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Changes in car ownership due to life events: Insights from the UK Longitudinal Survey

Cristian Domarchi • C.A.Domarchi2@Newcastle.ac.uk
Elisabetta Cherchi • Elisabetta.Cherchi@Newcastle.ac.uk

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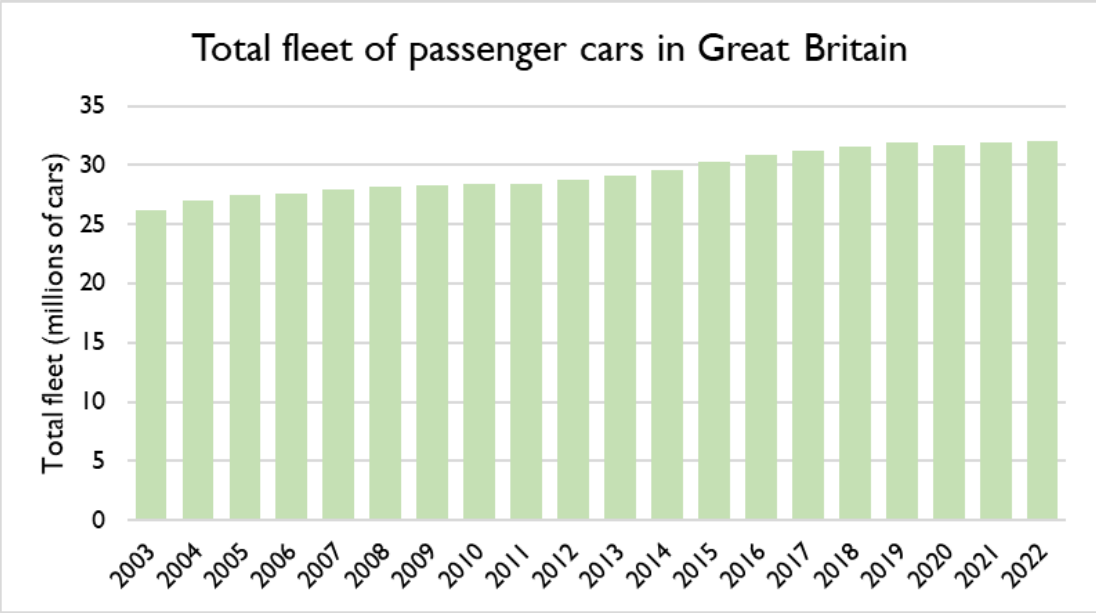
Context

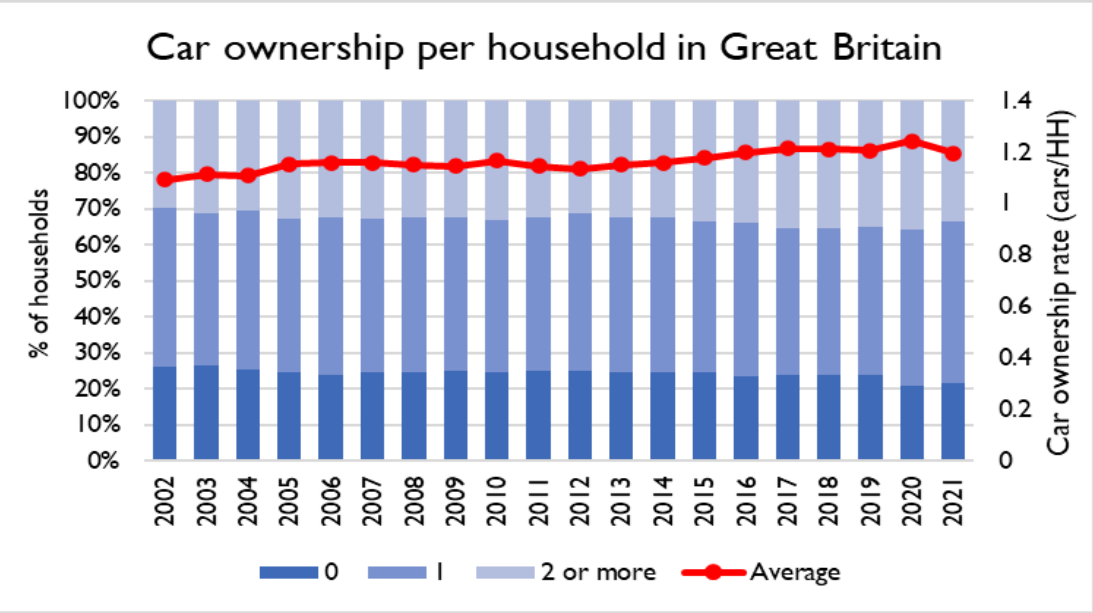
- Licensed vehicles at the end of each year in Great Britain:



Mean annual increase (last 10 years): 1.1%

Source: Department for Transport (2023)

- Number of cars per household per year in Great Britain:



Mean annual increase (last 10 years): 0.4%

Source: Department for Transport (2023)

Context

- Household vehicle ownership is a key variable for transportation analysis and planning:
  - **Car ownership state models** (reviews: de Jong et al., 2004 and Anowar et al., 2014).
  - **Car ownership state change models:**
    - Dedicated retrospective surveys (Oakil et al., 2014; Zhang et al., 2014; Wang et al., 2018; Guo et al., 2019) – small sample sizes, detailed information, respondent memory might play a role.
    - Nationwide household surveys (Prillwitz et al., 2006; Clark et al., 2014; 2016) – large sample sizes, (not always) detailed information, memory is not important.
  - A longitudinal approach is required, as car ownership depends on **life events**; e.g., childbirth, changes in household structure, changes in income.

Aims and contribution

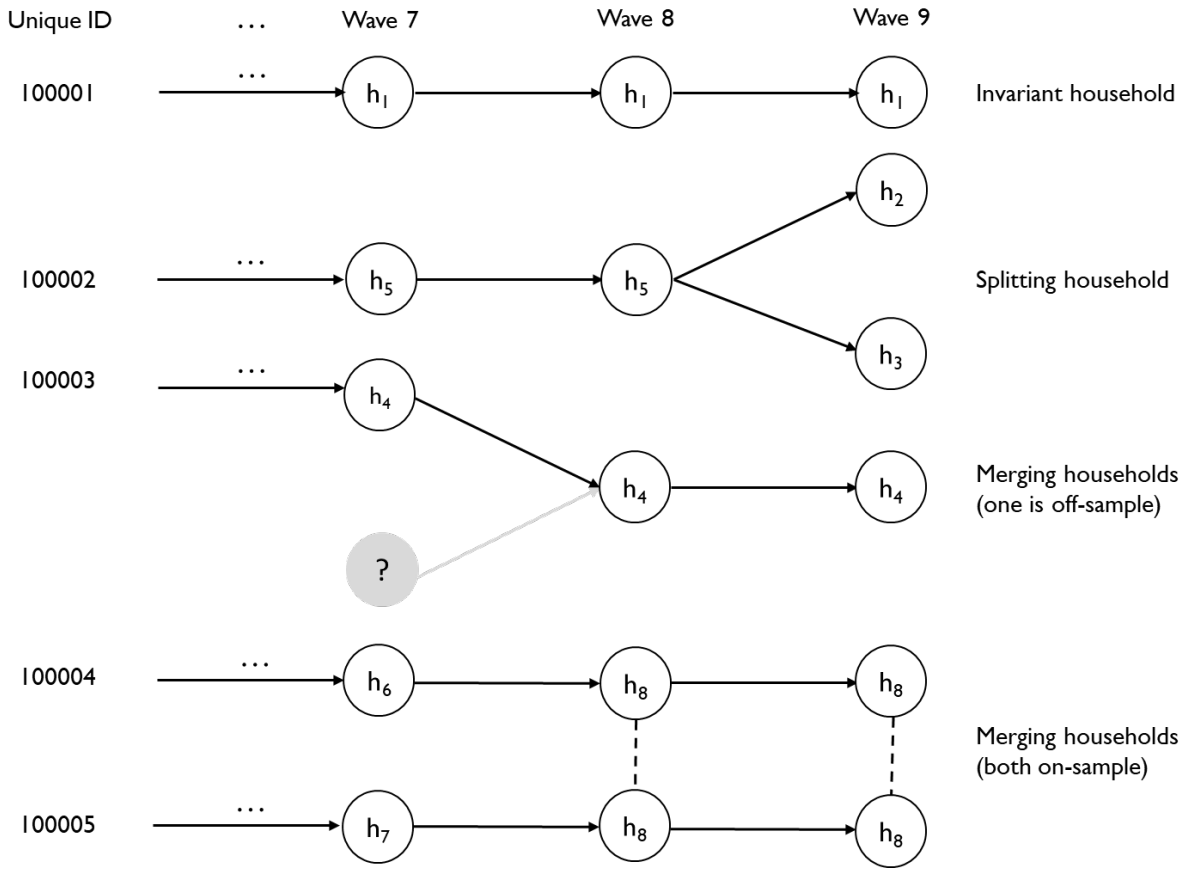
- In the present study…
  - We model the decision of **increasing or decreasing the number of vehicles in the household**…
  - …using a **discrete choice model** accounting for **household and personal life events**…
  - …estimated with a large sample from 8 waves (years) of data from a **nationwide household panel survey in the UK**…
  - …considering **car ownership level-specific effects** and **baseline** conditions…
  - …including **panel and dynamic effects**… and
  - …using a **holdout dataset for validation**.

