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A Dynamic Analysis of Household Car Ownership in Ireland

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Abstract: This paper examines the determinants of household car ownership in Ireland, using longitudinal data for the period 1995-2001. This was a period of rapid economic and social change in Ireland, with the proportion of households with one or more cars growing from 74.6 per cent to 80.8 per cent over the period. Understanding the determinants of household car ownership, a key determinant of household travel behaviour more generally, is particularly important in the context of current policy developments which seek to encourage more sustainable means of travel. In this paper, we exploit the availability of longitudinal data to estimate dynamic models of household car ownership, controlling for unobserved heterogeneity and state dependence. We find income and previous car ownership to be the strongest determinants of differences in household car ownership. Other important influences include household composition (in particular, the presence of young children) and lifecycle effects, which create further challenges for policymakers in seeking to change travel behaviour.

Key words: Car Ownership; Panel Data; Random Effects Probit; Ireland

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1 Introduction

This paper examines the determinants of household car ownership in Ireland, using longitudinal data from the Living in Ireland Survey (LIIS) from 1995-2001. This was a period of rapid economic and social change in Ireland, with large increases in employment and average incomes. The number of private car registrations grew by approximately 40 per cent, from 990 000 in 1995 to 1 385 000 in 2001 (Central Statistics Office, 2007), while the number of private cars per household grew from 0.94 per cent in 1996 to 1.12 in 2002 (Central Statistics Office, 2008; Department of the Environment and Local Government, 2003). Despite this rapid growth, in 2004, Ireland had 385 cars per 1 000 inhabitants, considerably below the EU15 average of 495 (Eurostat, 2006).

The well-documented shift towards the private car is increasingly regarded as unsustainable on economic, environmental and social grounds. Data for journeys to work, school and college confirm this shift towards the private car; the proportions driving their car to work in Ireland increased from 38.9 per cent in 1996 to 55.1 per cent in 2002, while the proportion of primary school students (aged 5-12 years) travelling as a passenger in a car increased from 35.8 per cent in 1996 to 50.3 per cent in 2002, overtaking the proportions walking (26.0 per cent), which has traditionally been the primary means of transport to school for this age-group (Central Statistics Office, 2008). The resulting levels of congestion impact on all those using the road and public transport network; in the Dublin area for example, average journey speeds in the morning peak for car and bus[1] decreased by 12.4 per cent and 6.2 per cent respectively between 2003 and 2004 (Dublin Transportation Office, 2005). Understanding the determinants of household car ownership, a key determinant of household travel behaviour more generally, is particularly important in the context of current policy developments which seek to encourage more sustainable methods of travel.

[1] Bus speeds on Quality Bus Corridor routes (i.e., routes with dedicated road space for buses) only.

In this paper, we use micro-data from a large nationally representative survey of the population over the period 1995-2001 to analyse the determinants of household car ownership in Ireland. Longitudinal data allow us to extend previous cross-sectional analyses of household car ownership behaviour to consider the impact of state dependence and unobserved heterogeneity, as well as the impact of observed household characteristics such as age and gender of the head of household, household income, size and location. Controlling for state dependence means that we can determine the degree of persistence or mobility in car ownership at the household level over time. For example, studies of poverty dynamics often find that poverty is a more common experience when examined using longitudinal rather than cross-sectional data (see Layte and Whelan, 2002). A similar picture emerges when examining the extent of household car ownership using both cross-sectional and longitudinal data; if we treat each of the seven waves of our data as an independent cross-section, approximately 22 per cent of households do not own a car, but when examining the data on a longitudinal basis, just over 14 per cent of households present in all seven waves have no car over the course of the panel while approximately 64 per cent always own a car (see Table 1). This suggests that there is some mobility in household car ownership, with approximately one fifth of all households moving from no car to one or more cars or vice versa over the period. Determining the degree of persistence or mobility in household car ownership decisions is particularly important in this context, with international research highlighting the importance of previous car ownership choices on current levels of ownership (see for example, Hanly and Dargay, 2000; Huang, 2005). This in turn has implications for policy measures designed to encourage more sustainable forms of travel.

