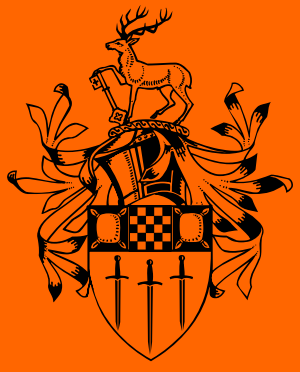
SEEDS
Surrey **E**nergy **E**conomics
Discussion paper **S**eries

SURREY
ENERGY
ECONOMICS
CENTRE

The Determinants of Household Car Ownership: Empirical Evidence from the Irish Household Budget Survey

John Eakins

November 2013



SEEDS 144
ISSN 1749-8384

School of Economics
University of Surrey

The **Surrey Energy Economics Centre (SEEC)** consists of members of the School of Economics who work on energy economics, environmental economics and regulation. The School of Economics has a long-standing tradition of energy economics research from its early origins under the leadership of Professor Colin Robinson. This was consolidated in 1983 when the University established SEEC, with Colin as the Director; to study the economics of energy and energy markets.

SEEC undertakes original energy economics research and since being established it has conducted research across the whole spectrum of energy economics, including the international oil market, North Sea oil & gas, UK & international coal, gas privatisation & regulation, electricity privatisation & regulation, measurement of efficiency in energy industries, energy & development, energy demand modelling & forecasting, and energy & the environment.

SEEC research output includes SEEDS - Surrey Energy Economic Discussion paper Series and SEERS - Surrey Energy Economic Report Series (details at www.seec.surrey.ac.uk/Research/SEEDS.htm) as well as a range of other academic papers, books and monographs. SEEC also runs workshops and conferences that bring together academics and practitioners to explore and discuss the important energy issues of the day

SEEC also attracts a large proportion of the School's PhD students and oversees the MSc in Energy Economics & Policy. Many students have successfully completed their MSc and/or PhD in energy economics and gone on to very interesting and rewarding careers, both in academia and the energy industry.

Enquiries:

***Director of SEEC and Editor of SEEDS*:**
Lester C Hunt
SEEC,
School of Economics,
University of Surrey,
Guildford GU2 7XH,
UK.

Tel: +44 (0)1483 686956
Fax: +44 (0)1483 689548
Email: L.Hunt@surrey.ac.uk

www.seec.surrey.ac.uk

Surrey Energy Economics Centre (SEEC)
School of Economics
University of Surrey

SEEDS 144
ISSN 1749-8384

THE DETERMINANTS OF HOUSEHOLD CAR OWNERSHIP: EMPIRICAL EVIDENCE FROM THE IRISH HOUSEHOLD BUDGET SURVEY

John Eakins

November 2013

ABSTRACT

This paper analyses the factors which influence the level of possession of cars in Irish households using four rounds of the Household Budget Survey, a large micro cross sectional data set of Irish households. Two qualitative choice models, the multinomial logit model and the ordered logit model are applied and their results compared. Based on various measures of fit, the multinomial logit model appears to be the preferred model. The main factors found to influence car possession include location, age, education and marital status of the head of household, use of public transport, the number of workers, number of non-workers and number of children in the household and total household expenditure. These factors are also consistently observed to influence car ownership over time although the effect of socioeconomic factors such as education and marital status appears to be diminishing. The number of workers in the household and total household expenditure are key determinants and mirror changes experienced at the macro level. The estimated income elasticities for these variables show that the number of workers in the household determines the decision to purchase more than one car to a greater extent than total household expenditure and total household expenditure determines the decision to purchase one car to a greater extent than the number of workers in the household.

JEL Classifications: R41, C35, D12.

Key Words: Motor Vehicle ownership; Household Survey Data; Multinomial Logit Model; Ordered Logit Model; Income Elasticities.

The Determinants of Household Car Ownership: Empirical Evidence from the Irish Household Budget Survey

John Eakins

School of Economics, University College Cork and

Surrey Energy Economics Centre (SEEC), School of Economics, University of Surrey.

E-mail: j.eakins@ucc.ie

1: INTRODUCTION

The objective of this study is to examine the determinants of car ownership across Irish households using a large micro data set, the Irish Household Budget Survey (HBS). Between 1995 and 2008, Irish households experienced a rapid change in living standards as levels of unemployment decreased and average incomes increased. This made the purchase of cars more affordable. Large increases in the levels of investment into the infrastructural network during this period of expansion also made the purchase of cars more attractive as a mode of travel. In 1995, the number of private motor vehicles licensed in Ireland was 990,384[1]. During the period from 1995-2000 this figure increased by 33.2%. Between 2000 and 2005 it increased by 26% and between 2005 and 2008 there was a further increase of 15.8%. At its peak in 2008, the number of private motor vehicles licensed in Ireland totalled 1,924,281. Whilst there has been a decrease in the overall number to 1,887,810 in 2011 due to the recent downturn in the economy, the number of cars licensed in Ireland has effectively doubled since 1995.

Increasing levels of private car ownership in a country is a sign of affluence but there are also many negative consequences including increased traffic congestion, road accidents and environmental costs. Between 1990 and 2011 Ireland's final energy consumption increased from 7,249 kilo tonnes of oil equivalent (ktoe) to 11,154ktoe. The biggest contributor came from the transport sector which increased from 2,019ktoe to 4,448ktoe, or 3.8% on average annually over the period. In 2011, the share of overall energy attributable to the transport sector stood at 39.9%, the largest of all sectors in the economy. It should be borne in mind

[1] All figures in this paragraph are taken from the CSO's Transport Omnibus publication

that these figures also take into account the recent slowdown in the economy. In 2007, the level of final energy consumption and energy consumption in the transport sector peaked at 13,312ktoe and 5,749ktoe respectively. Within the transport sector itself, the use of private transportation contributed 42.5% of overall transport energy use. Thus, in an overall context private road use contributed approximately 17% of the overall amount of energy consumption nationally in 2011.

Oil is the predominant fuel used by the country at 6,558ktoe or 58.8 per cent of the national share. The transport sector contributed 4,346ktoe to this total and of this, private road transportation contributed 1,843ktoe. Therefore, private road transportation in itself contributes close to 28% of overall oil use nationally. Given that Ireland is a signatory to a number of climate agreements both at global and European levels, its reliance of carbon based fossil fuels, especially in the transport sector, will add to the difficulty in meeting the targets set out in these agreements[2]. In response to this, the Irish government changed the structure of vehicle registration tax in 2008 to one that was based on based on the emissions of the vehicle in contrast to the engine size. They also introduced a carbon tax on transport fuels in 2009 and have set up schemes to incentivise the purchase of electric cars. Hennessy and Tol (2011a, 2011b) in their analysis however suggest that these changes may have only a minimal effect on carbon dioxide emissions due to rebound effects arising from the purchase of more fuel efficient cars.

Whilst much research has been devoted to analysing changes in car ownership at an aggregate level, there is little recent research on the application of a disaggregate model of household car ownership. According to Bhat and Pulugurta (1998), a disaggregate model is structurally more behavioural and better captures the casual relationship between car ownership and its determinants. Nolan (2010) is one exception to this but her research uses longitudinal data for the period 1995–2001 and thus does not capture recent changes in the Irish economy. Thus study in contrast uses the most up to date release of the HBS from 2009/10. The main purpose of the HBS is collect detailed information on the amount of money spent by households on a wide variety of commodities. In addition to this however, the HBS also provides information

[2] The latest projections from Irelands, Environmental Protection Agency indicate that Greenhouse Gas emissions are approximately 4.1 to 5.1 Mtonnes of CO_2 equivalent (CO_2e) above the 5 year Kyoto protocol limit. Under the EU Commission's 'Energy and Climate Package' Ireland is required to deliver a 20 per cent reduction in non-ETS Greenhouse Gas emissions by 2020 (relative to 2005 levels). The current projections indicate that total non-ETS emissions will be approximately 4.1 to 7.8 Mtonnes of CO_2e above the 2020 target.

on the number of motor vehicles possessed by the household. This data can be related to a range of household characteristics, such as location, age, gender, marital status, etc., which is also collected by the HBS. Finally the effect that income has on motor vehicle possession can also be examined using data provided by the HBS.

In addition to the most recent survey carried out in 2009/10, data from previous surveys carried out in 2004/05, 1999/00 and 1994/95 will also be examined. This will allow for a comparison to be made of the estimated relationship between car ownership and the socio-economic characteristics of the households across a large time period. The households surveyed in the HBS differ from survey to survey so a longitudinal or dynamic analysis of car ownership cannot be carried out. Still by examining a number of repeated cross sectional household surveys from pre, during and post the Celtic tiger phrase, valuable insights into how the relationship between vehicle ownership and socio economic characteristics of the households has evolved over that time period will be provided.

The next section outlines previous research in this area. Section 3 describes the HBS data set in more detail while section 4 outlines the econometric methodology based on the use of qualitative choice models. Section 5 presents the results and section 6 concludes.

2: PREVIOUS RESEARCH

As the dependent variable under investigation is qualitative in nature the methodology that will be adopted in this paper is based on the use of qualitative choice models. One of the earliest studies to use discrete choice models was by Cragg and Uhler (1970) who employ a logit model to analyse a sequence of dichotomous decisions based on the adding, selling, replacing or keeping a new or existing car. Lerman and Ben-Akiva (1976), Lave and Train (1979) and Manski and Sherman (1980) are early examples of studies which apply the multinomial logit model to the household motor vehicle ownership decision. Lerman and Ben-Akiva (1976) analyse the different choices for the journeys to work in Washington while Lave and Train (1979) and Manski and Sherman (1980) carry out similar work on the decisions made by households with regard to the purchase of different makes and models of vehicles. The Lerman and Ben-Akiva (1976) article is also notable as it is one of the first to

adopt McFadden's (1974) random utility framework in a disaggregated model of household car ownership.

More recent studies of household car ownership have attempting to simultaneously model the discrete choice of vehicle ownership (or vehicle type) with other choices such as car use and modal choice. Train (1980) and Mannering and Winston (1985) are viewed as the first studies to adopt such an approach. Train (1980) analyse the different choices for the journey to work in San Francisco conditional on the vehicle ownership choice and Mannering and Winston (1985) use data from both a cross section and panel of U.S. households to estimate a discrete/continuous model of vehicle quantity, vehicle type and utilisation choice. Vehicle quantity and vehicle type were estimated using the discrete model and utilisation choice was estimated using the continuous model. Studies which have subsequently following the approach of Train (1980) and Mannering and Winston (1985) include Train (1986), De Jong (1990), Berkowitz et al. (1990), Bjorner (1999), Kayser (2000), Asensio (2002), and Johansson-Stenman (2002). These studies model the joint decisions of car ownership and car use while De Palma and Rochat (2000) examine the joint decision of car ownership and mode of transport to work.