Data

- The **Understanding Society Survey (USS)** (University of Essex *et al.*, 2020), a UK-based household longitudinal survey collecting social, economic and behavioural information.
- The survey is collected in *waves*, with each wave roughly equivalent to one year.
- Only some waves include transport-specific information.
- Every individual over the age of 16 in the household responds to the interview.
- **Individuals (not households)** are followed over waves.

Data

- A household panel was built from the individual-level "*longitudinal teaching dataset*" (University of Essex and Institute for Social and Economic Research, 2021).



Data

- Inter-wave life events – for households and individuals.

Dimension	Life event	Inter-wave period							Sample Average
		2 (2010-12)	3 (2011-13)	4 (2012-14)	5 (2013-15)	6 (2014-16)	7 (2015-17)	8 (2016-18)	
Household level – % *of households per wave*									
Car ownership change	Lost one car	7.3	7.4	8.0	7.2	5.4	6.9	6.4	**7.0**
	Lost two or more cars	1.0	0.9	1.0	1.0	0.7	1.1	0.8	**1.0**
	Gained one car	7.7	7.0	6.5	7.1	8.5	6.9	8.1	**7.4**
	Gained more than one car	0.7	0.7	0.8	0.7	1.4	0.7	0.7	**0.8**
Change in number of adults	Lost one adult	5.2	4.9	4.8	4.6	5.1	4.5	4.4	**4.8**
	Lost two or more adults	1.5	0.9	1.0	0.8	0.8	0.8	0.8	**0.9**
	Gained one adult	5.5	5.6	5.4	5.2	4.9	4.8	4.8	**5.2**
	Gained two or more adults	0.4	0.5	0.4	0.5	0.5	0.4	0.3	**0.4**
Residential relocation	Address move (total)	1.6	2.1	2.3	3.4	3.1	2.8	2.5	**2.5**
	Long distance move	0.8	0.7	1.0	1.0	0.9	0.8	0.6	**0.8**
	Urban to rural move	0.4	0.6	0.5	0.7	0.7	0.6	0.6	**0.6**
	Rural to urban move	0.4	0.4	0.5	0.4	0.4	0.4	0.3	**0.4**
Individual level – % *of individuals per wave*									
Personal life	Gained partner	1.0	1.0	0.9	1.1	1.0	0.7	0.5	**0.9**
	Lost partner	1.8	1.5	1.0	1.2	1.0	1.0	0.9	**1.2**
	Child born	2.9	2.8	2.6	2.4	2.0	1.4	1.6	**2.3**
Employment	Enter employment	4.3	3.7	3.6	3.3	3.2	2.7	2.3	**3.3**
	Exit employment	3.1	2.7	2.3	2.1	2.2	2.0	2.0	**2.3**
	Retired	1.7	2.0	1.8	1.7	1.8	1.8	1.8	**1.8**
	Employment switch	4.6	4.3	4.8	4.9	4.9	4.8	4.7	**4.7**
Transport	Driving licence acquisition	1.4	0.8	0.7	0.6	0.5	0.5	0.4	**0.7**
Total number of households		**9,814**	**9,870**	**9,927**	**9,958**	**9,992**	**10,021**	**10,049**	

