

# THE DYNAMICS OF CAR AVAILABILITY IN EU COUNTRIES

## – A Comparison Based on the European Household Panel Survey –

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*(Received September 5, 2008)*

This paper investigates the dynamics of car availability in EU countries. Of particular interest is the relative contribution of state dependence, heterogeneity and serial correlation. A dynamic probit model with unobservable heterogeneity is estimated using eight (1994-2001) waves of European Community Household Panel surveys. Car availability is expressed as a function of income and a number of social-demographic factors. The dynamic probit model is estimated using simulated maximum likelihood (MSL) estimation, to overcome the computational difficulties inherent in maximum likelihood estimation of models with nontrivial error structures. The results indicate that car availability is characterized by significant state dependence, unobserved heterogeneity and negative serial correlation in the error component.

**Key Words:** Car ownership, Dynamic probit, Panel data, ECHP

## 1. INTRODUCTION

This paper utilises the European Community Household Panel (ECHP) to investigate car availability in a number of European countries. The objective of the ECHP was to gain better information on household and individual income in the EU member states. The survey was instituted in 1994 by EUROSTAT in conjunction with member states and the data are collected by national statistical institutes or research centres in the individual countries. In the first wave (1994) a sample of 60,500 nationally representative households (approximately 130,000 adults aged 16 or over) were interviewed in the then 12 member states. Austria, Finland and Sweden were included from 1995, 1996 and 1997, respectively. In 1997, the original surveys were stopped in Germany, Luxembourg and the UK and comparable data derived from existing national panels.

The panel or longitudinal design of the ECHP makes it possible to follow individuals and households over consecutive years, so that information on dynamics and transitions over time can be analysed at the micro level. Since the ECHP is not primarily a transport survey, only few questions are asked relating to car ownership. These are: (1) whether the household has a car available

for private use (either privately owned or company owned); (2) if not, whether they cannot afford a car; and (3) whether they have access to a company car for private use. Questions (1) and (2) were asked in all waves and question (3) in waves 7 and 8. In addition, socio-economic, demographic and locational information is included.

In some cases, particular variables were not available for all countries or all waves. In the analyses that follow, the included countries/waves in figures and tables are limited by the information available.

The outline of the paper is as follows. The next section presents a comparison amongst countries based on national aggregation of the information in the ECHP. Section 3 compares the distribution of car availability among households with different incomes and characteristics. The volatility of car availability over time for individual households is addressed in Section 4 and the results of econometric modelling of car availability in Section 5. Section 6 concludes.

## 2. AGGREGATE COMPARISON AMONG COUNTRIES

Before considering car availability on the individual household level, it is useful to obtain a picture of over-

all car availability in the different countries. On the basis of the data from the ECHP, the percentage of households who have a car is obtained from the question "Do you have a car or van available for private use?". Since the question concerns "availability" rather than "ownership", cars not owned by the household are also included, e.g., company cars, leased or borrowed cars used by household members. The aggregate figures are shown in Table 1. The first column indicates the first and last year for which data are available from the ECHP, which are unfortunately not the same for all countries. Comparing the percent of households with access to a car in the various countries for the first and last year for which data are available shows a considerable difference between countries. It is clear, however, that the difference has declined over the period of the research. In the first year (1994) the percentage of households with access to a car varied from 49.9% in Portugal to 81.8% in Italy, a difference of 32 percentage points. By 2001, the difference was reduced to 23 percentage points: from 62.6% in Greece to 85.6% in France. In general, growth has been greatest in those countries with the lowest initial car availability levels, particularly Portugal and Greece, and only marginal in those countries with the highest car availability, i.e. Luxembourg and Italy. One country, Finland, shows a decline in availability, due, most probably, to worsening economic conditions.

As mentioned earlier, the information on car availability includes company cars available for the household's private use as well as cars owned or leased directly by the household. For waves 7 and 8, the ECHP also in-

cludes a specific question on company cars available for private use. The percentage of households with access to a company car for private use is shown in the next column for those countries for which this information is available. Relatively few households in Italy and France have company cars (less than 5%), while the greatest proportions are noted for the UK and Belgium, at 13.6% and 11% respectively. Given the high proportion of company cars in the UK, its relatively low overall car availability implies that the actual *ownership* of cars is even lower in relation to its income.

The last column shows the number of cars per 1000 inhabitants from EUROSTAT. These will obviously be different from the ECHP, as they include all cars in the country and give no indication of the distribution of ownership among individuals or households. Although Luxembourg has the greatest number of cars per capita and the greatest percentage of households with cars, and Greece has the smallest percentage for both measures, in general the relationship between cars per capita and households with access to a car is not clear cut, since multi-car ownership and the number of persons per household varies for the individual countries, as does the number of cars used solely for business purposes.