[insert Table 1 here]

However, a large part of persistence or habit in household car ownership may be simply due to unobserved household or individual characteristics that do not vary over time such as attitudes towards the environment, time preference rates etc. Longitudinal data afford us the opportunity to control for these unobserved characteristics, and as such overcome the problem of spurious state dependence. Controlling for state dependence and unobserved heterogeneity necessarily complicates the estimation of the models, and

Section 4 deals in detail with the appropriate specification and estimation of the models employed.

The purpose of this paper is therefore to estimate dynamic models of household car ownership, decomposing the observed variation in car ownership into components attributable to observed characteristics, unobserved heterogeneity and state dependence. With cross-section data we are able to identify the influence of observed characteristics only. Section 2 provides an overview of previous research in the area, while Section 3 describes the data set employed in this paper and presents some descriptive statistics on household car ownership from both a cross-sectional and longitudinal perspective. Section 4 presents the specification of the model and the econometric modelling techniques employed. Section 5 discusses the estimation results. Section 6 summarises and concludes and details areas in need of further research.

2 Previous Research

In this paper, we use micro-data from a large nationally representative survey of the population over the period 1995-2001 to analyse the determinants of household car ownership in Ireland. This microeconomic approach to car ownership demand modelling has its roots in studies based on aggregated data, which attempt to explain the general relationships between car ownership and variables such as population density and average incomes at regional or country level (see Buxton and Rhys, 1972; Fairhurst, 1965; McCarthy, 1977; Said, 1992; Stanovnik, 1990). However, the nature of the data limits the extent to which the underlying behavioural influences on car ownership can be examined.[2]

Studies based on micro-data have become increasingly common (see Alperovich et al., 1999; Bennett, 1967; Cragg and Uhler, 1970; Dargay and Vythoulkas, 1999; Lave and Train, 1979; McCarthy, 1996; Matas and Raymond, 2008). The discrete nature of the car ownership decision means that discrete choice econometric methodologies, such as binary and multinomial probit and logit, are often employed in modelling the

[2] See Storchmann, 2005 for a recent review of research in this area, including his own analysis which finds a significant effect for income inequality as well as income levels on cross-country differences in car ownership rates.

determinants of car ownership (see Alperovich et al., 1999; Bhat and Pulugurtha, 1998; Cragg and Uhler, 1970; Golob, 1990; Matas and Raymond, 2008; Potoglou and Kanaroglou, 2008; Stanovnik, 1990; Whelan, 2007). In a similar vein, McCarthy (1996) and Lave and Train (1979) use the multinomial logit methodology to model choice of car type, while Hensher et al. (1989) use a nested logit model to examine the car type-size-quantity decision. More recently, the demand for car ownership at the micro-level has also been analysed in the context of other transport decisions such as car use and modal choice. Asensio (2001), Berkowitz et al. (1990), Bjorner (1999), De Jong (1990), Johansson-Stenman (2002), Kayser (2000) and Mannering and Winston (1985) all model the joint decisions of car ownership and car use using a variety of econometric methodologies. De Palma and Rochat (2000), Thobani (1984) and Train (1980) examine the joint decisions of car ownership and mode of transport to work.

In addition, a number of recent papers have utilised longitudinal or repeated cross-sectional data with a view to gaining more accurate estimates of households' dynamic decisions with regard to car ownership. Dargay and Vythoulkas (1999) use data from successive annual UK Family Expenditure Surveys to construct a 'pseudo-panel' and find that factors such as income, the costs of car ownership and use, public transport fares and the socio-demographic characteristics of the household are all important in determining differences in household car ownership. This research was extended in Dargay (2001) and Dargay (2007) to examine the extent of asymmetry in the relationship between household income and household car ownership and use respectively. Huang (2005) also applied the pseudo-panel approach to the UK Family Expenditure Survey over the period 1982-2000 and found positive and significant income and state dependence effects on the probability of household car ownership. Similar to the approach we employ in this paper, Dargay and Hanley (2007), Dargay et al. (2007) and Hanly and Dargay (2000) use the British equivalent of the data we employ in this paper to estimate dynamic models of household car ownership, focussing specifically on the role of unobserved heterogeneity and state dependence in behaviour. In a related analysis of convergence in consumption patterns in Ireland over the period 1975-2003, Lyons et al., 2007 find particularly strong effects for habit formation in Irish consumption on transport.