An alternative qualitative choice model known as the nested logit model is estimated by Hocherman et al. (1983), Thobani (1984), Berkovec and Rust (1985), Berkovec (1985) and Hensher et al. (1989). The nested logit model overcomes the restrictive requirement of the multinomial logit methodology to have distinct and independent alternatives. An issue with the nested logit model however is the requirement to have a detailed data set in order to create a set of choices which can be nested. For example in the Hensher et al. (1989) study the authors analyse the different choices households make based on car type first, then size and then quantity. There are also a number of papers that have utilised longitudinal or repeated cross-sectional data in order to assess the dynamic element to a households' decision with regard to car ownership. These include Dargay and Vythoulkas (1999), Dargay (2001), Dargay (2002), Huang (2005) and Dargay and Hanly (2007). These studies use UK household data and adopt a pseudo-panel approach whereby similar cohorts of households are identified and analysed across the different cross-sectional surveys.

A number of studies have also estimated alternative qualitative choice models to see which performs best in explaining the household car ownership decision. Examples of these studies include Bhat and Pulugurta (1998), Matas and Raymond (2008), Potoglou and Kanaroglou (2008) and Ritter and Vance (2013). The authors in these studies estimate and compare results from a multinomial logit model and an ordered logit model for different levels of car ownership. Bhat and Pulugurta (1998) use data from three regions of the United States and a Dutch national dataset. Matas and Raymond (2008) analyse changes in the structure of car ownership in Spain using three rounds of the Spanish household budget survey while Potoglou and Kanaroglou (2008) model micro data obtained through an internet survey of households in Hamilton, Canada. Ritter and Vance (2013) use household data from Germany to analyse motor vehicle ownership with a specific focus on the extent to which changes in family size have an effect on motor vehicle ownership at the national level.

All studies highlight the importance of household income and the number of working adults in explaining trends in private motor vehicle ownership. Matas and Raymond find evidence of a diminishing income elasticity over time suggesting that motor vehicle ownership is becoming less of a luxury for Spanish households. Potoglou and Kanaroglou (2008) also include measures of urban density and land use diversity in their study, and found these significantly influence the households' decision on how many vehicles to own. Ritter and Vance (2013) find that projected decreases in the German population will not cause motor vehicle ownership to correspondingly fall and instead suggest that motor vehicle ownership will increase due to increases in household income. In terms of a comparison of the two models, Bhat and Pulugurta (1998), Potoglou and Kanaroglou (2008) and Ritter and Vance (2013) all find the multinomial logit model to be a better representation of the decision to own different levels of motor vehicles. Potoglou and Kanaroglou (2008) indeed suggest that "the global utility maximization framework in the unordered-response mechanism adds both theoretical and behavioural context to the study of household choices on car ownership. On the contrary, there is no clear theoretical framework when estimating models of the ordered-response mechanism." (2008: 45). Matas and Raymond (2008) on the other hand, find the two competing models to be almost undistinguishable. Ritter and Vance support this stance, stating that they "would not unequivocally advocate for the superiority of unordered response models" (2013: 81-82).

There are a limited number of Irish studies on the determinants of car ownership using disaggregate data. McCarthy (1977) analyses the variations in private car ownership at the county level in Ireland, using data on average county incomes and population densities. The results confirmed a positive relationship between incomes and car ownership rates and a negative relationship between population density and car ownership rates. Nolan (2003) uses cross-sectional micro-data from the 1994/1995 Irish Household Budget Survey to estimate a binary probit model for the household car ownership decision. She finds a positive but non-linear effect of income on household car ownership, with an estimated income elasticity of 1.1. Commins and Nolan (2010) use the 2006 Census of Population and estimate a conditional logit model to analyse an individuals' decision among six discrete alternatives representing three mode of transport alternatives (on foot or bicycle; bus or train; motorcycle, car driver, car passenger) within the two car ownership alternatives (no car or one of more cars). Nolan (2010) uses the Irish longitudinal data for the period 1995–2001 to examine the dynamics of the household car ownership decision in Ireland. She finds income and previous car ownership to be the strongest determinants of differences in household car ownership, with the effect of permanent income having a stronger and more significant effect on the probability of household car ownership than current income. She also finds that the estimated income elasticities are higher for those households who didn't own a car in the previous time period.

3: DATA

The data set that will be used in this paper is a large anonymised micro data set of Irish households, the Household Budget Survey (HBS). The survey has been carried out by the Central Statistics Office (CSO) at regular intervals since 1951 and on a five yearly basis since 1994. The most recent results came out of a survey of households that took place in 2009/10. The main purpose of the survey "is to determine in detail the pattern of household expenditure in order to update the weighting basis of the Consumer Price Index" (CSO, 2013: 7). As well as household expenditures, the HBS also gives detailed information on all sources of household income as well as a wide range of household and house characteristics.

The household budget survey records whether a household possesses, zero, one, two or three or more cars. Table 1 presents this information across all households for the 1994/95, 1999/00, 2004/05 and 2009/10 surveys.

Table 1: Possession of Cars, Proportion of All Households, 1994/95, 1999/00, 2004/05 and 2009/10 HBS

	1994/95	1999/00	2004/05	2009/10
None	34.8	23.4	18.2	18.4
1 car	51.2	51.1	45.7	50.6
2 cars	12.9	22.6	31.4	27.4
3 cars or more	1.2	2.9	4.8	3.6
HBS Sample Size	7,877	7,644	6,884	5,891

The vast majority of households possess only one car in all of the surveys. However there is a trend toward increased levels of possession especially between the period 1994/95 and 2004/05. This can be seen in the reduction in the proportion of households with no car or just one car and an increase in the proportion of households with two or more cars in this period. The increase in the proportion of households possessing two or more cars in particular, is quite significant and reflects the trends previously described in section 1. What is also notable from the above table is the reversal of this trend of increasing car possession in the 2009/10 survey. The proportion of households possessing none or one car increased while the proportion of households possessing two or more cars decreased. Again, as previously discussed in section 1, this reflects the downturn that the Irish economy experienced since 2008 which resulted in falling incomes and increased unemployment.

In order to identify the microeconomic determinants of motor vehicle possession, previous research has used variables such as the number of workers in the household, location, sex, age, marital status, education of the head of household and transport related variables such as availability of public transport or alternative forms of transport e.g. bicycles or motorcycles. Income is another important determinant, but in this study data on total household expenditure is used instead of the data on income. There are a number of reasons for this. Firstly the CSO themselves, state that the income data that is collected in the HBS is not the primary source of data on income in Ireland. An alternative micro data survey, EU Survey on Income and Living Conditions (EU-SILC) also collected by the CSO, is recognised as the of income data. Secondly, incomes, such as those of self-employed people, can fluctuate over time whereas

total household expenditure can be seen as measuring expected or average levels of income over a long period and thus provides a better long run gauge of incomes.

Table 2 provides sample statistics for the socioeconomic characteristics of the household that will be used as explanatory variables in the motor vehicle possession models across the four rounds of the HBS under examination. Location is broken down by urban/rural and town size status. The categories for this variables change slightly as the definitions of town size changed over the four rounds of the HBS. Sex, age, marital status and education are all categorical variables and are defined based on the status of the head of household (or household reference person in the 2009/10 survey). The number of persons with free travel[3], a dummy to represent the purchase of public transport during the survey period and whether the household possess at least one motorcycle or not are included to represent the availability of public transport or alternative forms of transport. The number of workers present in the household is included as this variable is found to be key determinant in many previous studies. The number of non-workers (those available to work but unemployed) present in the household is also included as many have neglected to analyse its effect motor vehicle possession. The influence of the presence of children (aged under 14) in the household is also explored. The anecdotal evidence would suggest that the presence of children may have an influence on the size of the car purchased rather than the purchase of an additional car. Finally total household expenditure, which captures incomes effects as previously discussed, is included and adjusted per adult equivalent of the household to control for households with multiple incomes. This variable will also be transformed into natural log values in the final specification to reduce the effect of extreme outliers.

Table 2 provides insights into the changing socioeconomic characteristics of Irish households over the past two decades. The changes can be attributed to a number of factors including increases in the overall population from both domestic and foreign sources and a large increase in house building over the past two decades. For example, the increase in the proportion of households living in urban areas compared to rural areas is likely to have been driven by increased amount of house building. The characteristics of the HOH is also changing with greater proportion of younger, female, and better educated HOH's in latersurveys compared to earlier surveys. The proportion of HOH's who are married increased

[3] Free travel is available to people aged 66 or over or if an individual is getting a social welfare allowance such a disability allowance, blind pension, carer's allowance or an invalidity pension.

between the 1994/95 and 1999/00 surveys and then fell back slightly in the 2004/05 survey before a significant fall in the 2009/10 survey. This decrease probably reflects a trend toward cohabiting couples in a household rather than an increase in the number of single HOH's. The proportion of households with members possessing free travel is falling probably because the age profile of the average household is also falling[4]. The proportion of households making a purchase of public transport is decreasing also which in all likelihood is due to the increase in the level of possession or motor vehicles. The proportion of households possessing motor cycles, on the contrary, has remained relative static.

The average number of workers per household increased significantly between the 1994/95 and 1999/00 surveys, then remained static up to the 2004/05 before falling back again in the 2009/10 survey. The average number of unemployed persons per household follows a similar but opposite trend increasing significantly between the 2004/05 and 2009/10 surveys. When looking at these figures, it should be borne in mind that the overall average level of occupancy per household has been falling progressively since the 1994/95 survey. As previous mentioned this may be due to the increase in the number of houses in the country, allied with an increase in the amount of young adults moving into these houses rather than living with their parents and the increase in households having smaller families. So the ratio of workers and unemployed to the overall number of occupants would produce slightly different figures albeit probably with the same trend. Finally, total household expenditure per adult is increasing over the time period reflecting increases in the standards of living of Irish households. As can be seen the biggest increases in total household expenditure per adult occurred between 1994/95 and 1999/00 and from 1999/00 to 2004/05

[4] The actual number of recipients of free travel has been increasing however. According to Department of Social Protection statistics, in 2000 there were 582,928 recipients of free travel, in 2005, there were 639,657 and in 2010 there were 699,164. This suggests that the increase in population and thus the number of households without free travel is outweighing the number of households with free travel.