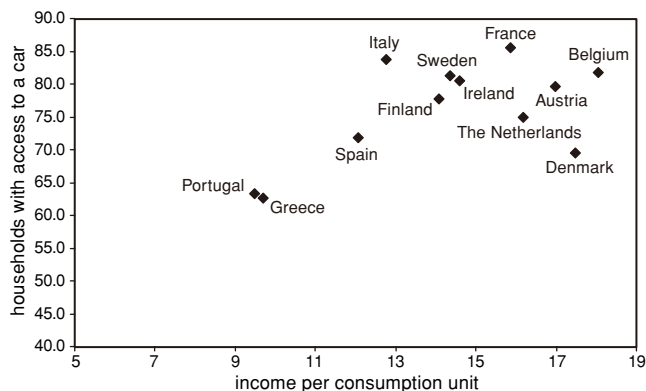
From the table, we see that according to the latest figures about 13 and 37 percent of households in the individual countries do not have a car available for their use. Much of the difference between countries can be explained by differences in income, that is, by differences in both mean income levels and in income distribution. Here we only consider mean income levels and will look

**Table 1 Car availability, ECHP and EUROSTAT**

	Period available	Percent of households with at least 1 car		Average annual percent change	Percent with company car	Cars per 1,000 inhabitants (EUROSTAT)
	First – last year	First year	Last year	First to last year	2001	2001
Austria	1995-2001	76.7	79.7	0.6	7.3	521
Belgium	1994-2001	78.2	81.8	0.6	11.0	461
Denmark	1994-2001	63.4	69.5	1.3	6.5	350
Finland	1996-2001	80.4	77.8	-0.7	5.9	417
France	1994-2001	79.9	85.6	1.0	4.8	485
Germany	1995-2001	77.7	80.6	0.6	...	539
Greece	1994-2001	55.9	62.6	1.6	...	312
Ireland	1994-2001	73.9	80.5	1.2	6.4	359
Italy	1994-2001	81.8	83.8	0.3	4.7	579
Luxembourg	1995-1999	84.7	86.2	0.4	9.2	635
Portugal	1994-2001	49.9	63.3	3.5	8.8	538
Spain	1994-2001	67.7	71.7	0.8	8.7	451
Sweden	1997-2001	80.4	81.3	0.3	...	452
The Netherlands	1994-2001	69.0	75.0	1.2	...	418
United Kingdom	1994-1999	72.2	76.6	1.2	13.6	433

at the effect of income distribution in the next section. Figure 1 shows the expected positive relationship between car availability and household income (measured in common currency units per consumption unit using the purchasing power parity and the modified OECD scale taken from the ECHP)\*. The countries with the lowest car availability also have the lowest household income (Greece and Portugal). At higher incomes, however, there is a considerable difference in car availability between countries. Italy, for example, has a relatively high car availability compared to household income, while the opposite is the case for Denmark. This is explained by the vast difference in car taxation. In 1999, car registration tax in the EU ranged from an average of €267 in Italy to €15659 in Denmark and the average annual road tax ranged from €30 per vehicle per year in Italy to €463 in Denmark. Although costs in the other countries are more comparable, there are substantial differences in car availability which are not explained by income. For instance, income is marginally higher in the Netherlands than in France, yet the proportion of households with cars is considerably higher in France.

The importance of economic factors for car availability can be seen by the number of households in the ECHP replying that they “would like a car but cannot afford one”. In 1994, 31% of Portuguese households said they could not afford a car; at the other extreme, only 3% of Italian households could not afford one. Over the period, cars have become “affordable” to many more households in Portugal, Greece, Spain, Ireland and Denmark, due to rising income and/or falling costs, while there has been little change in subjective affordability in the remaining countries (about 5% say they cannot afford a



**Fig. 1 Percentage of households with access to a car versus income per consumption unit, 2001**

\* Unfortunately, data on income do not exist for all countries for this year.

car). Still, over 10% of households in Denmark, 14% in Greece and 17% in Portugal say they cannot afford a car in 2001.

However, being unable to afford a car is not the predominant reason given for not having one. In 1994, the average proportion of households without a car who said they cannot afford one was 38%, which, for the individual countries, ranged from 19% in Italy to 63% in Portugal. Apart from Portugal, more than 50% of non-car households were “not able to afford a car” in only Greece, Spain and Ireland. In 2001, the average fell to 29%, ranging from 19% in Italy to 49% in Portugal. “Other reasons” are thus more often stated than economic reasons for not owning a car. Unfortunately, what these “other reasons” was not asked in the survey.

### 3. THE DISTRIBUTION OF CAR AVAILABILITY

This section investigates how car availability is distributed amongst different types of households. First, we consider economic circumstances. To do this, households in each country are grouped into quintiles on the basis of net household income per consumption unit. Consumption units are defined as the modified OECD scale given in the ECHP (1 for the 1<sup>st</sup> adult, 0.5 for each additional person 16 years of age and over and 0.3 for each child under 16). Incomes are measured in common currency units using the purchasing power parity exchange rates provided in the ECHP.

Car availability by income quintile for each country is shown in Tables 2 and 3 for 1994 and 2001. As expected, access to a car increases with income, although in a few countries saturation appears to be reached by the next-highest quintile (Luxembourg and the Netherlands). However, there is a considerable difference amongst countries. In 1994, car availability in the highest income quintile ranged from 81% in Greece to 96% in Luxembourg. Far fewer households in the lowest income quintile have access to a car: from 26% in Portugal to 72% in Luxembourg. A measure of the inequality in car availability amongst income groups is the coefficient of variation shown in the last column: a value of zero indicates perfect equality, while higher values denote greater inequality. Italy shows the most equitable car availability and Portugal the least equitable. Other countries showing higher than average inequality are Denmark, the UK and Greece, while France, Luxembourg and Germany display a higher than average equality. Clearly, there is a significant difference in the distribution of car availability amongst countries, which, in part, is related to differences in the