Accounting for unobserved heterogeneity and state dependence reduces substantially the estimated income elasticities in comparison with those from cross-sectional models, with Hanly and Dargay (2000) reporting an income elasticity of household car ownership of 0.06. They also find that income elasticities decline with previous car ownership status, suggesting saturation (i.e., the effect of income becomes smaller at higher car ownership levels).

Irish research on the determinants of car ownership is limited. McCarthy (1977) estimated the demand for car ownership at the county level in Ireland using data on average county incomes and population densities. While confirming that car ownership rates are positively affected by income and negatively affected by population density, the nature of the data limited the number and type of explanatory variables that could be considered. Nolan (2003) used cross-sectional micro-data from the 1994/1995 Irish Household Budget Survey to examine the influence of a variety of household demographic and socio-economic characteristics on household car ownership. She found a positive but non-linear effect of income on household car ownership, with an estimated income elasticity of 1.1. This paper is therefore the first to examine the dynamics of the household car ownership decision in Ireland using detailed longitudinal data.

3 Data, Variables and Descriptive Statistics

We use data from the Living in Ireland Survey, which constitutes the Irish component of the European Community Household Panel (ECHP). The ECHP began in 1994 and ended in 2001. It involved an annual survey of a representative sample of private households and individuals aged 16 years and over in each EU member state, based on a standardised questionnaire. It is not a transport survey, but information on household car ownership is provided, as well as a variety of individual and household characteristics such as age, education, working status, income and household location.

We base our analysis on the unbalanced sample of households over the period 1995-2001[3], which amounts to 20 437 observations. While the rate of sample attrition in the Living in Ireland survey is quite high with only 37.5 per cent of those interviewed in 1995 still participating in the survey in 2001, the 2000 survey added a substantial new random sample which comprised about half the households interviewed. To further reduce bias due to selective attrition, the sample for analysis was re-weighted to ensure representativeness in terms of a variety of demographic and socio-economic characteristics (see Russell et al., 2004 for further details). Nonetheless, we test for attrition bias (see Section 4). We delete observations for which information on variables of interest is missing, and as we use lagged values of the dependent variable, this reduces the size of the final sample for estimation to 18 441 (see Table 2).

The dependent variable (*car*) is a dichotomous indicating that the household 'has or can avail of' a car. Unfortunately, data on the number of household cars is not available, and while it would be useful to distinguish between cars for personal use and company cars, only the final two waves of the Living in Ireland Survey (2000 and 2001) explicitly ask about company cars (see also Whelan, 2007). As illustrated in Table 2, the proportion of households with at least one car increased from 74.6 per cent in 1995 to 80.8 per cent in 2001 (based on the full unbalanced sample used for estimation). However, cross-sectional snapshots provide no guidance as to whether it is the same households who own cars year after year, or whether there is more mobility in car ownership among households over time. Table 3 suggests that the latter may be the case. Of those owning no car in year *t*, 14.2 per cent owned one or more cars in year *t+1*, while among those owning one or more cars in year *t*, 2.7 per cent of households owned no car in year *t+1* (see also Dargay et al., 2007). While transition matrices are a useful descriptive tool, and suggest that there is some mobility in household car ownership behaviour over time, random effects models offer the opportunity to identify persistence/mobility more accurately through the inclusion of a lagged value of the dependent variable in the model.

[insert Table 2 here]

[3] Information on the presence of children under 12 years in the household is not available for 1994; we therefore begin our analysis in 1995.