Table 2: Descriptive Statistics, 1994/95, 1999/00, 2004/05 and 2009/10 HBS

	1994/95 HBS					1999/00 HBS			
	Mean	**Std. Dev.**	**Min.**	**Max.**		**Mean**	**Std. Dev.**	**Min.**	**Max.**
Location:					*Location:*				
Rural	0.357	0.479	0	1	Rural	0.454	0.498	0	1
Urban – Dublin Metropolitan Area	0.273	0.445	0	1	Urban – Dublin Metropolitan Area	0.234	0.423	0	1
Urban – Towns >10,000 pop	0.133	0.340	0	1	Urban – Towns >20,000 pop	0.138	0.345	0	1
Urban – Towns 1,500-10,000 pop	0.172	0.377	0	1	Urban – Towns 3,000-20,000 pop	0.148	0.355	0	1
Urban – Towns <1,500 pop	0.066	0.248	0	1	Urban – Towns <3,000 pop	0.026	0.158	0	1
Sex of HOH:					*Sex of HOH:*				
Male	0.733	0.443	0	1	Male	0.708	0.455	0	1
Female	0.267	0.443	0	1	Female	0.292	0.455	0	1
Age of HOH:					*Age of HOH:*				
15-34	0.187	0.390	0	1	15-34	0.154	0.361	0	1
35-44	0.240	0.427	0	1	35-44	0.233	0.423	0	1
45-54	0.189	0.392	0	1	45-54	0.212	0.409	0	1
55-64	0.137	0.344	0	1	55-64	0.161	0.368	0	1
65 +	0.246	0.431	0	1	65 +	0.239	0.427	0	1
Marital Status of HOH:					*Marital Status of HOH:*				
Married	0.674	0.469	0	1	Married	0.716	0.451	0	1
Unmarried	0.326	0.469	0	1	Unmarried	0.284	0.451	0	1
Education of HOH:					*Education of HOH:*				
No education or Primary education	0.432	0.495	0	1	No education or Primary education	0.326	0.469	0	1
Secondary education	0.452	0.498	0	1	Secondary education	0.467	0.499	0	1
Third Level education	0.134	.341	0	1	Third Level education	0.208	0.406	0	1
Number of persons with Free Travel:					*Number of persons with Free Travel:*				
None	0.735	0.441	0	1	None	0.733	0.442	0	1
One	0.201	0.401	0	1	One	0.178	0.382	0	1
Two or more	0.064	0.245	0	1	Two or more	0.089	0.285	0	1
Public Transport Dummy:					*Public Transport Dummy:*				
Zero Public Transport Spend	0.649	0.477	0	1	Zero Public Transport Spend	0.687	0.464	0	1
Positive Public Transport Spend	0.351	0.477	0	1	Positive Public Transport Spend	0.313	0.464	0	1
Possession of Motor Cycles:					*Possession of Motor Cycles:*				
None	0.985	0.121	0	1	None	0.986	0.116	0	1
One or more	0.015	0.121	0	1	One or more	0.014	0.116	0	1
Number of Persons at Work	1.112	0.945	0	7	Number of Persons at Work	1.247	1.000	0	7
Number of Persons Unemployed	0.149	0.402	0	4	Number of Persons Unemployed	0.094	0.319	0	3
Number of Children <14	0.829	1.238	0	9	Number of Children <14	0.749	1.129	0	9
Total HH expenditure per adult equiv.	126.08	81.84	0.88	902.93	Total HH expenditure per adult equiv.	254.98	176.45	12.44	4456.91

Table 2: continued

	2004/05 HBS					2009/10 HBS			
	Mean	**Std. Dev.**	**Min.**	**Max.**		**Mean**	**Std. Dev.**	**Min.**	**Max.**
Location:					*Location:*				
Rural	0.342	0.474	0	1	Rural	0.317	0.465	0	1
Urban – Dublin Metropolitan Area	0.220	0.414	0	1	Urban – Cities	0.395	0.489	0	1
Urban – Towns >20,000 pop	0.105	0.307	0	1	Urban – Towns >10,000 pop	0.145	0.353	0	1
Urban – Towns 3,000-20,000 pop	0.237	0.425	0	1	Urban – Towns 5,000-10,000 pop	0.095	0.293	0	1
Urban – Towns <3,000 pop	0.096	0.295	0	1	Urban – Towns <5,000 pop	0.047	0.211	0	1
Sex of HOH:					*Sex of HRP:*				
Male	0.599	0.490	0	1	Male	0.523	0.500	0	1
Female	0.401	0.490	0	1	Female	0.477	0.500	0	1
Age of HOH:					*Age of HOH:*				
15-34	0.167	0.373	0	1	15-34	0.274	0.446	0	1
35-44	0.241	0.428	0	1	35-44	0.240	0.427	0	1
45-54	0.218	0.413	0	1	45-54	0.184	0.388	0	1
55-64	0.164	0.371	0	1	55-64	0.143	0.350	0	1
65 +	0.210	0.407	0	1	65 +	0.159	0.365	0	1
Marital Status of HOH:					*Marital Status of HRP:*				
Married	0.707	0.455	0	1	Married	0.505	0.500	0	1
Unmarried	0.293	0.455	0	1	Unmarried	0.495	0.500	0	1
Education of HOH:					*Education of HRP:*				
No education or Primary education	0.238	0.426	0	1	No education or Primary education	0.114	0.318	0	1
Secondary education	0.481	0.500	0	1	Secondary education	0.319	0.466	0	1
Third Level education	0.281	0.449	0	1	Third Level education	0.468	0.499	0	1
Number of persons with Free Travel:					*Number of persons with Free Travel:*				
None	0.739	0.439	0	1	None	0.842	0.365	0	1
One	0.170	0.376	0	1	One	0.107	0.309	0	1
Two or more	0.091	0.288	0	1	Two or more	0.052	0.221	0	1
Public Transport Dummy:					*Public Transport Dummy:*				
Zero Public Transport Spend	0.725	0.446	0	1	Zero Public Transport Spend	0.729	0.445	0	1
Positive Public Transport Spend	0.275	0.446	0	1	Positive Public Transport Spend	0.271	0.445	0	1
Possession of Motor Cycles:					*Possession of Motor Cycles:*				
None	0.986	0.118	0	1	None	0.984	0.125	0	1
One or more	0.014	0.118	0	1	One or more	0.016	0.125	0	1
Number of Persons at Work	1.277	0.989	0	9	Number of Persons at Work	1.040	0.897	0	5
Number of Persons Unemployed	0.064	0.269	0	4	Number of Persons Unemployed	0.271	0.542	0	4
Number of Children <14	0.704	1.097	0	7	Number of Children <14	0.653	1.042	0	7
Total HH expenditure per adult equiv.	388.68	257.10	20.73	3245.24	Total HH expenditure per adult equiv.	427.76	268.35	47.19	4614.11

4: ECONOMETRIC METHODOLOGY

This paper will follow the approach taken by Bhat and Pulugurta (1998), Matas and Raymond (2008), Potoglou and Kanaroglou (2008) and Ritter and Vance (2013) and estimates both the unordered and ordered discrete choice models to analyse levels of possession of motor vehicles across Irish households. The following sub-sections outline these two models in more detail.

4.1 The Multinomial Logit (MNL) Model

As previously stated, the study by Lerman and Ben-Akiva (1976) was one of the first to adopt McFadden's (1974) random utility framework when applying a multinomial logit model to disaggregated household motor vehicle ownership data. To formulise McFadden's (1974) random utility theory, suppose that there is a choice between M alternatives, j = 1, 2, …, M and the utility level that individual i attaches to each of these alternatives is given by U_{ij}. Assuming that alternative j is chosen by individual i if it gives the highest utility and that the utility of each alternative is a linear function of observed characteristics i.e. $U_{ij} = x_{ij}\beta + \varepsilon_{ij}$ gives the following relationship between the observed values of y_i and the unobserved levels of utility U_{ij},

$$\begin{aligned} P\{y_i = j\} &= P\{U_{ij} = \max\{U_{i1},\ldots,U_{iM}\}\} \\ &= P\left\{x_{ij}\beta + \varepsilon_{ij} > \max_{k=1,\ldots,M,k\neq j}\{x_{ik}\beta + \varepsilon_{ik}\}\right\} \end{aligned} \qquad (1)$$

Evaluation of this probability is complicated but can be made straightforward by assuming that the error terms ε_{ij} follow are particular type of distribution[1]. Using this assumption gives the conditional logit model as follows,

$$P\{y_i = j\} = \frac{\exp\{x_{ij}\beta\}}{1+\exp\{x_{i2}\beta\}+\cdots+\exp\{x_{iM}\beta\}}, j = 1,2,\ldots,\mathrm{M} \qquad (2)$$

[1] The ε_{ij} are assumed to have a Type I Extreme Value (or Weibull) distribution. The convenience of making this assumption is that the difference between two Extreme variable I values has a logistic distribution, hence the 'logit' element of the conditional logit.

In this model, what is included in $x_{ij}\beta$ are referred to as alternative-specific characteristics. For example, when explaining the mode of transportation, variables such as travelling time and costs are included. A negative β coefficient can be interpreted as a reduction in the utility of an alternative if a variable such as travelling time is increased. Consequently, if travelling time in this alternative is reduced, the probability that it will be chosen increases.

Jones (2000) refers to the conditional logit model as the "characteristics of the choices" model. The multinomial logit model on the other hand is based on utilising the "characteristics of the chooser". In this model only the information on the characteristics of the decision-makers, for example, their age, gender, income etc. is observed. To derive this model, the left hand side is reformulated as $x_i\beta_j$ where x_i represents the characteristics of the individual and β_j represents the coefficients which can vary across the different alternatives.

This gives the following specification,

$$P\{y_i = j\} = \frac{\exp\{x_i\beta_j\}}{1+\exp\{x_i\beta_2\}+\cdots+\exp\{x_i\beta_M\}}, j = 1,2,\ldots,\mathrm{M} \qquad (3)$$

which is the multinomial logit model. In contrast to the conditional logit model, slope coefficients (plus an intercept term) are estimated for all but one of the alternatives (i.e. β_j as opposed to β). In other words, the coefficients produced by the multinomial logit model are interpreted as a change in the natural log of the odds of choosing an alternative over a reference or base alternative which is excluded from the analysis.

Both the conditional logit model and multinomial logit model assume that all ε_{ij}'s are independent. This assumption can be particularly troublesome if two or more alternatives are very similar. This is commonly referred to as the independence of irrelevant alternatives or IIA assumption. An example that is frequently used to explain the problem is when transportation options include travel by a red bus or travel by a blue bus. Because the two options are very similar, the unmeasured reasons for taking the red bus are likely to be similar to the unmeasured reasons for taking the blue bus. In other words, the error terms are likely to be correlated. As a consequence, the introduction of red bus option should take proportionally more commuters away from the blue bus option than say, train or private car options.

However both the conditional logit model and multinomial logit model do not allow this to happen and thus can produce misleading results if irrelevant alternatives such as blue bus/red bus are included.

A number of tests have been developed to test for the IIA assumption. Hausman and McFadden (1984) propose a Hausman type test and McFadden et al. (1976) propose an approximate likelihood ratio test that was further improved by Small and Hsiao (1985). Both these tests have limitations however. Firstly the tests often give inconsistent results. This is especially relevant to the Small and Hsiao test as it is based on randomly dividing the sample into two subsamples and thus it is possible to get different results which successive executions of the test. Secondly, the assumptions underlying the Hausman test in particular can be too restrictive as it suffers from small sample bias and it is possible to get a negative chi-squared test statistic (for which no probability can be evaluated) if the estimated model does not meet asymptotic assumptions of the test. Further evidence of the problems associated with the tests is provided by Cheng and Long (2007) who carried out a series of Monte Carlo simulations and concluded that they were unsatisfactory for applied work. They suggest that researchers follow the advice of McFadden (1974), who stated that the multinomial and conditional logit models should only be used in cases where the outcome categories "can plausibly be assumed to be distinct and weighed independently in the eyes of each decision maker" (1974: 113). Another option is to use a generalized alternative to the Hausman test. This test involves using a seemingly unrelated post-estimation procedure to save the results from unrestricted and restricted models and compare the coefficients estimates to see if any systematic differences are present[2].