**Table 2 Percentage of households with access to a car by income quintile, 1994**

	Income Quintile					Coefficient of variation* 100	
	1	2	3	4	5	Car Access	Income
Austria (1995)	55	71	80	86	92	18.8	56.8
Belgium	57	68	84	90	92	19.6	58.5
Denmark	39	48	67	75	87	30.6	46.5
Finland (1996)	57	75	86	90	94	18.5	46.3
France	64	73	83	89	92	14.6	67.6
Germany	61	73	81	88	92	15.8	62.5
Greece	30	46	56	66	81	34.2	73.0
Ireland	50	59	78	87	93	24.9	63.3
Italy	71	74	81	89	92	11.6	63.3
Luxembourg	72	82	85	96	96	11.6	61.0
Portugal	26	27	46	67	85	51.4	81.3
Spain	56	53	66	76	87	21.0	67.3
Sweden (1997)	54	73	85	91	95	20.7	42.5
The Netherlands	45	59	76	83	83	24.5	52.2
United Kingdom	46	51	74	89	93	30.5	73.8
Mean, above countries	52	62	75	84	90	23.2	61.1

**Table 3 Percentage of households with access to a car by income quintile, 2001**

	Income Quintile					Coefficient of variation* 100	
	1	2	3	4	5	Car Access	Income
Austria	58	75	85	89	92	17.2	50.0
Belgium	61	75	84	93	95	16.9	58.4
Denmark	41	60	73	83	90	26.4	47.0
Finland	50	72	84	89	93	22.5	55.3
France	69	80	88	94	96	12.5	53.6
Greece	36	52	65	74	87	26.5	66.6
Ireland	51	71	89	94	98	24.5	61.6
Italy	73	78	84	91	94	9.1	57.6
Portugal	32	43	69	80	94	34.8	72.4
Spain	53	59	73	82	90	18.7	62.5
Sweden	52	75	87	93	94	22.5	46.6
The Netherlands	57	67	80	86	85	17.3	49.8
Mean, above countries	53	67	80	87	92	20.7	56.8

Note: Germany, Luxemburg and the UK were omitted owing to lack of data.

distribution of income itself. This can be seen in the last column of the table which shows the coefficient of variation of equivalent income for each quintile. The countries with the least equitable car availability, also have the least equitable income distribution (Portugal, Greece and the UK), while those with more equitable car availability also have a more equitable income distribution (Italy, Germany, France and Luxembourg). The Scandinavian countries are an exception: they have the greatest income equality, but equity in access to cars is lower than for countries with greater income inequality.

By 2001 (Table 3), car availability had increased in all countries for most income groups. In the highest income group, at least 90% of households had access to a car in 11 out of the 12 countries, compared to 7 of the same 12

in 1994. Access to a car increased in the lowest income quintile in all countries with the exception of Spain, Austria, Finland and Sweden, so that on average slightly over half of households in this group have access to a car. Nevertheless, there are still large differences amongst countries: only 32% of Portuguese households in the lowest income quintile have access to a car, compared to 73% of Italian households.

As in the previous table, Italy has the most equitable car access, while Portugal has the least equitable. Again, we note that countries with high car inequality generally have high income inequality, although there are exceptions. Car access has become more evenly distributed in most countries, the only exceptions being Ireland, Finland and Sweden. The latter two countries have also

witnessed an increase in income inequality over the period, whereas all other countries show the opposite trend.

As discussed earlier, “not being able to afford a car” was a major reason for not having one. As expected, the proportion of households unable to afford a car is highest for the lowest income groups. This is illustrated in Table 4. For the first year of the sample, the proportion of the lowest income quintile which cannot afford a car ranges from 6.2% in Italy to 43.2% in Portugal; for the highest income quintile the proportion ranges from 0.5% in Luxembourg to 10.7% in Greece. Of the higher income countries, the discrepancy between the highest and low-

est group is largest in the UK and Ireland. Italy shows the least difference between income groups: cars are affordable even to those with relatively low income which is reflected in the high car availability levels in this group noted earlier. Generally, cars have become affordable to a larger proportion of both income groups over the period shown. The exception is Denmark, where cars have become unaffordable for a larger proportion of low-income households, despite their increase in car availability.

Factors other than income are associated with car availability, although many of these may be related to income. In Table 5, households without access to a car are

**Table 4 Households who say they would like a car but cannot afford one**

	Years	% of households who say they cannot afford a car				
		First – Last year	First year		Last year	
			Lowest quintile	Highest quintile	Lowest quintile	Highest quintile
Austria	1995-2001	11.0	1.5	6.9	1.4	
Belgium	1994-2001	16.8	0.9	13.1	0.4	
Denmark	1994-2001	17.6	6.6	20.4	2.6	
Finland	1996-2001	14.6	1.1	11.6	0.8	
France	1994-2001	15.3	1.4	11.7	0.5	
Germany	1995	10.1	1.2	...	...	
Greece	1994-2001	33.7	10.7	21.9	5.5	
Ireland	1994-2001	26.2	3.2	14.8	0.9	
Italy	1994-2001	6.2	1.2	6.2	1.1	
Luxembourg	1995	10.9	0.5	...	...	
Portugal	1994-2001	43.2	8.6	32.4	1.4	
Spain	1994-2001	29.9	2.9	14.9	1.2	
The Netherlands	1994-2001	16.2	0.8	9.7	0.6	
United Kingdom	1994	23.0	1.4	...	...	