- 51% of households *never* change their number of car holdings during the survey period.
- For households *<u>with</u>* car ownership changes (increases <u>or</u> decreases), these happen, on average, every 3.9 years.

Data

- Car ownership levels – Summary:

Wave t	Next wave $t+1$						Total	Fraction Increasing	Fraction Decreasing
	No car	1 car	2 cars	3 cars	4 cars	5+ cars			
No car	15.8%	1.3%	0.1%	0.0%	0.0%	0.0%	17.2%	8.5%	–
1 car	1.4%	40.1%	3.4%	0.3%	0.0%	0.0%	45.2%	8.2%	3.0%
2 cars	0.1%	3.6%	23.9%	1.6%	0.2%	0.0%	29.4%	6.1%	12.6%
3 cars	0.0%	0.3%	1.7%	3.4%	0.4%	0.1%	6.0%	8.9%	34.6%
4 cars	0.0%	0.0%	0.2%	0.5%	0.7%	0.1%	1.6%	9.5%	46.4%
5+ cars	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.6%	–	48.4%
Total	17.3%	45.4%	29.4%	5.8%	1.5%	0.6%	100.0%	–	–

In 83.8% of the observations in the dataset, car ownership level remains unchanged.

Modelling framework

- Car ownership state change is modelled as a **discrete choice**.
- During each inter-wave period, the household faces three alternatives:
  - Keeping the number of vehicles in the household constant ($j = 0$).
  - Buying one or more additional vehicles ($j = 1$).
  - Discarding one or more vehicles ($j = 2$).

Modelling framework

- Systematic utility specifications:

Alternative	Utility function
Keep $(j = 0)$	$V_{0ht} = 0$
Increase $(j = 1)$	$V_{1ht} = \alpha_1 + \sum_{k=1}^{K} \beta_{1k} \cdot X_{kht} + \sum_{l=1}^{L} \theta_{1l} \cdot Y_{lh}$
Decrease $(j = 2)$	$V_{2ht} = \alpha_2 + \sum_{k=1}^{K} \beta_{2k} \cdot X_{kht} + \sum_{l=1}^{L} \theta_{2l} \cdot Y_{lh}$

j: alternative
h: household
k: inter-wave life event
l: baseline attribute
t: wave

Baseline coefficients, to be estimated.

Life-events coefficients, to be estimated. They are assumed to have the following form:

$$\beta_{jk} = \beta_{jk}^{[1]} + \beta_{jk}^{[0]} \cdot N_{h(t-1)}^{[0]} + \beta_{jk}^{[2]} \cdot N_{h(t-1)}^{[2]}$$

- $N_{h(t-1)}^{[C]}$ equals 1 if household h had C cars during wave $(t-1)$
- $\beta_{2k}^{[0]} = 0 \; \forall k$ (carless households cannot choose to discard a car)