4.2 The Ordered Logit (OL) Model

Another extension is situations where the dependent variable is categorical but can be ordered in a logical fashion. Walker and Duncan (1967) are credited with the development of the ordered logit model. This model is still based on only one underlying latent variable but with a different match for the latent dependent variable y^*_i and the observed dependent variable, y_i which represents the actual ordered outcomes. The model is specified as follows,

[2] Most statistical packages would have the capability to do this. For example, the 'suest' command in Stata 11 can save parameter estimates and carry out subsequent tests of hypothesis.

$$y^*_i = x_i\beta + \varepsilon_i \tag{4a}$$

$$y_i = \begin{cases} 1 & \text{if } -\infty < y^*_i \le \mu_1 \\ 2 & \text{if } \mu_1 < y^*_i \le \mu_2 \\ 3 & \text{if } \mu_2 < y^*_i \le \mu_3 \\ \vdots & \\ j & \text{if } \mu_{j-1} < y^*_i \le \infty \end{cases} \tag{4b}$$

Thus the probability that alternative j is chosen is the probability that the latent variable y^*_i is between two boundaries or cutpoints μ_{j-1} and μ_j. These are estimated along with the coefficients β.

$$P\{y_i = j\} = P\{\mu_{j-1} < y^* \le \mu_j\} = F(\mu_j - x_i\beta) - F(\mu_{j-1} - x_i\beta) \tag{5}$$

Assuming that ε_i is based on the logistic distribution gives the ordered logit model. A number of studies have examined the relative appropriateness of applying either the multinomial logit model or ordered logit model to examine the levels of ownership of motor vehicles. From a theoretical perspective, the multinomial logit is used if it is assumed that households assign a utility value to each car ownership level and choose the one with maximum utility (Bhat and Pulugurta, 1998). Conversely, the ordered logit model is used when the households propensity to own a particular level of vehicles is represented by a single continuous variable where the utility assigned to a particular car ownership level nests the previous one. That is, the household assigns utility to having zero ownership of cars and more than zero ownership, less than or equal to one car ownership and more than one car ownership, etc. Bhat and Pulugurta (1998) suggest that the MNL model captures a more flexible representation of the relationship between the dependent and independent variables, as each utility value (for each car ownership level) is determined by a set of alternative specific variables. On the other hand, in the OL model this match between utility and the independent variables is more rigid or as stated more succinctly by Bhat and Pulugurta (1998) as monotonic, that is, the utility ordering is preserved..

The conventional tool used to compare different qualitative response models is McFadden's R^2 or likelihood ratio index. This compares the log-likelihood from fitting the full model with the log-likelihood from fitting a model with a constant term only.

$$\text{McFadden}\,R^2 = 1 - \frac{\ln L_{Full}}{\ln L_{Constnat}} \qquad (6)$$

The value is bounded by zero and one so has the same intuitive interpretation as the R^2 from an OLS regression. If all the slope coefficients are zero then *ln* L_{Full} = *ln* $L_{Constant}$ and McFaddens R^2 equals zero. The value can never exactly equal one however but it can come close and obviously the closer it is to one the better the fit. Given that the multinomial logit model estimates more parameters than the ordered logit model a more appropriate statistic adjusts for the number of parameters in each model.

$$\text{McFadden}R^{2}{}_{\text{Adjusted}} = 1 - \frac{\ln L_{Full} - K^*}{\ln L_{Constnat}} \qquad (7)$$

where K* is the number of parameters in each model.

A statistical test to compare the multinomial and ordered logit model which has been applied by Bhat and Pulugurta (1998) and Potoglou and Kanaroglou (2008) is Ben-Akiva and Lerman's (1985) adjusted likelihood ratio test. This test determines whether the difference in McFadden's adjusted R^2 between the two models is significantly or not. The test is carried out by calculating the probability that the difference the relative adjusted R^2's of two competing models could have occurred by chance. The smaller the value of this probability, the more likely that the difference is statistically different and the preferred model is thus the one with the higher adjusted R^2. The probability is calculated as follows:

$$\Phi(-[-2\tau\{\ln L_{\text{Constant}}\} + \{M_2 - M_1\}]^{0.5}) \qquad (8)$$

where τ is the difference between the adjusted R^2's of the two competing models, *ln* $L_{Constant}$ is the log-likelihood from fitting a model with a constant term only, M_2 and M_1 are the number of parameters estimated in the two competing models and Φ represents the cumulative standard normal distribution function.

5: ECONOMETRIC RESULTS

5.1 Tests of IIA assumption and Measures of Model Fit

Before examining the results from estimating the multinomial logit model and ordered logit models, tests of the IIA assumption and a comparison of the relative measures of fit of each model are presented. Table 3 shows the results from applying the generalised Hausman test to the estimated multinomial logit model for each round of the HBS.

Table 3: Generalised Hausman test results of IIA assumption

H0: Odds (Outcome-J vs Outcome-K) are independent of other alternatives.

	1994/95	**1999/00**	**2004/05**	**2009/10**
None	1101.09***	50.84	41.41	45.67
1	532.57***	91.02***	64.62**	69.33***
2	8309.61***	154.83***	105.82***	110.98***
3+	53.28	57.28*	67.28***	37.38

*** p < 0.01, **, p< 0.05, * p <0.1.

The results show some evidence for the violation of the IIA assumption across each of the four models. The evidence is not overwhelming however with one alternative found to be independent of other alternatives in the 1994/95, 1999/00 and 2004/05 surveys (at the 10% level of significance) and two alternatives found to independent of other alternatives in the 2009/10 survey. The pattern of volition/non-volition of the IIA assumption over the different rounds of the HBS also could be interpreted in a logical fashion. In all surveys, the '3+' alternative is statistically independent of other alternatives (at the 5 per cent level of significance) which is plausible given the distinct nature of households possessing this amount of motor vehicles. In the 1999/00, 2004/05 and 2009/10 surveys the 'zero' alternative is independent of others along with the '3+' alternative. This period most closely represents the peak of motor vehicle ownership levels, so it is not surprising to see a statistical difference between the category of households which represents zero possession of motor vehicles and other categories.

Table 4 displays the measures of fit statistics and the Ben-Akiva and Lerman's (1985) adjusted likelihood ratio test. In all rounds of the HBS, the multinomial logit model fits the data better than the ordered logit model. In addition the adjusted likelihood ratio test finds that the difference between the competing adjusted R^2's to be statistically different and therefore the multinomial logit model is the better alternative. This finding confirms the previous work

of Bhat and Pulugurta (1998) and Potoglou and Kanaroglou (2008). The evidence from these tests highlights both the advantages and disadvantages of both models. On the one hand the adjusted R^2 and adjusted likelihood ratio test clearly favour the multinomial logit model. And as previously mentioned the multinomial logit model is preferred from the perspective of a model which fits into the assumed behavioural framework. On the other hand the fact that the IIA isn't universally accepted in the multinomial logit model weakens its case somewhat. One however, can point to the work by previous researchers like Cheng and Long (2007) who suggest applying discretion in the results which arise out of tests of the IIA assumption. Thus, in the context of data on Irish motor vehicle ownership the multinomial logit model appears to be the preferred model.

To further assess the relative performance of the two competing models an in sample validation test was performed in a similar vein to Matas and Raymond (2008). This involves setting aside a certain proportion of each HBS sample (e.g. 20%) and comparing the predicted probabilities of the remaining larger proportion with the holdout sample using measures such as the root mean square error (RMSE) or mean absolute error (MAE). The test can be repeated a number of times using a different randomly selected holdout sample each time. In doing this one can assess which model better explains the underlying relationship rather than just random noise. Using the 2009/10 data set the validation was replicated 500 times and in 254 cases the RMSE from the MNL was smaller than the corresponding RMSE from the OL model while in 260 cases the MAE from the MNL was smaller than the corresponding MAE from the OL model. Similar results showing slightly better RMSE and MAE values from the MNL model were also found for the other HBS surveys. The actual difference in the RMSE and MAE values between the two models was negligible however supporting previous findings made by Matas and Raymond (2008) and indicating little difference in the forecasting ability of both models.

Table 4: Measures of Fit and Ben-Akiva and Lerman's (1985) adjusted likelihood ratio test

	1994/95		1999/00		2004/05		2009/10	
	MNL	**OL**	**MNL**	**OL**	**MNL**	**OL**	**MNL**	**OL**
LL with constant term only	-8090.96	-8090.96	-8579.03	-8579.03	-8103.22	-8103.22	-6652.26	-6652.26
LL at convergence	-5297.08	-5642.56	-5730.41	-6217.72	-5445.12	-5708.53	-4970.75	-5151.22
Number of parameters	60	20	60	20	60	20	60	20
Number of observations	7877	7877	7644	7644	6884	6884	5891	5891
McFadden's Adjusted R^2	0.338	0.300	0.325	0.273	0.321	0.293	0.244	0.223
$\Phi(-[-2\tau\{\ln L_{\text{Constant}}\}+\{M_2-M_1\}]^{0.5})$	Φ(-25.51)		Φ(-30.57)		Φ(-22.06)		Φ(-17.91)	
Adjusted likelihood ratio test result†	$=7.6 \times 10^{-144}$		$=1.5 \times 10^{-205}$		$=3.8 \times 10^{-108}$		$=4.9 \times 10^{-72}$	

† The smaller the probability, the more likely that the difference between the adjusted R^2 of the two competing models is statistically different. If this is the case the preferred model is the one with the higher adjusted R^2.

5.2 Estimates of Marginal Effects from the MNL and OL models

The tables that follow present the estimated marginal effects from the multinomial logit and ordered logit models. Marginal effects represent the change in the probability of being in a particular motor vehicle ownership category for a unit change in an explanatory variable. In the case of discrete (or dummy) variable the unit change is a move from 0 to 1. The marginal effects sum to zero across the four categories which intuitively means that if the probability of being in, for example, two of the vehicle ownership categories increases (for an change in an independent variable), then the probability of being in the other two vehicle ownership categories must decrease by the same amount. Estimating marginal effects also facilitates an easier comparison of the two models as the interpretation of the marginal effects in the two models is the same.

As will be seen in the tables and the discussion that follows the estimated marginal effects from both the MNL model and OL model do not differ substantially especially for the continuous variables. There are some exceptions to this especially in the results for the age of HOH variable. This could be because of the correlation that this variable has with a number of other variables in the model, including marital status, educational status and the extent of free travel. This association between variables may be accounted for in differing ways in the MNL and OL models due to the relative flexibility in the former and relative rigidity in the latter of their theoretical structures.