[insert Table 3 here]

Independent variables correspond to the demographic/socio-economic characteristics of the household or household reference person (HRP). Age, gender, education level, employment status and marital status all refer to the HRP. Age is represented by a categorical variable with five indicators of 10-year groups (age 16-34[4], age 35-44, age 45-54, age 55-64, age 65+), with age 16-34 regarded as the reference group. Gender is represented by a dummy variable, with males as the reference group. A binary variable indicates households with a HRP with a third level qualification, with those with primary level education, lower second level or upper second level regarded as the reference category. The employment status of the household is represented by the employment status of the HRP, with a binary variable indicating households with a HRP in full- or part-time employment (with those that are unemployed, students, retired, economically inactive or engaged in home duties regarded as the reference category). We use a binary indicator of the present marital status of the HRP that distinguishes between being married and separated/divorced, widowed or never married (the reference category).

We include a binary indicator for those households living in rural areas, based on population size[5]. Income is real net household income in Irish pounds, adjusted for the size and composition of the household using equivalence scales[6]. A squared term is included to capture possible non-linearities in the relationship between household income and car ownership. A binary variable indicating households with one or more children younger than 12 years of age is included to identify households with school-age children. A continuous variable represents the number of adults aged 18 years and older. The number of working adults was also considered (see also Whelan, 2007). However, it is highly collinear with the number of adults, meaning that the results were not independently significant when both variables were included.

[4] As there are so few households with a HRP aged 16-24 years, we merge the two youngest age groups.
[5] Rural residents are those living in open countryside or in villages with a maximum of 1,500 inhabitants.
[6] The HRP is given the value one, each additional adult over the age of 14 the value 0.66 and all children the value 0.33 (see also Whelan et al., 2007).

Unfortunately, the data do not contain any information on prices and potentially important supply-side factors such as public transport availability, frequency and quality, ease of parking, bus and cycles lanes etc. To some extent, the year dummies will capture aggregate changes in affordability over time, while the regional variable will act as a proxy, albeit imperfect, for supply-side differences between rural and urban areas. We could potentially use data from the Central Statistics Office on car purchase and operating costs (including fuel), and bus, rail and taxi fares over the period 1995-2001. However, because such data is only available at a highly aggregated national level and has varied little over the period 1995-2001, these variables are highly correlated with time and income, meaning that plausible results were impossible to identify (a problem also identified by Whelan, 2007).

4 Econometric Methods

The nature of the dependent variable (a binary indicator variable) determines the type of econometric methodology employed. In this paper, we follow the approach of Wooldridge (2005) and specify a dynamic random effects probit model, as follows:

$$P\left(y_{it}=1 \mid y_{it-1},....y_{i0}, x_{it}, c_i\right)=\Phi\left(\beta x_{it}+\rho y_{it-1}+c_i\right) \qquad i=1,2,....N \quad t=1,2,.....T \qquad (1)$$

where $\Phi(.)$ is the standard normal cumulative distribution function, y_{it-1} are lagged values of the dependent variable y_{it}, x_{it} are the set of independent variables and c_i is the unobserved effect.

A crucial assumption of the random effects specification is that the unobserved effects must not be correlated with the observed independent variables; otherwise, parameter estimates are inconsistent. This is possibly the case here, with unobserved factors such as attitudes towards the environment or time preference rates likely to be highly correlated with such variables as education and income. In addition, moving to a dynamic specification and controlling for state dependence means that we must also take account of the problem of initial conditions. In a series where the observations are unlikely to be serially independent and where the first observation is not the true beginning of the process, we cannot assume that the initial condition is exogenous. To allow for correlated effects, state dependence and initial conditions, we follow the

approach of Mundlak (1978) and Wooldridge (2002, 2005) and parameterise the individual/household effects by way of the following auxiliary distribution:

$$c_i = \alpha_0 + \alpha_1 y_{i0} + \alpha_2 \bar{z}_i + a_i \quad (2)$$

where y_{i0} is the initial condition (i.e., the first observation for the dependent variable) and $\bar{z}_i$ is the vector of within-individual/household means for the time-varying independent variables.