Note: ... data not available

**Table 5 Characteristics of households without access to a car, %, 2001**

	Single person	Woman head	1+ over 65 years	Children	None Employed	% of average income
Austria	70	50	59	11	71	72
Belgium	<b>81</b>	<b>57</b>	62	14	80	65
Denmark	77	44	30	11	<b>49</b>	70
Finland	79	48	<b>29</b>	<b>8</b>	56	64
France	81	55	58	12	75	68
Germany	67	44	49	11	67	...
Greece	47	32	62	9	65	62
Ireland	63	33	50	<b>21</b>	64	<b>51</b>
Italy	67	49	<b>72</b>	6	<b>81</b>	72
Luxembourg*	69	46	44	14	57	...
Portugal	<b>45</b>	<b>29</b>	57	16	52	<b>51</b>
Spain	52	32	62	9	73	66
Sweden	75	43	...	12	...	66
The Netherlands	64	41	36	16	<b>49</b>	<b>80</b>
United Kingdom*	71	42	51	15	68	...
Mean all households in all countries	31	14	23	30	30	...

Notes: ... denotes information not available; \* 1999

examined in terms of various socio-economic and demographic characteristics. From the first column, we see that between 45% and 81% of households without access to a car are single-person households. This is far higher than the average for all households in all countries, which is 31%, shown in the final row (for the individual countries, the average ranges from 23% in Portugal to 39% in Denmark). Non-car households are also more likely to be headed by a woman: between 29% and 57%, compared to an average for all households of only 14%. They are also more likely to be older: between 29% in Finland and 72% in Italy have one or more persons over the age of 65, compared with an average for all households of 23%. Related to this, very few households without cars have children: from 8% in Finland to 21% in Ireland, compared to an average of 30%. The relatively large proportion in Ireland is explained by the high number of households with children in Ireland, 37%. A high percentage of households without cars have no one employed (unemployed, retired, or for any other reason not working): between 49% in Denmark and the Netherlands and 81% in Italy. Italy also has the highest overall percentage of non-working households: 38%, compared to the average of 30% for all countries.

The final column shows the average income for households without cars in relation to average income for all households in each country. The difference is particularly apparent in Greece and Portugal, where households without cars have just over half of the average income. Belgium, shows the smallest difference, with 80% of the average.

The concluding table in this section (Table 6) examines car availability in by population density of the residential area of households. Generally, the results are as expected: car availability increases as population den-

sity declines. The need for a car is greater in rural areas, where the accessibility to public transport is poor. This relationship, however does not hold in the lower income countries, Greece and Portugal and in Austria. This is due to the fact that the differences in income between rural and urban inhabitants is greater in these countries, so that it is largely an income effect. A number of interesting points can be noted. We recall that car ownership was relatively low in Denmark, particularly in relation to its income level. Despite this, 92% of Danes in sparsely populated areas have access to a car – the highest of the countries for which data exist. On the other hand, only 46% of Danes living in densely populated areas have a car. We also recall that Italy had the most equitable car availability in terms of income. The same is also the case for areas of different population density: car availability in these areas differs less than in the other countries.

#### 4. VOLATILITY OF CAR AVAILABILITY

As we have seen, the number of households with access to a car has been increasing more-or-less continually over observed period in most countries. From year to year the changes are generally relatively small. However, the net changes observable on the aggregate level conceal more substantial changes on the individual household level. The net increase in car availability is composed of some households increasing the number of cars they own, and some, although fewer, households reducing the number of cars they own. As shown in Dargay et al.<sup>1</sup>, 15% of British households and 10% of French and German households change the number of cars they own between any two years. Multi-car ownership is particularly volatile, but there is also a significant number of households who give up (or loose) access to a car between any two years. The objective of this section is to examine these changes in car availability for individual households. Since the ECHP only reports whether or not a car is available, rather than the number of cars available, we can only consider households which have a car available in one year, and do not in the following year and vice versa. The overwhelming majority of households – between 92 and 98% -did not change their status as either car households or non-car households (Table 7). Since car availability was generally increasing over the period, more households became car households than vice-versa. A significant proportion, however, do give up their car, and this proportion differs amongst countries. Greece and Spain have the largest proportions (3.8% and 3.4%), while Luxembourg, Germany, France and Belgium have small-

**Table 6 Car accessibility by degree of urbanisation, %, 2001**

	Densely populated area	Intermediate populated area	Sparsely populated area
Austria	83	85	68
Belgium	78	87	87
Denmark	46	77	92
Finland	72	87	86
Greece	67	63	56
Ireland	77	75	84
Italy	83	86	82
Portugal	69	66	52
Mean, above countries	72	78	75

Note: data not available for other countries

**Table 7 Changes in car availability between two consecutive years, % of households**

	Car to No Car	No change	No Car to Car
Austria	2.1	96.0	1.9
Belgium	1.9	96.2	1.8
Denmark	2.6	94.1	3.4
Finland	2.5	94.7	2.8
France	1.9	96.0	2.1
Germany	1.7	96.4	1.9
Greece	3.8	91.8	4.4
Ireland	2.2	94.5	3.3
Italy	2.5	95.1	2.4
Luxembourg	1.1	98.0	0.9
Portugal	2.5	93.8	3.7
Spain	3.4	93.0	3.5
The Netherlands	2.2	94.8	3.0
United Kingdom	2.3	95.1	2.7

est (1.1% to 1.9%). For all other countries, the proportion is between 2 and 3%. It is difficult to explain these differences, but it may be related to income and car ownership costs in the individual countries.