The results from the most recent HBS (2009/10) are presented and discussed first and then the results from previous HBS to observe any trends in the determinants of household car ownership.

5.2.1 2009/10 Household Budget Survey results

Location – The results suggest that those households living in urban areas are more likely to possess ‘zero’ or ‘1’ cars and less likely to possess ‘2’ or ‘3+’ cars although this pattern is clearer in the ordered logit model. The size of the estimated marginal effects decreases for a smaller town size indicating that the bigger the urban area, the more likely it is that a household does not own a car. Thus factors such as increased congestion and increased public transport make owning a car less attractive. This result would corroborate with the findings

from the analysis by Potoglou and Kanaroglou (2008) who found that their measures of urban density and land use diversity had a significant negative effect on household car ownership

Sex of the HOH – The expectation would be that males are less likely to be in the non-possession categories and more likely to be in the possession categories but this doesn't appear to be the case. It is likely that the increase in the number of females who are the head of household as seen in table 2, and the number of females possessing a car is negating the differences that are expected for this variable.

Age of the HOH – In the OL model, older HOH's are less likely to possess 'zero' or '1' cars and are more likely to possess '2' or '3+' cars. At first, this may appear contrary to expectations but the magnitude of the marginal effects is smaller for the 65+ age group relative to their younger counterparts. Nolan (2010) found similar evidence in her study suggesting that car ownership increases with the age of the household head up to about the age of 50, and thereafter decreases. In the MNL model, this pattern is less pronounced with fewer significant coefficients although it is still generally the case that over 65's are less likely to possess zero cars. It could be that older HOH's are more mobile in comparison to previous generations and are therefore more likely to possess higher numbers of cars. Matas and Raymond (2008) found such an effect present in their data.

Marital Status of HRP – A married HRP is less likely to possess 'zero' or '1' cars and are more likely to possess '2' or '3+' cars. Marital status is in fact a very strong predictor of car ownership in the 2009/10 results with the highest estimated negative marginal effect for non-ownership of a car and the highest estimated positive marginal effect for ownership of 2 car. The importance of marital status in explaining car ownership levels in Ireland has been found previously by Commins and Nolan (2010) and Nolan (2010). As with all of the qualitative variables discussed here, its significance reflects an association rather than a casual effect, although it could be suggested that in recent years a large majority of married Irish couples have moved into newly built homes in suburban areas, necessitating the need for the purchase of extra cars. There could also be an indirect income effect with an extra income present in the household.

Table 5: Marginal Effects, Multinomial Logit and Ordered Logit, 2009/10 HBS

	Multinomial Logit Model				Ordered Logit Model			
Independent Variable	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
Location:								
Rural (ref)								
Urban – Cities	0.103***	-0.047***	-0.049***	-0.007	0.062***	0.019***	-0.065***	-0.017***
Urban – Towns >10,000 pop	0.066***	-0.019	-0.042***	-0.004	0.037***	0.010***	-0.038***	-0.009***
Urban – Towns 5,000-10,000 pop	-0.005	0.003	0.006	-0.004	-0.004	-0.002	0.005	0.001
Urban – Towns <5,000 pop	0.045**	0.009	-0.050**	-0.004	0.030*	0.008***	-0.030**	-0.007**
Sex of HRP:								
Male	0.034***	-0.050***	0.008	0.008*	0.007	0.003	-0.008	-0.002
Female (ref)								
Age of HOH:								
15-34	0.006	-0.008	-0.007	0.009	-0.002	-0.001	0.002	0.001
35-44 (ref)								
45-54	-0.035**	-0.017	-0.003	0.055***	-0.049***	-0.024***	0.056***	0.016***
55-64	-0.045***	-0.042*	0.012	0.075***	-0.069***	-0.038***	0.080***	0.027***
65 +	-0.044*	0.002	0.041	0.000	-0.049***	-0.023**	0.054***	0.018**
Marital Status of HRP:								
Married	-0.145***	-0.015	0.158***	0.002	-0.116***	-0.051***	0.139***	0.028***
Unmarried (ref)								
Education of HRP:								
No education or Primary education (ref)								
Secondary education	-0.017	0.015	0.006	-0.005	-0.013	-0.005	0.014	0.004
Third Level education	-0.055***	0.032*	0.032**	-0.010	-0.028***	-0.010***	0.030***	0.008***
Number of persons with Free Travel:								
None (ref)								
One	0.002	-0.083**	0.021	0.060**	-0.033*	-0.015	0.037*	0.011*
Two or more	-0.075***	-0.113**	0.075	0.113	-0.093***	-0.065***	0.112***	0.046***
Public Transport Dummy:								
Zero Public Transport Spend (ref)								
Positive Public Transport Spend	0.119***	-0.072***	-0.046***	-0.002	0.064***	0.016***	-0.064***	-0.016***
Possession of Motor Cycles:								
None (ref)								
One or more	0.025	0.038	-0.071**	0.007	0.041	0.009***	-0.041*	-0.010*
Number of Persons at Work	-0.069***	-0.098***	0.127***	0.040***	-0.122***	-0.043***	0.129***	0.035***
Number of Persons Unemployed	-0.024***	-0.064***	0.057***	0.031***	-0.062***	-0.022***	0.066***	0.018***
Number of Children <14	-0.054***	0.008	0.046***	-0.000	-0.038***	-0.013***	0.040***	0.011***
Natural log of Total HH expenditure per adult equiv.	-0.174***	-0.010	0.168***	0.016***	-0.141***	-0.049***	0.149***	0.041***
		LR $\chi 2$ (60) = 3363.02***				LR $\chi 2$ (20) = 3002.08***		

*** p < 0.01, **, p< 0.05, * p <0.1.

Education Level of the HOH – Similar effect to marital status, more educated HOH's (especially those with third level education) are less likely to possess 'zero' or '1' cars and more likely to possess '2' or '3+' cars. Nolan (2003, 2010) also found significant positive effects for the education of the HOH. Higher levels of education have two indirect positive effects on car ownership. Firstly, it increases the probability of getting into the labour market and secondly, it increases the probability of getting a higher wage.

Free Travel – those households with occupants in possession of free travel are less likely to possess 'zero' or '1' cars and more likely to possess '2' or '3+' cars. This at first appears counter intuitive although it does support the previous result observed for the 65+ age group. Thus this group may have already possessed one or two cars before qualifying for the free travel scheme. One should therefore caution against the suggestion that possession of free travel does not reduce car ownership as there may be other factors which are influencing the relationship. Indeed the expansion of the free travel scheme over the last number of years to include groups such as the disabled and widowed may also be capturing households who are more likely to possess motor vehicles.

Public Transport Use – As expected for this variable, there is a large positive effect on the non-ownership of cars and predominantly negative effects for each of the possession of car categories. Along with location, public transport use is a strong predictor of non-ownership of cars. This finding is replicated in many international studies including Matas and Raymond (2008) and Potoglou and Kanaroglou (2008).

Motor Cycle Ownership – There is some evidence that those households in possession of motor cycles are less likely to possess cars, especially in larger numbers but the effect is only partial.

Number of Persons at Work – For this variable, there are clear negative effects in the 'zero' and '1' categories and clear positive effects in the '2' and '3+' categories. The finding in many previous studies of the importance of this variable in explaining levels of possession of motor vehicles is thus highlighted in this study as well. Clearly, mobility for work purposes is a key driver of household car possession.

Number of Persons Unemployed – Most previous Irish and international studies have included a variable representing the number of persons who are employed in the household (e.g. Nolan, 2010) but have neglected to analyse the effect of the number of persons who are unemployed. The results in this study suggest that having unemployed persons in the household has in fact a similar effect as having employed persons in the household, albeit with a smaller magnitude. This is an unexpected result, but could be explained by the possibility that the adjustment in the stock of motor vehicles which has taken place as a result of the downturn in the economy (see table 1 figures) may not have occurred for this cohort of households as much as expected. Nolan (2010) found evidence of a strong habit effect in household car ownership which would provide support for this hypothesis. In essence, mobility becomes habitually important even for non-work purposes.

Number of Children < 14 – Similar effects were found for this variable when compared to the number of workers and numbers unemployed although once again the estimated marginal effects are smaller in size. The increase in the number of children in a household therefore does not have the same effect as an increase in the number of workers and could indicate that increasing number of children has a greater influence on car size and possibly distance travelled rather than influencing the decision to purchase an extra car.

Total Weekly Household Expenditure per adult – Not surprisingly, the higher the overall level of household expenditure the less likely it is that the household possesses 'zero' or '1' cars and the more likely it is that they possess '2' or '3+' cars. The largest negative effect appears in the 'zero' category and the largest positive effect appears in the '2' category, indicating that incremental changes in overall weekly expenditures affects these categories to the greatest degree. More specifically, a one per cent proportional increase in the total level of weekly household expenditure (per adult) decreases the probability of owning zero cars by approximately 14-18 per cent, decreases the probability of owning 1 car by approximately 5 per cent, increases the probability of owing 2 cars by approximately 15-17 per cent and increases the probability of owing 3+ cars by approximately 2-4 per cent.

5.2.2 Comparison of results across all rounds of the Household Budget Survey

Location – The task of making appropriate comparisons of the location variable across different rounds of the HBS is hampered somewhat by the fact that the categories defining location change over time. However, some trends as discernible. For example, it is clear that the size of the urban area has a consistent effect across all surveys with households in larger urban areas more likely to possess zero cars relative to households in smaller urban areas. Also from the 1994/95 HBS to the 2004/05 HBS the size of the negative probabilities of owning '2' or '3+' cars which exist for the urban variables appear to increase. Taking the Dublin Metropolitan area as an example, in 1994/95 the probability of owning '2' and '3+' cars was -0.063 and -0.006 respectively whereas in 2004/05 the corresponding values increased to -0.141 and -0.030. This supports the expectation that as urban areas become larger and more densely populated the benefits of owning multiple motor vehicles in particular decreases.

Sex of the HOH – In the earlier rounds of the HBS a significant difference existed in ownership levels by the gender of the HOH with households with a male HOH tending to own more cars. By the latest HBS (2009/10) this difference seems to be non-existent. As previously postulated, this could be because there are more females as the HOH as well as an equalising of gender differences in car ownership levels.

Age of the HOH – The results produced using the 2009/10 HBS, are generally replicated in the earlier rounds of the HBS. That is, in the OL model, older HOH's are less likely to own 'zero' and '1' cars and more likely to own '2' and '3+' cars and in the MNL this pattern is also present but is less pronounced with fewer significant coefficients. It is also generally the case across the rounds of the HBS, that the magnitude of the marginal effects is smaller for the 65+ age group relative to their younger counterparts. This may point toward a stable life-cycle effect over the time period examined, that is, older generations continually requiring the use of cars but at a consistently lower rate relative to younger generations.