Unobserved heterogeneity represents such time-invariant characteristics as ability/motivation, wealth, genetic inheritance, attitudes, time preference rates etc. Due to the nature of the data, longitudinal data allow us to control for such factors and as such obtain more accurate estimates of the effects of observed characteristics such as age, gender or household composition. The estimated coefficient on the lagged value of car ownership (ρ) can be interpreted as a measure of persistence or mobility in household car ownership. A coefficient close to zero indicates high mobility in ownership since the level of ownership in the previous period does not affect current ownership. If the coefficient on lagged ownership is positive and large, households are characterised by relatively low mobility in ownership. A negative coefficient would indicate cyclical fluctuations in ownership over time.

Using likelihood ratio tests, the random effects specification of the model is preferred to the pooled specification of the model. However, Table 4 provides estimation results for both specifications for comparison:

(a) pooled model
(b) dynamic random effects model with correlated effects[7], state dependence and initial conditions

Estimation results are presented in the form of marginal effects. The marginal effects are partial effects at the sample means of the independent variables. They assume a sample mean of zero for the unobserved heterogeneity c_i. For continuous independent variables, marginal effects are calculated at the means of the independent variables, and for categorical independent variables these are calculated as the difference in the

[7] Within-individual means that are significant at the five per cent level or above are included in the model (see also Table 4).

predicted number of events when the variable takes the value zero and one. The difference between specifications (a) and (b) will indicate the importance of controlling for unobserved heterogeneity between households, as well as state dependence and possible correlation between unobserved heterogeneity between households and the observed characteristics. Income elasticities are also calculated and are presented in Table 5.

When using longitudinal data, the possibility of attrition bias, whereby observations drop out of the panel in a non-random manner, must be considered (see also Section 3). To test for attrition, we apply tests suggested by Verbeek and Nijman (1992) and applied by Contoyannis et al. (2004). We add an indicator of whether the household is present in the following wave (*next wave*), an indicator of whether the household is present in all seven waves (*all waves*) and a count of the number of waves observed for each household (*count waves*) to our model in an attempt to indicate whether our results are sensitive to possible attrition in the sample. The results of these variable addition tests are presented in Table 6 and discussed in Section 4. We also present the results of model (c) with the addition of *all waves* in column (d) of Table 4 (the largest and most significant of the attrition indicators), to show how the effects of the other independent variables change, if at all, after the inclusion of this indicator.

5 Empirical Results

Focussing on the results from the preferred dynamic random effects specification in column (b) of Table 4, the age of the HRP exerts a significant effect on the probability of household car ownership, with households with a HRP aged 35+ being significantly more likely than households with a HRP aged 16-34 years to own a car. Interestingly, the effect for those aged 65+ years, while positive and significant, is smaller in magnitude than for many of the younger age groups. Dargay (2007) and Dargay and Vythoulkas (1999) also find a 'life-cycle' effect with respect to household car ownership whereby ownership increases with the age of the household head up to about the age of 50, and thereafter decreases. In Ireland, this pattern may also be explained partly by the fact that all those aged over 65 years in Ireland are entitled to free public transport. However, it is difficult to distinguish the effect of free public transport from a

simple age effect (which is found in many other studies) or indeed a cohort effect (Dargay, 2007; Matas and Raymond, 2008). Unfortunately, our data do not allow us to identify separately a cohort effect, which would indicate whether households with a HRP of the same age, but from different generations differ significantly in their probability of car ownership (see also Section 6).

Moving from the pooled probit specification, (a), to the dynamic probit specification controlling for correlated effects, state dependence and initial conditions, (b), reduces the size and significance of the age effects. While households headed by a female are significantly less likely to own a car in the pooled specification of the model (a), the gender of the HRP becomes insignificant in determining household car ownership once correlation between the individual/household effects, state dependence and initial conditions are controlled for (although neither age nor gender are included in the vector of within-individual/household means).