Reductions in car availability can be either a temporary or a long-term phenomenon. The former implies a reduction in the number of cars for one or more years followed by an increase. An example of this could be a period of unemployment of a household member – a car is sold when the person becomes unemployed and another car is purchased when the person begins work again. Long-term reductions in car availability can be thought of as permanent. Examples are when a car driver leaves the household and takes their car with them, when people give up driving for reasons of age or health, or because they no longer need a car for travel. Unless we have information about why the number of cars has been reduced, the conclusions that we can draw concerning permanence are limited by the number of years over which the same household is observed.

Changes in car availability in the longer term are illustrated in Table 8. Only countries with data for 8 waves are included, and only households responding in all waves, so that changes in car availability over 8 years are considered. The majority of households do not change their car availability over the eight years: between 41% and 76% have access to a car for all eight years, while between 10% and 32% do not have access to a car for all eight years. As expected, the largest proportions of households having a car during all eight years are in countries with the highest car availability. The next column gives the proportion of total households who have a car in 1994 (wave one), but do not in a subsequent year and from then until 2001 (the 8<sup>th</sup> wave) remain without a car. There is

**Table 8 Changes in car availability over the longer term, % of households**

	No car all waves	Car all waves	Car to No Car	No Car to Car	Erratic
Belgium	12.8	74.8	4.0	2.4	6.0
Denmark	17.1	62.4	5.2	7.2	8.0
France	9.5	76.4	3.3	2.7	8.1
Greece	28.4	43.2	4.6	6.9	16.9
Ireland	13.1	67.8	2.5	6.1	10.5
Italy	9.5	74.0	4.2	2.5	9.8
Portugal	32.0	40.8	4.3	9.4	13.4
Spain	18.7	56.1	5.9	4.4	14.9
The Netherlands	16.7	63.0	5.6	6.5	8.3

quite a difference between countries, but there is no obvious reason for these differences. Acquisition of a car is shown in the next column. This is the proportion of total households who do not have a car in 1994, but acquire one in a later year, and keep it until 2001. The differences between households reflect their differing growth in car availability: high growth countries have higher proportions. All of the households in the first four columns have relatively stable car availability: they either have or do not have a car for all eight years, or they change from having (not having) a car to not having (having) one only once. There are, however, a number of households whose access to a car changes from year to year or every few years. These are shown in the last column, labelled “erratic”. Between 6% and 16.9% of households moved into and out of car ownership more than once over the eight years. The most erratic behaviour is noted for countries with lowest car availability.

## 5. MODELLING CAR AVAILABILITY

In order to better understand the factors determining car availability in the EU countries, dynamic probit models were estimated. In all cases, the dependent variable was set equal to 1 if the household has access to a car, and equal to 0 if they do not. The explanatory variables included were limited by the data available for the largest number of countries and waves. These are defined in Table 9. As an alternative to net income, we also use permanent income, both expressed in logarithmic form. Permanent income, of course, is an abstract concept that is impossible to measure directly. We use the King and Dicks-Mireaux<sup>2</sup> methodology, extended by Kazarian<sup>3</sup> and Ourti<sup>4</sup> in a panel context.

All variables with the exception of income are binary: equal to 1 if the condition holds and equal to 0 if it

**Table 9 Variable definitions**

Variable name	Definition
Have access to a car in (t-1)	1 or 0
Net income	Euros, in real terms, purchasing power parity logarithm
Permanent income	
3 or more adults in the household	= 1 if 3 or more adults; = 0 otherwise
Single	= 1 if single-person hh; = 0 otherwise
Child aged less than 16 (yes or no)	= 1 if children (<16); = 0 otherwise
One or more persons aged 65 or more	= 1 if 1 or more hh member 65+; = 0 otherwise
Household reference person female	= 1 if reference person woman; = 0 otherwise
Household reference person unemployed	= 1 if reference person unemployed; = 0 otherwise

does not. Since this implies perfect collinearity between groups of variables (e.g. female/male) one variable in each group is omitted from the estimation (and from the table above). This is the reference group: in this case, a 2-adult household, both under 65, with a male head, one worker and no children. The estimated coefficients of the models are interpreted in relation to this group. This definition of variables allows the coefficients of the individual variables, with the exception of income, to be compared directly. The number of observations included (households, countries and waves) in the models differs because not all variables are given for all households, all countries and all years.

The model is estimated for 10 countries for which we have sufficient data. We consider three sources of differences in car availability between countries. The *first* are differences in the characteristics of individuals in the countries. These are represented by the explanatory variables in the model. The *second* concerns differences in the response to these factors. For example, does income affect car availability to the same degree in all countries? By allowing the coefficients of each independent variable to be country-specific, such structural differences can be captured. The *third* source of variation relates to differences resulting from factors not included in the model that are the same for each individual but differ between countries. Such differences are captured in the intercept terms. If the intercept term is significantly greater for one country, individuals in that country are more likely to have access to cars despite being identical in terms of the factors included in the model, the difference being explained by omitted factors. For example, we exclude the costs of car ownership and use, which are substantially higher in some countries than in others. If this is reflected in lower car availability, the intercept terms for high-cost countries will be lower than for low-cost countries. Of course, the intercepts will also include the influence of other country-specific factors omitted from the model.