Table 6a: Marginal Effects, Multinomial Logit and Ordered Logit Models, 1994/95 HBS

	Multinomial Logit Model				Ordered Logit Model			
Independent Variable	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
Location:								
Rural (ref)								
Urban – Dublin Metropolitan Area	0.220***	-0.152***	-0.063***	-0.006**	0.169***	-0.073***	-0.084***	-0.012***
Urban – Towns >10,000 pop	0.188***	-0.125***	-0.058***	-0.005**	0.148***	-0.070***	-0.069***	-0.009***
Urban – Towns 1,500-10,000 pop	0.158***	-0.089***	-0.062***	-0.007***	0.130***	-0.056***	-0.065***	-0.009***
Urban – Towns <1,500 pop	0.106***	-0.084***	-0.011	-0.010***	0.068***	-0.027***	-0.035***	-0.005***
Sex of HOH:								
Male	-0.102***	0.079***	0.021**	0.001	-0.085***	0.036***	0.043***	0.006***
Female (ref)								
Age of HOH:								
15-34	0.121***	-0.081***	-0.046***	0.005	0.091***	-0.037***	-0.048***	-0.007***
35-44 (ref)								
45-54	-0.044***	0.021	0.016	0.007	-0.043***	0.013***	0.026***	0.004***
55-64	-0.064***	0.041**	0.007	0.016*	-0.065***	0.017***	0.041***	0.007***
65 +	-0.007	-0.021	-0.000	0.028*	-0.027*	0.008**	0.017*	0.003*
Marital Status of HOH:								
Married (ref)	-0.155***	0.077***	0.079***	-0.001	-0.153***	0.073***	0.071***	0.009***
Unmarried								
Education of HOH:								
No education or Primary education (ref)								
Secondary education	-0.098***	0.064***	0.027***	0.007**	-0.084***	0.029***	0.046***	0.008***
Third Level education	-0.178***	0.078***	0.088***	0.012**	-0.149***	0.025***	0.105***	0.019***
Number of persons with Free Travel:								
None (ref)								
One	0.023	-0.085***	0.051***	0.011*	-0.013	0.004	0.008	0.001
Two or more	0.021	-0.077***	0.042	0.014	-0.020	0.006	0.012	0.002
Public Transport Dummy:								
Zero Public Transport Spend (ref)								
Positive Public Transport Spend	0.107***	-0.067***	-0.038***	-0.002	0.084***	-0.029***	-0.048***	-0.007***
Possession of Motor Cycles:								
None (ref)								
One or more	0.111***	-0.045	-0.053***	-0.013***	0.135***	-0.066***	-0.062***	-0.008***
Number of Persons at Work	-0.060***	-0.028***	0.073***	0.016***	-0.114***	0.037***	0.066***	0.010***
Number of Persons Unemployed	0.074***	0.001	-0.065***	-0.011***	0.104***	-0.034***	-0.060***	-0.009***
Number of Children <14	-0.040***	0.027***	0.014***	-0.001	-0.027***	0.009***	0.016***	0.002***
Natural log of Total HH expenditure per adult equiv.	-0.251***	0.110***	0.131***	0.010***	-0.220***	0.072***	0.128***	0.020***
		LR $\chi 2$ (60) = 5587.76***				LR $\chi 2$ (20) = 4896.80***		

*** p < 0.01, **, p< 0.05, * p <0.1.

Table 6b: Marginal Effects, Multinomial Logit and Ordered Logit, 1999/00 HBS

	Multinomial Logit Model				Ordered Logit Model			
Independent Variable	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
Location:								
Rural (ref)								
Urban – Dublin Metropolitan Area	0.205***	-0.105***	-0.074***	-0.026***	0.141***	-0.000	-0.115***	-0.026***
Urban – Towns >20,000 pop	0.185***	-0.080***	-0.089***	-0.016***	0.131***	-0.005*	-0.104***	-0.022***
Urban – Towns 3,000-20,000 pop	0.146***	-0.046***	-0.078***	-0.021***	0.112***	0.000	-0.092***	-0.020***
Urban – Towns <3,000 pop	0.157***	-0.052*	-0.082***	-0.023***	0.123***	-0.009	-0.095***	-0.019***
Sex of HOH:								
Male	-0.075***	0.026*	0.044***	0.005	-0.054***	-0.006***	0.049***	0.011***
Female (ref)								
Age of HOH:								
15-34	0.103***	-0.041**	-0.061***	-0.001	0.064***	0.005***	-0.057***	-0.013***
35-44 (ref)								
45-54	-0.030**	-0.000	0.018	0.012*	-0.033***	-0.008***	0.032***	0.009***
55-64	-0.046***	0.002	0.010	0.034***	-0.068***	-0.021***	0.068***	0.021***
65 +	-0.027*	-0.049*	0.042*	0.034**	-0.069***	-0.022***	0.068***	0.023***
Marital Status of HOH:								
Married (ref)	-0.121***	-0.006	0.126***	0.001	-0.123***	0.002	0.102***	0.020***
Unmarried (ref)								
Education of HOH:								
No education or Primary education (ref)								
Secondary education	-0.076***	0.043***	0.043***	-0.010**	-0.052***	-0.008***	0.047***	0.013***
Third Level education	-0.103***	0.015	0.099***	-0.011**	-0.079***	-0.024***	0.080***	0.023***
Number of persons with Free Travel:								
None (ref)								
One	0.016	-0.049**	0.027	0.006	-0.005	-0.001	0.005	0.001
Two or more	0.006	0.006	-0.028	0.017	-0.008	-0.002	0.007	0.002
Public Transport Dummy:								
Zero Public Transport Spend (ref)								
Positive Public Transport Spend	0.089***	-0.042***	-0.041***	-0.005	0.056***	0.008***	-0.052***	-0.013***
Possession of Motor Cycles:								
None (ref)								
One or more	0.126***	-0.058	-0.077***	0.009	0.096***	-0.003	-0.077***	-0.016***
Number of Persons at Work	-0.038***	-0.089***	0.095***	0.031***	-0.108***	-0.020***	0.101***	0.026***
Number of Persons Unemployed	0.034***	0.061***	-0.064***	-0.031***	0.076***	0.014***	-0.071***	-0.019***
Number of Children <14	-0.048***	0.015**	0.037***	-0.005*	-0.031***	-0.006***	0.029***	0.008***
Natural log of Total HH expenditure per adult equiv.	-0.223***	0.023**	0.171***	0.029***	-0.179***	-0.033***	0.168***	0.044***
		LR $\chi 2$ (60) = 5697.23***				LR $\chi 2$ (20) = 4722.62***		

*** p < 0.01, **, p< 0.05, * p <0.1.

Table 6c: Marginal Effects, Multinomial Logit and Ordered Logit, 2004/05 HBS

	Multinomial Logit Model				Ordered Logit Model			
Independent Variable	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
Location:								
Rural (ref)								
Urban – Dublin Metropolitan Area	0.160***	0.010	-0.141***	-0.030***	0.125***	0.049***	-0.135***	-0.040***
Urban – Towns >20,000 pop	0.149***	-0.011	-0.108***	-0.029***	0.104***	0.036***	-0.110***	-0.030***
Urban – Towns 3,000-20,000 pop	0.139***	-0.022	-0.096***	-0.021***	0.089***	0.039***	-0.098***	-0.030***
Urban – Towns <3,000 pop	0.041**	-0.011	-0.032**	0.002	0.019**	0.010**	-0.022**	-0.008**
Sex of HOH:								
Male	-0.044***	0.008	0.041***	-0.005	-0.023***	-0.013***	0.026***	0.009***
Female (ref)								
Age of HOH:								
15-34	0.063***	-0.025	-0.024	-0.014	0.032***	0.017***	-0.036***	-0.012***
35-44 (ref)								
45-54	-0.043***	0.020	-0.013	0.037***	-0.033***	-0.022***	0.040***	0.016***
55-64	-0.050***	-0.003	0.008	0.044***	-0.054***	-0.038***	0.063***	0.029***
65 +	-0.033**	-0.002	0.008	0.027	-0.047***	-0.032***	0.053***	0.026***
Marital Status of HOH:								
Married	-0.112***	-0.088***	0.202***	-0.002	-0.122***	-0.049***	0.137***	0.033***
Unmarried (ref)								
Education of HOH:								
No education or Primary education (ref)								
Secondary education	-0.061***	0.034**	0.032**	-0.005	-0.040***	-0.023***	0.046***	0.018***
Third Level education	-0.080***	0.030	0.061***	-0.011	-0.045***	-0.029***	0.053***	0.021***
Number of persons with Free Travel:								
None (ref)								
One	0.033***	-0.027	-0.037*	0.031**	0.004	0.002	-0.004	-0.002
Two or more	-0.016	-0.015	0.020	0.012	-0.029***	-0.019***	0.034***	0.015**
Public Transport Dummy:								
Zero Public Transport Spend (ref)								
Positive Public Transport Spend	0.058***	-0.019	-0.036***	-0.003	0.031***	0.017***	-0.036***	-0.013***
Possession of Motor Cycles:								
None (ref)								
One or more	0.100***	0.017	-0.149***	0.033*	0.074***	0.028***	-0.079***	-0.023***
Number of Persons at Work	-0.036***	-0.107***	0.092***	0.051***	-0.103***	-0.061***	0.119***	0.045***
Number of Persons Unemployed	0.042***	0.048**	-0.079***	-0.012*	0.062***	0.037***	-0.072***	-0.027***
Number of Children <14	-0.045***	0.006	0.044***	-0.004	-0.025***	-0.015***	0.029***	0.011***
Natural log of Total HH expenditure per adult equiv.	-0.172***	-0.024**	0.166***	0.029***	-0.127***	-0.075***	0.146***	0.055***
		LR $\chi 2$ (60) = 5316.19***				LR $\chi 2$ (20) = 4789.38***		

*** p < 0.01, **, p< 0.05, * p <0.1.

Marital Status of HRP – As mentioned previously, the marital status of the HRP is a strong predictor of car ownership and this has been the case throughout the rounds of the HBS. Its effect changes however as can been seen in the magnitude of the marginal effects over time. Generally, the non-ownership negative marginal effects are decreasing and the positive marginal effects for the ownership of two cars are increasing. This would suggest that been married is becoming less of a predictor for the non-ownership of motor vehicles and a greater predictor of the ownership of two motor vehicles. In addition in relative terms, a household with a married HRP is less likely to own one car in 2009/10 compared to the same household in 1994/95.

Education Level of the HOH – This is another variable which produces some interesting results. In general the estimated marginal effects are consistent across all of the surveys with more educated HOH's possessing greater numbers of cars. However, over time, this 'returns to education' effect appears to be diminishing as both the negative marginal effects and positive marginal effects are falling. Hence, 20 years ago education was a strong influence on car ownership but now it is not as important. The increase in the numbers attaining second and third level education over the time period is the most likely explanation for this.