[insert Table 4 here]

The effects for the highest level of education, employment status and marital status of the HRP are all significant and consistent with expectations, with the effects for marital status being particularly significant. The presence of children under the age of 12 in the household is associated with an increased probability of household car ownership, as is an increasing numbers of adults in the household. Households living in rural areas are significantly more likely to own a car, highlighting the importance of such factors as residential and commercial density, public transport availability etc. on household car ownership decisions.

As expected, household equivalised income is highly significant in explaining variations in household car ownership, with some limited evidence for a non-linear effect. In addition, the marginal effects for the within-individual/household means of household income (also presented in column (b) in Table 4) are highly significant (and larger in magnitude), indicating the importance of permanent income levels in determining differences in household car ownership across the population over time (see also

Alperovich et al., 1999; Matas and Raymond, 2008). Table 5 presents the estimated income elasticities. Evaluated at the means of the independent variables, the income elasticities range from 0.017 (-0.001) for current income to 0.049 (-0.008) for permanent income (results similar to those found by Hanly and Dargay, 2000). Income elasticities are also calculated for different car ownership states; the results show the income elasticities are much higher for households with no car in the initial period, in comparison with households with one or more cars in the initial period. While our measure of car ownership is necessarily crude and cannot incorporate the effect of income on different levels of car ownership, the results do suggest however that as car ownership becomes the norm among households, future increases in income will have smaller effects on (first) car ownership levels, i.e., whether households have a car available or not.

[insert Table 5 here]

Whether the household owned a car in the previous period, and whether the household owned a car in the initial period exert large and highly significant effects on the current probability of household car ownership. In addition, the highly significant results for the initial conditions suggest a high degree of correlation between the initial conditions and unobserved characteristics. In comparison with the effects of other highly significant variables such as age 35-44, married and number of adults (which increase the probability of household car ownership by 0.013, 0.065 and 0.019 respectively), whether the household owned a car in the previous year, and in the initial period, increases the probability of current household car ownership by 0.099 and 0.307 respectively. These positive and significant effects suggest that there is indeed a strong degree of habit or persistence in household car ownership decisions from year to year.

Overall then, controlling for unobserved heterogeneity, state dependence and initial conditions adds considerably to the explanatory power of our model, as does accounting for possible correlation between the unobserved individual/household effects and our observed individual/household characteristics. Moving from the pooled probit specification, (a), to the dynamic probit specification controlling for correlated effects,

state dependence and initial conditions, (b), reduces the magnitude of many of the effects. In the final specification (b), particularly significant effects are evident for age, household composition, marital status, household income and lagged and initial levels of household car ownership. The within-household mean of income is also particularly significant, suggesting that, for example, "permanent" high levels of income increase significantly the probability of household car ownership.

Table 6 presents the coefficient estimates for the variable addition tests for attrition suggested by Verbeek and Nijman (1992). While the indicator of participation in the following wave *(next wave)* is insignificant, *all waves* (an indicator for households present in all seven waves of the survey) and *count waves* (an indicator for the number of waves for which the household is present) are both highly significant, suggesting that the probability of household car ownership varies non-randomly by household response characteristics. However, the inclusion of *all waves* (the largest and most significant of the attrition indicators) does not change substantially the effects of any of the other variables, either in significance or magnitude. For example, the linear current income effect remains at 0.009 and significant at the one per cent level when we include the additional attrition variable (see column (c) of Table 4).

[insert Table 6 here]

6 Summary and Conclusions

This paper analysed the determinants of household car ownership in Ireland, using longitudinal data for the period 1995-2001. Over the period, the proportion of households with one or more cars grew from 74.6 per cent to 80.8 per cent. Understanding the determinants of household car ownership, a key determinant of household travel behaviour more generally, is important for forecasting purposes and for the design of appropriate policies to encourage more sustainable means of travel. While the data are now seven years old, the period of analysis was one of rapid economic and social change in Ireland. The results also provide the first estimates of the determinants of household car ownership decisions in Ireland using longitudinal data, and are consistent with recent international research in this area.

