownership.

The results of this study can be compared with those reported in Dargay and Vythoulkas (1999), which were based on the same data, but using a shorter time period and with no distinction between rural, urban and other households. The main advantage of the current study is that differences between households living in different areas are examined. In addition, a number of tests are carried out to determine the functional form of the car ownership relationship, instead of assuming a linear model. For this reason, the results presented in the current study are better grounded statistically. The functional form chosen on the basis of the statistical tests is also more plausible economically - the income elasticity declines with increasing income, which allows for vehicle saturation, and the remaining variables follow the constant elasticity formulation typically used in demand studies. The linear form used in our earlier study is more questionable, since it implies that the elasticity of each independent variable increases as the variable increases and decreases as car ownership increases. This is particularly implausible for transport costs. Although the elasticity may increase at higher cost levels, it is unlikely that it decreases at higher car ownership.

Given these differences, it is not surprising that the elasticities obtained in the two studies are not identical. The income elasticity was found to be slightly greater (0.65 compared to 0.51) and the purchase cost elasticity substantially lower (-0.33 compared to -0.64). The elasticity with respect to total running costs, which was included instead of the fuel cost variable used here, was found to quite high (-0.51), but as argued earlier, this variable is not a good measure of running costs as it does not take into account the effects of improvements in vehicle fuel efficiency on the costs of car use. The fuel cost measure used in the current study is somewhat better, although it excludes other running costs, which may be important. The exclusion of these costs, however, is unlikely to have a significant effect on the estimated elasticities, as the correlation between them and the variables included is probably not substantial. Unfortunately, the data is not available to allow examination of this issue.

As mentioned earlier, adjustment was found to be slower in our earlier study, but this could be explained by the fact that residential location is held constant in the current study so that longer-run adjustment involving changes in residential location is not included. The long-run elasticities obtained in this study will thus not reflect the complete impact of the explanatory variables, but rather a constrained impact, i.e. at a given area of residential location.

CONCLUSION

The results presented in this paper illustrate the usefulness of the pseudo-panel methodology in analysing dynamic transport relationships. The main contribution of this study compared to our earlier work - and to the majority of car ownership studies - is that it examines differences in the factors determining car ownership in rural and urban areas. Two major conclusions are worthy of note.

Elasticities differ substantially for different household groups. In particular, the results indicate that car ownership is more sensitive to changes in motoring costs for urban households than is the case for rural households. Inhabitants of all areas respond significantly to changes in car purchase costs, but the elasticity of car ownership with respect to these costs is twice as high in urban areas as it is in rural areas. Fuel costs, on the other hand, have no significant effect in rural areas, but do have a small influence on car ownership in urban areas. The relative insensitivity of car ownership to costs for rural households is an important consideration in the formation of transport policy, and especially for the distributional aspects of such policies. The results suggest that general increases in the costs of car transport would pose a considerable economic burden for rural households, and that other area-specific measures may be more suitable, particularly from an equity point of view. Examples of such measures are congestion pricing, urban tolls and non-monetary traffic restraint measures in urban areas.

Adjustment to changes in prices and income takes time. The estimated elasticities are around 40% higher in the long run than they are in the short run, and full adjustment takes about 4 years. Although we have shown that a static model can be used to estimate the long-run elasticities, the dynamic formulation is preferable in that it distinguishes between the impacts of income and prices in different time horizons and allows estimation of the speed of adjustment. This is clearly of importance in forecasting car ownership or assessing the implications of price-related transport policy, where we are interested in car ownership and the response to transport measures at specific points in time rather than at an undefined equilibrium. As illustrated in Dargay and Goodwin (1995), ignoring the temporal nature of the response to policy or price changes will lead to a bias in the evaluation of consumer surplus, and thus in cost-benefit assessment.

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Appendix. Estimated Log-Inverse model, static specification

	Unrestricted Model			Restricted Model		
Variable	Coefficient	Std. Error	p-value	Coefficient	Std. Error	p-value
1/Income				-121.68	7.55	0.00
Urban	-118.57	7.54	0.00			
Other	-107.43	9.71	0.00			
Rural	-78.90	12.10	0.00			
Fuel costs				-0.07	0.03	0.04
Urban	-0.14	0.05	0.01			
Other	-0.08	0.05	0.10			
Rural	-0.06	0.06	0.32			
Car purchase costs				-0.59	0.08	0.00
Urban	-0.69	0.12	0.00			
Other	-0.64	0.11	0.00			
Rural	-0.47	0.15	0.00			
Adults per household				0.60	0.09	0.00
Rural	0.61	0.10	0.00			
Other	0.79	0.11	0.00			
Urban	0.75	0.13	0.00			
Children	0.04	0.02	0.01	0.03	0.02	0.10
Rural household	0.00	0.12	1.00	0.11	0.01	0.00
Urban household	-0.01	0.09	0.89	-0.19	0.01	0.00
G1	-0.59	0.17	0.00	-0.37	0.15	0.01
G2	-0.48	0.12	0.00	-0.26	0.10	0.01
G3	-0.35	0.12	0.00	-0.14	0.10	0.16
G4	-0.21	0.12	0.07	0.00	0.09	0.96
G5	-0.14	0.12	0.22	0.06	0.09	0.49
G6	-0.09	0.11	0.41	0.10	0.09	0.26
G7	-0.03	0.12	0.81	0.16	0.09	0.08
G8	-0.02	0.12	0.87	0.18	0.10	0.07
G9	0.01	0.12	0.97	0.20	0.10	0.04
G10	0.01	0.12	0.93	0.20	0.09	0.03
G11	0.00	0.11	1.00	0.19	0.09	0.03
G12	-0.02	0.11	0.86	0.17	0.09	0.05
G13	-0.06	0.11	0.58	0.13	0.08	0.12
G14	-0.12	0.11	0.25	0.07	0.08	0.42
G15	-0.33	0.12	0.01	-0.15	0.11	0.17
Log-Likelihood		556.19			531.80	
Observations		445			445	
Estimated Parameters		30			22	
R^2		0.973			0.970	
LR-test for restrictions χ^2 (probability)						
$G_I = C$ for all i =1 to 15		163.13	(0.00)		142.42	(0.00)
Restricted vs unrestricted					48.77	(0.00)
Lagged term = 0		73.34	(0.00)		95.10	(0.00)

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