### 5.1 Dynamic panel probit model

The model that we estimate can be written in terms of latent variable,  $h_{it}^*$ :

$$h_{it}^* = x_{it}\beta + \gamma h_{it-1} + u_{it} \quad i = 1, \dots, N \text{ and } t = 1, \dots, T, \quad (1)$$

$$h_{it} = \begin{cases} 1 & \text{if } h_{it}^* > 0 \\ 0 & \text{if } h_{it}^* \leq 0 \end{cases}$$

and where  $h_{it} = 1$  if household  $i$  has a car in year  $t$  and 0 otherwise,  $x_{it}$  is a vector of observable individual characteristics and  $u_{it}$  is a random variable reflecting both non-observable individual characteristics that are constant over time and a time-varying random residual component.  $\beta$  is a vector of coefficients of the independent variables and  $\gamma$  is a parameter describing the dynamics. The heterogeneity term of equation (1) can be written  $u_{it} = \alpha_i + \varepsilon_{it}$ , where  $\alpha_i$  is a non-observable component of individual heterogeneity, here an individual specific and time-invariant random component, assumed to be distributed as  $N(0, \sigma_\alpha^2)$ .  $\varepsilon_{it}$  is a time and individual specific error term uncorrelated with  $x_{it}$  and  $\alpha_i$  and across individuals, but which may be serially correlated. In particular, we consider that the error process may be of the AR(1) form:  $\varepsilon_{it} = \rho \varepsilon_{it-1} + \eta_{it}$ , where,  $\eta_{it}$  is assumed to be independently and identically distributed as  $N(0, \sigma_\eta^2)$ .

The parameter  $\gamma$  represents true state dependence in car availability. A positive  $\gamma$  implies that car availability in the previous period increases the likelihood of availability in the current period. The term  $\alpha_i$  is a source of spurious serial correlation attributable to permanent unobserved differences across individuals in earnings potential and tastes.

Because at each period, the endogenous variable is binary, some assumptions have to be made in order to assure the identification of the model. Thus we assume:  $\sigma_\eta^2 + \sigma_\varepsilon^2 = 1$  and  $\text{var}(u_{i0}) = \sigma_\theta^2 = 1$ .

### 5.2 Heckman approach

Estimation of the nonlinear random effects model in (1) requires specification of the distributional proper-

ties of  $\alpha_i$  and  $\varepsilon_{it}$ , their statistical relationship to the regressors, and the initial conditions for the dynamic process. Common approaches to the initial conditions are either to assume that  $h_{i0}$  is exogeneous and can be treated as fixed<sup>5-8</sup> or that the process generating  $h_{it}$  is in equilibrium at the beginning of the sample period. Neither assumption is satisfactory<sup>9</sup>. Heckman<sup>6-8</sup> and Wooldridge<sup>10</sup> describe two approaches to handle the problem. In this paper, we follow the Heckman approach<sup>6-8</sup>. The Heckman approach is to approximate the reduced form of the marginal probability of the initial observed outcome using a probit model while allowing the error terms in the initial period to be freely correlated with the error terms in all periods\*. The regressors in this model are the exogenous variables in the first period with no restrictions imposed on the parameters of the first period index function and that of later periods. The likelihood function to be maximized is then constructed as the product of the first period marginal probability and the joint probability of the future value conditional of the first observation.

**5.3 Estimation method**

For each year and each individual, we observe car availability,  $h_{it} = 0$  or 1. The probability of observing the sequence  $h_{i1}, h_{i2}, \dots, h_{iT}$  for a particular individual  $i$  is:

$$\int_{a_{i0}}^{b_0} \int_{a_{i1}}^{b_1} \dots \int_{a_{iT}}^{b_T} \phi(u_{i0}, u_{i1}, \dots, u_{iT}; \Omega) du_{i0}, du_{i1}, \dots, du_{iT} \quad (2)$$

where  $u_{it} \sim N(0, \Omega)$  and  $\phi$  is the normal probability density function with zero mean and variance one and with:

$$\begin{aligned} a_{it} &= -\infty \text{ if } h_{it} = 0 \\ b_{it} &= -x'_{it} \beta \text{ if } h_{it} = 0 \text{ and } 1 \leq t \leq T \\ b_{i0} &= -x'_{i0} \beta_0 \text{ if } h_{i0} = 0 \end{aligned}$$

and

$$\begin{aligned} a_{it} &= -x'_{it} \beta \text{ if } h_{it} = 1 \text{ and } 1 \leq t \leq T \\ a_{i0} &= -x'_{i0} \beta_0 \text{ if } h_{i0} = 1 \\ b_{it} &= +\infty \text{ if } h_{it} = 1 \end{aligned}$$

So the likelihood function is:

$$L(\theta) = \prod_{i=1}^n L_i(\theta) \quad (3)$$

To estimate this model, we use the maximum simulated likelihood. Simulation-based estimation procedures replace functions which are computationally intractable using numerical or analytical methods, by random approximations (simulators) for these functions. The simulators are generally sample averages obtained by drawing pseudo-random samples from an appropriate distribution

and evaluating a known function of these sample points. Maximum simulated likelihood has been used in the context of the binary panel probit model by Keane<sup>11</sup> and Hyslop<sup>12</sup>. These studies provide support for the use of this approach. Maximum simulated likelihood is a conceptually simple extension of maximum likelihood estimation: instead of forming the log-likelihood through analytical or numerical methods, the log-likelihood is simulated and then maximized to obtain maximum simulated estimators of the model parameters. Implementation of simulated maximum likelihood estimation requires a simulator for the probabilities that enter the log-likelihood function. There are many alternatives available for the simulation of multivariate normal rectangle probabilities<sup>13,14</sup>. In this study, we use SRC\*\* (GHK)\*\*\* simulator.