The availability of longitudinal data allows us to control not only for differences in observed characteristics between households, but also for time-invariant unobserved heterogeneity and state dependence or persistence in behaviour. The results suggest that not only is persistence in behaviour an important factor in explaining differences in household car ownership across the population, but also that neglecting to control for time-invariant unobserved heterogeneity and state dependence will result in an overestimation of the effects of household characteristics such as income, household composition and age structure.

As with previous research on household and individual travel behaviour, a particular focus of the paper was the analysis of the income effect and as expected, income exerts a positive and highly significant effect on the probability of household car ownership. Our estimates suggest that permanent income (the so-called 'long-run' effect) exerts a stronger and more significant effect on the probability of household car ownership than current income (the 'short-run' effect). In addition, income elasticities differ by previous car ownership status, with income elasticities much higher for those households with no car in the initial period. State dependence, as captured by the level of household car ownership in the initial and previous years, was highly significant, suggesting that there is strong habit or persistence in household car ownership from one year to the next. The strength of the persistence in household car ownership levels creates challenges for policymakers in terms of designing policy initiatives to encourage more sustainable methods of transport. Future work could investigate whether this effect differs by other individual or household characteristics; for example, we might expect households with children, who may be less flexible in their travel patterns, to exhibit more habit or persistence in household car ownership than households without children.

The relatively short length of the panel available here limits the extent to which we can examine the impact of long-term behavioural changes on household car ownership, as well as the impact of variables such as cost, where there is insufficient variation over the short period of the panel. One solution is to use repeated cross-section data (as is now

available from the Irish Household Budget Survey) to construct a 'pseudo-panel' (see Dargay, 2007 for example). Such data would also allow us to assess the extent to which there is a generation or cohort effect associated with household car ownership, in addition to the lifecycle effect suggested by the results for age. For example, Matas and Raymond (2008) found that households with a HRP of the same age, but born in more recent decades, have higher levels of car ownership, possibly as younger age cohorts are more accustomed to car ownership and may find it harder to undertake daily activities without a car (in contrast, Dargay, 2007 finds little significant effect of birth cohort on household car use). In addition, this variable may also pick up unobserved differences in characteristics between individuals born in different decades, in terms of time preference rates, attitudes towards risk, attitudes towards the environment etc.

Finally, in terms of changing behaviour to encourage more sustainable methods of travel, information on related aspects of behaviour such as car type and use are crucial. Car type is an important issue to consider, particularly in light of recent fiscal measures in Ireland and elsewhere which aim to encourage the purchase and use of cars with lower emissions. Of course, of ultimate interest is how households use their cars, and how this decision is affected not only by their household characteristics but also by the policy environment and other supply-side variables such as public transport provision, parking restrictions etc. The Irish Household Budget Survey contains wider information on travel behaviour, such as expenditure on fuel, public transport and car purchases, which would allow us to examine these related but crucial issues.

TABLES

Table 1 Proportion with at least one car by year, and longitudinally

	No car	One or more cars	> 0 and < 1
1995	22.4	77.6	
1996	22.6	77.4	
1997	21.7	78.3	
1998	21.0	79.0	
1999	20.7	79.3	
2000	20.5	79.5	
2001	20.5	79.5	
1995-2001	14.2	63.7	22.1

[a] Based on the balanced sample of households

Table 2 Sample sizes and household car ownership, 1995-2001

	Estimation sample	One or more cars (%)
1995	3 358	74.6
1996	3 010	75.7
1997	2 765	76.9
1998	2 563	77.7
1999	2 266	79.0
2000	1 868	79.2
2001	2 611	80.8
1995-2001	18 441	77.4

[a] Based on the full unbalanced sample used for estimation

Table 3 Transition matrix for household car ownership, 1995-2001

	0	1	Total
0	**85.8**	14.2	100.0
1	2.7	**97.3**	100.0
Total	21.2	78.8	100.0

[a] Each row represents household car ownership in year *t* while each column represents household car ownership in year *t+1*. For example, figures in bold represent the proportion in each category of household car ownership in year *t* that remain in the same category of car ownership in year *t+1*.