Free Travel – this variable does not exhibit any consistent effect in the 1994/95 and 1999/00 results but in the 2004/05 and 2009/10 data, it decreases the probability of possessing 'zero' and '1' cars and increases the probability of possessing '2' and '3+' cars. An explanation for this trend could be due to the changing eligibility criteria for attaining free travel. As previously mentioned, in the past free travel was predominantly available to pensioners aged 65 or over. Thus in the 1994/95 and 1999/00 analysis its inclusion did not make any discernible difference as a variable representing the over 65 group was already present. However in more recent times the eligibility criteria has been expanded and thus the groups in possession of this benefit are more diverse than before.

Public Transport Use – Over the different rounds of the survey public transport use has remained a strong substitute for car ownership. The large positive marginal effect for zero ownership does diminish between the 1994/95 and 2004/05 surveys suggesting a weakening of this relationship during that period. This would correspond to a time when preferences for car ownership versus public transport were at their strongest. In more recent times though

there appears to be a switch back toward public transport use as the downturn in the economy has shifted relative costs for some households more favourably toward public transport.

Motor Cycle Ownership – In the 2009/10 survey it was found that the relationship between car ownership and motor cycle ownership was weak at best. In earlier surveys however the relationship was much stronger with car ownership viewed as a substitute to motor vehicle ownership. In particular, households in possession of at least one motor cycle were more likely to possess 'zero' cars and less likely to possess '2' or '3+' cars. It is perhaps surprising that motor cycles role as a substitute to motor vehicles waned as the downturn occurred but this could be because public transport became more of a popular alternative. Cycling has also become a very popular mode of transport in recent years due to the introduction of a number of cycling schemes. This may have taken some of the demand away from motor cycles.

Number of Persons at Work – As previously discussed this variable is a strong determinant of motor vehicle ownership, a role which it has maintained throughout the rounds of the HBS. In sum, the more people who are working in the households, the less likely it is that a household possesses 'zero' or '1' cars and the more likely it is that it possesses '2' or '3+' cars. The magnitudes of the marginal effects are interesting as they illustrate the changing behaviour of households as underlying economic conditions change. For example, between the 1994/95 and 2004/05 period, corresponding to a period of high growth and high employment, the negative likelihood of owning 'zero' cars decreased, the negative likelihood of owning '1' car increased and the positive likelihood of owning '2' or '3+' cars increased. One can think of a typical household during this period moving from 'zero' car ownership to purchasing '1' car or moving from having '1' car to purchasing an additional one or two. Between 2004/05 and 2009/10, when the economy contracted and unemployment increased, the trend is reversed, with an increase in the negative likelihood of owning 'zero' cars, a decrease in the negative likelihood of owning '1' car and a decrease in the positive likelihood of owning '3+' cars. Thus households in this period had on average a smaller stock of motor vehicles relative to earlier years.

Number of Persons Unemployed – Given the above discussion one would expect a different relationship to exist for the number of persons unemployed per household. Largely this holds true but not on a consistent basis. In 1994/95, the more people unemployed in a household, the more likely the household possessed zero cars and the less likely that it possessed '1', '2'

or ‘3+’ cars. In 1999/00 and 2004/05 this relationship changed with greater numbers of unemployed persons per household positively related to ‘zero’ and ‘1’ levels of car ownership and negatively related to ‘2’ and ‘3+’ ownerships levels. In 2009/10, the relationship reverses completely to a situation where higher levels of unemployment are negatively related to ‘zero’ and ‘1’ levels ownership levels and positively related to ‘2’ and ‘3+’ ownerships levels. This pattern suggests that over the rounds of the HBS, having persons unemployed in a household has become less of a factor in determining the non-ownership of a car. For example, in the 1999/00 and 2004/05 surveys there was a higher probability of owning one car compared to owning none. The marginal effects observed in 2009/10 are therefore a reflection of increased car ownership amongst this cohort of households over time and the recent downturn in the economy has not had an impact (as of yet) probably because a strong habit effect has developed.

Number of Children < 14 – The estimated marginal effects for this variable are generally consistent across time with negative values for the ‘zero’ category and positive values for the ‘2’ and ‘3+’ categories. The biggest incremental changes in the marginal effects can be seen in the ownership of the ‘2’ cars category which is plausible given the modern day requirement for two cars when children as present in the household. Also, the marginal effects are small which, as previously mentioned, may provide some evidence to suggest that children influence the size of the motor vehicle than the number of motor vehicles.

Total Weekly Household Expenditure per adult – Total weekly household expenditure is another variable which mirrors the trend in car ownership seen in table 1. That is, between 1994/95 and 2004/05 increases in total weekly household expenditure has led to increases in the ownership of ‘2’ and ‘3+’ motor vehicles per household especially. But in 2009/10 this behaviour is paused as total weekly household expenditure is diverted away from cars toward other goods. This change in behaviour is likely to have manifested itself in a number of ways. It could be the case that households have downsized their stock of car as their incomes fall. However given the evidence to suggest that there may be a habit effect (for example with unemployed persons) in the use of car it is more probable that households have ceased expanding on their existing stock of cars and newly formed households (particularly single or cohabiting occupants living in urban areas) have postponed the purchase of a car until economic conditions improve.

5.3 Elasticity Estimates

As the marginal effects are constrained to sum to zero, they do not appropriately measure the change in magnitude of a particular car ownership level being chosen for a change in an independent variable. Effectively they measure absolute changes in the likelihood of a particular motor vehicle ownership level being chosen rather than proportional changes. This is especially the case for the continuous independent variables. To analyse this aspect in more detail, elasticity estimates for the two key continuous independent variables, the number of workers and total weekly household expenditure per adult, are calculated for all four rounds of the HBS. To save on the space the elasticities derived from the multinomial logit model only are presented in table 7.

Table 7: Elasticity Estimates from the Multinomial Logit Model, 1994/95 to 2009/10 HBS

Independent Variable	HBS survey	0	1	2	3+
Number of Persons at Work	1994/95	-0.431***	0.061	1.040***	2.254***
	1999/00	-0.487***	-0.135***	0.976***	2.394***
	2004/05	-0.645***	-0.279***	0.828***	2.510***
	2009/10	-0.724***	-0.210***	0.825***	1.824***
Natural log of Total HH expenditure per adult equiv.	1994/95	-1.623***	0.422***	1.790***	1.882***
	1999/00	-2.112***	0.034*	1.371***	2.128***
	2004/05	-2.037***	-0.175***	0.993***	1.465***
	2009/10	-1.630***	-0.112***	0.966***	0.972***

*** p < 0.01, **, p< 0.05, * p <0.1.

The elasticities display the expected signs and magnitudes. For the category representing ‘zero’ ownership of motor vehicles the effect of a percentage change in income is unsurprisingly much greater than a corresponding change in the number of workers per household. The income elasticity in this category displays a pattern which is associated with the economic circumstances at the time. The category representing ownership of ‘1’ motor vehicle has the smallest elasticities as this category has the largest proportion of households. Between 1994/95 and 1999/00 owning ‘1’ motor vehicle was a necessity for households but since 1999/00 it has turned into an inferior good. That is, increases in the number of workers per household and/or increases in income, decreases the likelihood of owning ‘1’ motor vehicle.

In turn this increases the likelihood of owning two or more motor vehicles and the elasticities in these categories illustrate how responsive the likelihood of owning two or more motor

vehicles is to changes in the number of workers per household and/or incomes. The sizes of the elasticities in the '3+' category are in particular quite large. Interestingly, the elasticities for the number of workers are greater than the income elasticities in this category, an opposite effect to that found for the category representing zero ownership of motor vehicles. This would suggest that having more workers in the household increases the chances of possession of multiple motor vehicles to a greater extent than income. But income is more important in determining whether a household possesses a motor vehicle in the first place. Finally the elasticities in the category representing ownership of '2' motor vehicles are generally decreasing over time. Such a pattern reflects an improvement in the standards of living of households over time making the ownership of two motor vehicles more affordable and changing this category from a luxury into a necessity.

These elasticities can be best compared with results from studies using similar methodologies such as Bhat and Pulugurta (1998), Matas and Raymond (2008) and Potoglou and Kanaroglou (2008). The estimates in particular closely resemble the elasticities calculated from the Matas and Raymond (2008) study. They calculated negative inelastic values for the category representing 'zero' ownership of motor vehicles, low positive elasticities for the category representing ownership of '1' motor vehicle and high positive elasticities for the categories representing ownership of '2' and '3+' motor vehicles. In addition Matas and Raymond (2008) found the effect on income to be declining over time, a result which is also corroborated in this study especially for the category representing ownership of two motor vehicles. Bhat and Pulugurta (1998) produce similar estimates in terms of the sign with negative elasticities for the 'zero' and '1' categories and positive elasticities for higher levels of ownership. The magnitude of the elasticities differs slightly to this study however. For example, they estimate a lower income elasticity of 0.281 for the category representing ownership of two motor vehicles.

The elasticity estimates from the Bhat and Pulugurta (1998) study also illustrate the greater importance that the number of workers in the household has on the number of motor vehicle possessed relative to income and the greater importance that income has on motor vehicle possession (i.e. from zero to one motor vehicle) relative to the number of workers in the household. Further evidence of this comes from Potoglou and Kanaroglou (2008) who find that increases in the number of full-time workers shifts motor vehicle ownership shares towards three-or-more motor vehicle ownership.

In relation to Irish studies, the estimated income elasticity of 1.1 from Nolan (2003), while based on 1994/95 HBS data and a different methodology, is reasonably in line with the estimates produced here. Nolan (2010) calculated income elasticities ranging from 0.017 for current income to 0.049 for permanent income, although the methodology used in this study is not directly comparable with the methodology used here. What the author does find is that as motor vehicle ownership levels become saturated, future increases in income will have a smaller effect on the choice to own a motor vehicle or not. This also appears to be borne by the results in this study with both the number of workers per household and income generating inferior elasticity estimates in the 'zero' and '1' ownership categories.

6: CONCLUSIONS

The objective of this paper was to examine the determinants of motor vehicle ownership in Ireland using a micro data set, the Household Budget Survey. As well as analysing the most recent survey, previous surveys were also examined in order to detect any trends in the factors which determine motor vehicle ownership. The first contribution of the research was to the debate in the literature on the relative merits of using the multinomial logit model versus the ordered logit model for analysing different categories of motor vehicle ownership. For all rounds of the HBS examined, the MNL model fitted the data better relative to the OL model. The actual difference in fit was marginal however and validation tests found little difference in the forecasting ability of each model. Thus this study would also give some weight to the suggestion by Matas and Raymond (2008) that the two models are indistinguishable.