**5.4 Results**

The model was estimated for each of 10 countries separately. The remaining countries did not have adequate data or a sufficient number of time periods. The included variables are described in Table 9, with separate models estimated for net income and permanent income. Car availability in the previous period is significant and positive for all countries and both income measures. This is the case even though we have accounted for unobserved heterogeneity, so the strong persistence in car availability is not related to unobserved differences between households, or what Heckman<sup>8</sup> calls “spurious state dependence”.

Permanent income gives better results than net income for all countries with the exception of Greece, as the likelihood values are greater for the former specification. However, the estimated coefficients of the other variables are similar using both income measures, so only the results using permanent income are presented in Table 10. As expected, the intercept term is significant for all countries, but the magnitudes differ substantially, from 0.28 in Greece to 2.90 in Denmark. These differences reflect differences between the countries which are not captured by the explanatory variables.

As expected, income has a significant positive influence on car availability in all countries, with the exception of Greece and Spain. For most of the other countries, the coefficient lies in a narrow interval of 0.12 to 0.26. The notable exceptions are Denmark and Belgium which are 0.77 and 0.54, respectively. It is difficult to explain this since Belgium has a relatively high car availability

\* The variance of the error term in the initial period is also restricted to equal one.

\*\* For details, see Hyslop (1999) page 1288-1290.

\*\*\* Geweke-Hajivassiliou-Keane.

Table 10 Estimated coefficients

	Intercept	Car (t-1)	Income*	3+ Adults	Single	Child	65+	Female	Unemployed
Belgium	<b>2.82</b>	<b>1.00</b>	<b>0.54</b>	<b>0.29</b>	<b>-0.30</b>	0.07	0	<b>-0.34</b>	<b>-0.22</b>
Denmark	<b>2.9</b>	<b>1.80</b>	<b>0.77</b>	<b>0.47</b>	<b>-0.52</b>	0.13	0.16	<b>-0.36</b>	-0.15
France	<b>0.76</b>	<b>2.24</b>	<b>0.19</b>	-0.04	<b>-0.56</b>	0.08	<b>-0.12</b>	<b>-0.12</b>	0
Greece	<b>0.28</b>	<b>1.09</b>	-0.02	-0.06	<b>-0.39</b>	-0.01	<b>-0.16</b>	-0.07	<b>-0.18</b>
Ireland	<b>1.39</b>	<b>0.94</b>	<b>0.18</b>	0	<b>-0.30</b>	0.04	0.21	-0.02	<b>-0.35</b>
Italy	<b>2.47</b>	<b>1.13</b>	<b>0.12</b>	0.03	<b>-0.53</b>	0.11	0.01	<b>-0.20</b>	<b>-0.16</b>
Portugal	<b>0.31</b>	<b>1.53</b>	<b>0.12</b>	<b>0.10</b>	<b>-0.28</b>	0.05	<b>-0.21</b>	<b>-0.12</b>	<b>-0.20</b>
Spain	<b>0.92</b>	<b>0.94</b>	0.04	-0.02	<b>-0.44</b>	0.07	-0.08	<b>-0.28</b>	-0.03
The Netherlands	<b>1.20</b>	<b>1.33</b>	<b>0.25</b>	0.11	<b>-0.44</b>	0.05	0.04	<b>-0.10</b>	-0.09
United Kingdom	<b>1.11</b>	<b>2.28</b>	<b>0.26</b>	<b>0.27</b>	<b>-0.27</b>	<b>0.3</b>	<b>0.36</b>	-0.08	na

\* Permanent income; **bold**: significant at the 5% level; **bold italic**: significant at the 1% level

and Denmark's is comparatively low. There appears to be no relationship between the magnitude of the coefficient and income level, so there is no evidence of declining income elasticity.

The next two columns give the impact of the number of adults in the household on car availability. Households with more than two adults are more likely to own a car than households with 2 adults only in four countries: Belgium, Denmark, Portugal and the UK, while the other countries show no significant difference between households with 2 adults and those with more adults. Single-adult households, however, are much less likely to have a car than are households with 2 adults. The coefficient for "single" is negative and significant for all countries. The coefficient ranges from -0.27 in the UK to -0.56 in France. Recall that these effects are measured holding the other variables in the model constant, so the lower likelihood of single-adult households having access to a car is irrespective of income.

Further, we see that having children has no significant effect on car availability except in the UK where households with children are *ceteris paribus* more likely to have a car than households without children. Having a household member of retirement age (65+) has a significant effect on car availability only in four countries. In Greece, France and Portugal, the probability of owning a car is reduced, while in the UK it increases. Having a woman as the reference person in the household reduces car availability in all countries, and in 7 of the 10 countries, the effect is statistically significant. The interpretation of this depends on the definition of reference person. It is likely that a female is named reference person mainly in single-adult households, so a likely interpretation is that a female single-adult household is less likely to have a car than a male single-adult household. In addition, more single-parent households are headed by women than by men. Interestingly, gender does not seem to mat-

ter in some countries.