Table 4 Marginal effects for the pooled and random effects models

	Pooled	Random Effects	RE with attrition
HRP characteristics			
Age 35-44	0.073	0.013	0.012
	(0.011)***	(0.003)***	(0.003)***
Age 45-54	0.073	0.018	0.016
	(0.012)***	(0.003)***	(0.003)***
Age 55-64	0.080	0.019	0.018
	(0.012)***	(0.003)***	(0.003)***
Age 65+	0.046	0.016	0.014
	(0.015)***	(0.004)***	(0.004)***
Female	-0.023	-0.001	-0.001
	(0.013)*	(0.003)	(0.003)
Third Level	0.083	0.008	0.008
	(0.011)***	(0.003)**	(0.003)**
Employed	0.101	0.012	0.012
	(0.013)***	(0.005)**	(0.005)**
Married	0.219	0.065	0.062
	(0.018)***	(0.010)***	(0.009)***
Household characteristics			
Children under 12 in household	0.040	0.018	0.016
	(0.011)***	(0.003)***	(0.003)***
Number adults 18+	0.016	0.019	0.018
	(0.005)***	(0.003)***	(0.003)***
Rural	0.139	0.024	0.022
	(0.010)***	(0.004)***	(0.004)***
Income	0.130	0.009	0.009
	(0.008)***	(0.003)***	(0.003)***
$Income^2$	-0.004	-0.000	-0.000
	(0.001)***	(0.000)*	(0.000)*
Within-individual/household means			
Employed		0.021	0.021
		(0.006)***	(0.006)***
Number adults 18+		-0.019	-0.018
		(0.003)***	(0.003)***
Income		0.025	0.024
		(0.005)***	(0.005)***
$Income^2$		-0.001	-0.001
		(0.000)***	(0.000)***
State dependence, initial conditions			
Car ownership $_{t-1}$		0.099	0.096
		(0.019)***	(0.019)***
Car ownership $_{95}$		0.307	0.304
		(0.026)***	(0.025)***

[a] Standard errors are presented in parentheses.
[b] *** significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level.

Table 4 continued

	Pooled	Random Effects	RE with attrition
Attrition indicator			
All waves			0.008
			(0.003)***
Time dummies	Yes	Yes	Yes
NT	18 441	18 441	18 441
Log-Likelihood	-6 501.7	-3 094.9	-3 090.8

[a] Standard errors are presented in parentheses.
[b] *** significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level.

Table 5 Income elasticities

	Means	$Car_{95}=0$	$Car_{95}=1$
Current income	0.017	0.153	0.005
	(0.005)***	(0.042)***	(0.002)***
Current income^2	-0.001	-0.014	-0.000
	(0.001)*	(0.007)*	(0.000)*
Permanent income	0.049	0.426	0.013
	(0.009)***	(0.065)***	(0.004)***
Permanent income^2	-0.008	-0.067	-0.002
	(0.002)***	(0.013)***	(0.001)***

[a] Standard errors are presented in parentheses.
[b] *** significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level.
[c] From the random effects model controlling for correlation between the individual/household effects and time-varying independent variables, state dependence and initial conditions.

Table 6 Attrition tests

	Marginal effects
All waves	0.008
	(0.003)***
Next wave	0.002
	(0.003)
Count waves	0.002
	(0.001)***

[a] Standard errors are presented in parentheses.
[b] *** significant at 1 per cent level; ** significant at 5 per cent level; * significant at 10 per cent level.
c From the random effects model controlling for correlation between the individual/household effects and time-varying independent variables, state dependence and initial conditions.

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