The second contribution of the research was to identify the main factors affecting household motor vehicle ownership levels. In the 2009/10 model, being married was found to be a strong predictor of motor vehicle ownership whilst urban location and public transport use were found to be strong predictors of non-motor vehicle ownership. The study also provided a comprehensive analysis of the results over time which adds significantly to current literature. In particular the effect of some of the qualitative variables, including gender, marital status and education level of the HOH, appears to be diminishing over time. What this shows is that there is a trend toward greater levels of homogeneity amongst Irish households

in relation to motor vehicle ownership. Such a finding does not appear to be present in other studies. Public transport's role as a substitute for motor vehicle ownership did appear to be weakening up to the 2004/05 survey but the recent downturn in the economy has strengthened its role once again in the 2009/10 data set. From a policy perspective it is important to find that public transport still has a role as a substitute for motor vehicle ownership, albeit one that appears to be conditional on economic conditions. In relation to the results for the age of the HOH, there is evidence to suggest a stable life-cycle effect with older HOH's less likely to possess certain levels of motor vehicles relative to younger HOH's. Whilst lack of data on the actual age of the HOH in the household budget survey limits the application of a dynamic model just like Nolan (2010), it is reassuring to find evidence of a life-cycle effect in this study just like her research.

Turing to the continuous variables, it was found that the relationship between the number of household members who are unemployed and motor vehicle ownership changes over time. In the earlier surveys there was the expected negative relationship but in later surveys a positive relationship is found. Rather than suggesting that increased numbers of unemployed lead to increased levels of motor vehicle ownership, it is likely that the recent recession has increased the numbers unemployed but these households haven't necessarily reduced their stock of motor vehicles yet. Further evidence is required however and an analysis of the effect of the global recession on motor vehicle ownership in other countries would provide an interesting comparison.

Not surprisingly the number of workers and the total amount of household expenditure are found to be important variables reflected by the size of their estimated marginal effects. Their importance is also consistent across all of the surveys examined. Elasticity's for these two key variables were also estimated. Here it was found that increasing number of workers has a greater effect on '2' and '3+' categories compared to total household expenditure. On the other hand, total household expenditure has a greater effect on the move from zero ownership to ownership of one motor vehicle. This result is important for predicting where future growth in household car ownership will occur. Latest projections suggest that the economy may recover in the second of this decade with increasing level of economic growth allied with a reduction in unemployment levels. However our future prospects are still very uncertain at the moment and other scenarios are possible. A recovery which consists of an improvement in household income but not necessarily employment would, according to the

elasticity estimates in this study, have a different effect on household car ownership compared to a full recovery in both household income and employment.

Another important aspect is the role of policy, particularly in changing household preferences toward for example electric cars or other sustainable forms of transport. The implementation of these polices before the recovery occurs is of crucial importance. The results in this study suggest that policies that target work related travel decisions may have a greater effect on reducing incidence of household ownership of '2' and '3+' cars in particular. In 2009 the government introduced a tax incentive for the purchase of bicycles to encourage individuals to travel to work by this method and many cities across the country have also introduced public bicycle hire facilities. Such schemes allied with continued investment in public transport can play important roles in reducing our dependence on private car ownership.

REFERENCES

Alperovich, G., Deutsch, J. and Y. Machnes, (1999) “The demand for car ownership: evidence from Israeli data.” *International Journal of Transport Economics* 26 (3): 351–375.

Asensio, J. (2002) “Transport mode choice by commuters to Barcelona’s CBD.” *Urban Studies* 39 (10): 1881–1895.

Ben-Akiva, M. and S. R. Lerman (1985) “Discrete Choice Analysis: Theory and Application to Travel Demand.” MIT Press. Cambridge, Massachusetts, USA.

Berkovec, J. (1985). "New Car Sales and Used Car Stocks: A Model of the Automobile Market" *The RAND Journal of Economics* 16(2): 195-214.

Berkovec, J. and J. Rust (1985). "A nested logit model of automobile holdings for one vehicle households" *Transportation Research Part B: Methodological* 19(4): 275-285.

Berkowitz, M. K., N. T. Gallini, E. J. Miller and R. A. Wolfe (1990). "Disaggregate Analysis of the Demand for Gasoline" *The Canadian Journal of Economics / Revue canadienne d'Economique* 23(2): 253-275.

Bhat, C. R. and V. Pulugurta (1998). "A comparison of two alternative behavioral choice mechanisms for household auto ownership decisions" *Transportation Research Part B: Methodological* 32(1): 61-75.

Bjorner, T. (1999) “Demand for car ownership and use in Denmark: a micro econometric model.” *International Journal of Transport Economics* 26 (3): 377–395.

Central Statistics Office. 2013. Household Budget Survey 2009/10. Stationery Office. Dublin. Ireland.

Central Statistics Office, 2012. Transport Omnibus 2011, Stationery Office, Dublin. Ireland

Cheng, S. and J. S. Long (2007). "Testing for IIA in the Multinomial Logit Model" *Sociological Methods & Research* 35(4): 583-600.

Commins, N. and A. Nolan (2010) “Car ownership and mode of transport to work in Ireland.” *Economic and Social Review* 41: 43-75.

Cragg, J. and R. Uhler (1970) “The demand for automobiles.” *Canadian Journal of Economics* 3 (3): 386–406.

Dargay, J.M. (2001) “The effect of income on car ownership: evidence of asymmetry.” *Transportation Research Part A* 35 (9): 807–821.

Dargay, J.M. (2002) “Determinants of car ownership in rural an urban areas: a pseudo-panel analysis.” *Transportation Research Part E* 38: 351–366.

Dargay, J. and D. Hanley (2007) “Volatility of car ownership, commuting mode and time in the UK.” *Transportation Research Part A* 41 (10): 934–938.

Dargay, J. and P. Vythoulkas (1999) “Estimation of a dynamic car ownership model: a pseudo-panel approach.” *Journal of Transport Economics and Policy* 33 (3): 287–302.

De Jong, G. C. (1990). "An indirect utility model of car ownership and private car use" *European Economic Review* 34(5): 971-985.

De Palma, A. and D. Rochat (2000) “Mode choice for trips to work in Geneva: an empirical analysis.” *Journal of Transport Geography* 8: 43–51.

Environmental Protection Agency (2013) Ireland’s Greenhouse Gas Emission Projections 2012-2030. Wexford. Ireland.

Hausman, J. and D. McFadden (1984). "Specification Tests for the Multinomial Logit Model" *Econometrica* 52(5): 1219-1240.

Hennessy, H. and R.S.J Tol (2011a) “The Impact of Government Policy on Private Car Ownership in Ireland” The Economic and Social Review 42 (2): 135–157.

Hennessy, H. and R.S.J Tol (2011b) “The impact of tax reform on new car purchases in Ireland” Energy Policy 39: 7059–7067.

Hensher, D., Barnard, P., Smith, N. and F. Milthorpe, (1989) “An empirical model of household automobile holdings.” *Applied Economics* 21: 35–57.

Hocherman, I., J. Prashker and M. Ben-Akiva (1983). "Estimation and Use of Dynamic Transaction Models of Automobile Ownership" *Transportation Research Record* 944: 134-141.

Howley, M., Dennehy, E. Ó Gallachóir, B. and M. Holland. (2012) Energy in Ireland 1990 – 2011. Energy Policy Statistical Support Unit, Sustainable Energy Authority of Ireland.

Huang, B. (2005) “Car Demand Forecasting Using Dynamic Pseudo-Panel Models.” MVA Consultancy and Department of Economics, Birkbeck College. <http://www.mvaconsultancy.com>.

Johansson-Stenman, O. (2002) “Estimating individual driving distance by car and public transport use in Sweden.” *Applied Economics* 34: 959–967.

Jones, A. (2000). “Health Econometrics”. in A. Culyer and J. Newhouse (ed.), Handbook of Health Economics. Vol. 1A. Academic Press. New York, USA.

Kayser, H. (2000) “Gasoline demand and car choice. Estimating gasoline demand using household information.” *Energy Economics* 22: 331–348.

Lave, C. and K. Train (1979) “A disaggregate model of auto-type choice.” *Transportation Research Part A* 13 (1): 1–9.

Lerman, S. R. and M. E. Ben-Akiva (1976). A Behavioural Analysis of Automobile Ownership and Modes of Travel. prepared by Cambridge Systematics Inc., Cambridge MA, for the US Department of Transportation Office of the Secretary and Federal Highway Administration.

McFadden, D. L. (1974). “Conditional Logit Analysis of Qualitative Choice Behavior.” in P. Zarembka (ed.), Frontiers in Econometrics. Academic Press. New York, USA.

Mannering, F. and C. Winston (1985) “A dynamic empirical analysis of household vehicle ownership and utilisation.” *The Rand Journal of Economics* 16 (2): 215–236.

Manski, C. F. and L. Sherman (1980). "An empirical analysis of household choice among motor vehicles" *Transportation Research Part A: General* 14(5–6): 349-366.

Matas, A. and J. Raymond (2008) “Changes in the structure of car ownership in Spain.” *Transportation Research Part A* 42: 187–202.

McCarthy, C. (1977) Determinants of Variations in Private Car Ownership: Cross-section Evidence. Central Bank of Ireland, Dublin. Ireland.

McCarthy, P. (1996) “Market price and income elasticities of new vehicle demands.” *The Review of Economics and Statistics* 78 (3): 543–547.

McFadden, D., Tye, W. and K. Train (1976) “An application of diagnostic test for the irrelevant alternatives property of the multinomial logit model” *Transportation Research Record* 637: 39-46.

Nolan, A. (2003) “The determinants of urban households’ transport decisions: a microeconometric study using Irish data.” *International Journal of Transport Economics* 30 (1): 103–132.

Nolan, A. (2010) “A dynamic analysis of household car ownership.” *Transportation research Part A: Policy and Practice* 44: 446-455.

Potoglou, D. and P. Kanaroglou (2008) “Modelling car ownership in urban areas: a case study of Hamilton, Canada.” *Journal of Transport Geography* 16: 42–54.

Ritter, N. and C. Vance (2013) “Do fewer people mean fewer cars? Population decline and car ownership in Germany” *Transportation Research Part A* 50: 74–85.

Small, K. A. and C. Hsiao (1985). “Multinomial Logit Specification Tests” *International Economic Review* 26(3): 619-627.

Thobani, M. (1984) “A nested logit model of travel mode to work and auto ownership.” *Journal of Urban Economics* 15: 287–301.

Train, K. (1980) “A structured logit model of auto ownership and mode choice.” *Review of Economic Studies* 47 (2): 357–370.

Train, K. (1986). “Qualitative Choice Analysis: Theory, Econometrics and an Application to Automobile Demand.” MIT Press. Cambridge, Massachusetts, USA.

Walker, S. H. and D. B. Duncan (1967). "Estimation of the Probability of an Event as a Function of Several Independent Variables" *Biometrika* 54(1/2): 167-179.

Whelan, G. (2007) “Modelling car ownership in great Britain.” *Transportation Research Part A* 41: 205–219.

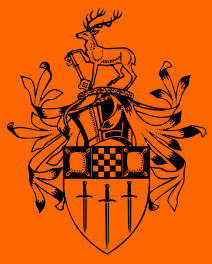
Surrey Energy Economics Centre (SEEC)

School of Economics

University of Surrey

Guildford

Surrey GU2 7XH



SURREY

ENERGY

ECONOMICS

DISCUSSION PAPER

SERIES

For further information about SEEC please go to:

www.seec.surrey.ac.uk