Finally, as expected, households where the reference person is unemployed are less likely to have a car than are households where the reference person is employed (or retired). The coefficient is statistically significant in about half of the countries.

Table 11 reports the estimates of unobserved heterogeneity and correlation. The significance of  $\sigma_{\alpha}^2$  for all countries but the UK shows that unobserved heterogeneity is important, so that omitting it would have biased the estimates of state dependence. The negative value of  $\rho$ , the autocorrelation of the error term, is also significant for all countries but the UK. The relatively small negative values indicate that the effects of transitory shocks are oscillatory but converge to zero very rapidly\*. Lastly,  $\rho_0$ , the correlation between the error term of the initial period and the error terms of other periods is significant and positive for all countries.

Table 11 Estimated parameters – heterogeneity and correlation coefficients

	$\sigma_{\alpha}^2$	$\rho$	$\rho_0$
Belgium	<b>0.67</b>	<b>-0.35</b>	<b>0.75</b>
Denmark	<b>0.47</b>	<b>-0.15</b>	<b>0.56</b>
France	<b>0.18</b>	<b>-0.42</b>	<b>0.36</b>
Greece	<b>0.59</b>	<b>-0.28</b>	<b>0.68</b>
Ireland	<b>0.68</b>	<b>-0.26</b>	<b>0.77</b>
Italy	<b>0.52</b>	<b>-0.3</b>	<b>0.57</b>
Portugal	<b>0.49</b>	<b>-0.24</b>	<b>0.63</b>
Spain	<b>0.62</b>	<b>-0.25</b>	<b>0.71</b>
The Netherlands	<b>0.6</b>	<b>-0.17</b>	<b>0.62</b>
United Kingdom	0	-0.08	<b>0.15</b>

**bold**: significant at the 5% level

\* Following Greene<sup>15</sup> (page 258) the autocorrelations between  $\varepsilon_{it}$  and  $\varepsilon_{it-s}$  are  $Corr[\varepsilon_{it}, \varepsilon_{it-s}] = E[\varepsilon_{it}, \varepsilon_{it-s}] = \frac{\rho\sigma_{\varepsilon}^2}{1-\rho^2}$ . With the stationarity assumption, the autocorrelations fade over time. Depending on the sign of  $\rho$ , they will either be declining in geometric progression or alternating in sign if  $\rho$  is negative.

## 6. CONCLUSIONS

Although the ECHP provides only limited information on car availability, it gives a basis for comparing a number of countries on an individual household level. The aggregate analysis revealed considerable differences in access to cars among countries, differences, which, however, have reduced over the years as incomes rose. Indeed, the share of households who say they cannot afford a car is declining over time in all countries, but, nevertheless, car access is still distributed very unevenly amongst income groups. In the different countries, between 85% (Netherlands) and 98% (Ireland) of the households in the highest income quintile have access to a car in 2001. The percentage ranges from 32% (Portugal) to 73 (Italy) in the lowest income quintile. These differences are likely due to differences in motoring costs and income in the individual countries. In 2001, only 6.2% of households without a car in the lowest income quintile in Italy said they could not afford one, whereas in Denmark, a country with a higher per capita income, the comparable figure is 20.4%, clearly reflecting the exceptionally high car taxation in Denmark.

By examining the extent to which car availability changes from year to year for individual households we find that car availability is quite volatile, but not equally so in all countries. Between 1% (Luxemburg) and nearly 4% (Greece) of households give up their cars between any 2 consecutive years. Over the longer term (7 years) the proportion increases to from 2.5% and nearly 6%. Many households, between 8% and 17%, go from having a car to not having one or vice-versa many times over the years observed, with the most erratic behaviour noted for the countries with lowest car availability and income.

Econometric modelling of car access was conducted for the 10 countries for which data were available from 1994 to 2001. The goal was not to characterize the aggregate level of motorization by country, but rather to highlight, for all or some countries, determinants of changing household motorization status. These models thus provide complementary results to aggregate analysis. While taking into account the effects of contextual and time changes, the dynamic modelling over 8 years allows us to highlight inertia (importance of the past in car dependency), as well as to estimate longitudinal elasticities.

The results obtained show that state dependence is important in determining car availability, even after controlling for heterogeneity. For all countries, access to a car increases with income, with the greatest impact noted in the lower income countries, thus corroborating the ag-

gregate results. We also find that car availability is lower for households with a single adult than for households with 2 adults or more, and it is lower for households where the reference person is a woman. Households where the reference person is unemployed or which include pensioners are also less-likely to own a car than other households, but not in all countries, and having children under 17 increases car availability only in the UK.

This paper represents a first attempt to analyze car availability on the basis of the ECHP and further work will concentrate on the developing the econometric modelling. The inclusion of cost data would be a particularly important improvement.

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## ACKNOWLEDGEMENTS

Financial support from the Agence de l'Environnement et de la Maîtrise de l'Energie of France is gratefully acknowledged. The ECPH data were made available through EUROSTAT. Neither bear any responsibility for the analyses and interpretations presented here. We are very grateful to J-L Madre, R. Collet and J-M. Etienne. We are also thankful to A. Dupont for her proof-reading.