Modelling framework

- Net utilities –

Model 1 (Panel):

$$U_{jht} = V_{jht} + \lambda_{jn} + \varepsilon_{jht}$$

Direct utility: V_{jht} — Logit error term: ε_{jht} — Panel effect: λ_{jn}

Direct utility	As previously described
Panel effect	$\lambda_{jn} = \sigma_j \eta_h$ • η_h are error components distributed Normal $(0,1)$. • σ_j are J coefficients to be estimated $(J = 3)$.
Logit error term	IID Extreme Value 1

Modelling framework

- Net utilities –

Model 2 (Panel + Dynamic):

$$U_{jht} = V_{jht} + \lambda_{jn} + \rho y_{jh,t-1} + \varepsilon_{jht}$$

Direct utility — Panel effect — Previous choice effect — Logit error term

Direct utility	As previously described
Previous choice effect	• $y_{jh,t-1}$: dummy variable, equals 1 when household h chooses alternative j at time $t-1$. • ρ: Coefficient to be estimated Adding this term introduces **endogeneity** to the specification.
Panel effect	To address the endogeneity, this term is modelled as: $\lambda_{jn} = \sigma_j \eta_h + \gamma \cdot y_{jh2} + \tau \cdot y_{jht}{}^{count}$ (Woolridge, 2005; Danalet et al., 2016): • y_{jh2}: the initial choice of household h (between waves 1 and 2). • $y_{jht}{}^{count}$: the count of previous choices of alternative j before time t (not including t). • As before, η_h are error components distributed Normal $(0,1)$. • σ_j, γ, τ: Coefficients to be estimated
Logit error term	IID Extreme Value 1

Results – General model fit and validation

Dimension	Indicator	Model 1	Model 1 (*Restricted*)	Model 2
Level-of-fit (80% estimation dataset)	Number of observations	48,930	41,838	41,838
	Log-likelihood (*)	-22,001	-18,779	-18,383
	AIC	44,162	37,720	36,916
	BIC	44,866	38,419	37,564
	Adjusted rho (Market shares)	0.157	0.148	0.163
Validation (20% holdout dataset)	AIC	19,500	16,804	16,234
	BIC	20,143	17,434	16,865
	Adjusted rho (Market shares)	0.151	0.132	0.164
	First percentage recovery	84.2%	84.3%	84.3%

Model 1 structure estimated with Model 2 dataset (without first choice)

Results

Attribute	Effect	Model 2			
		1: Increase		2: Decrease	
		Coef.	T-test	Coef.	T-test
Constant		-3.503	-22.66	-1.933	-11.67
Household size					
Adult number increase	*Base*	0.888	10.00	-0.676	-7.60
	+ 0 car HH	-0.548	-3.49	–	–
	+ 2 car HH	-0.554	-4.82	-1.329	-11.53
Residential relocation					
Household move	*Base*	0.517	3.93	–	–
	+ 2 car HH	-0.924	-3.93	–	–
+ Urban to rural move	*Base*	0.918	4.29	–	–
+ Rural to urban move	*Base*	–	–	1.102	4.21
+ Long move	*Base*	0.287	1.49	0.703	3.64
Household split	*Base*	–	–	0.386	1.59
Personal life					
Partner gain	*Base*	1.848	12.98	–	–
	+ 2 car HH	-1.762	-5.82	–	–
Partner loss	*Base*	–	–	0.525	6.16
New born child	*Base*	0.391	4.39	-0.737	-3.51
	+ 2 car HH	-1.180	-5.81	0.699	3.02
Employment					
Enter employment	*Base*	0.645	6.77	–	–
	+ 2 car HH	-0.911	-5.87	–	–
Exit employment	*Base*	–	–	0.321	3.17
Retired	*Base*	–	–	0.318	3.10
Switch employment	*Base*	0.609	7.04	-1.230	-5.62
	+ 2 car HH	-0.722	-5.85	1.560	6.72
Transport					
Licence acquisition	*Base*	1.109	6.55	–	–
	+ 0 car HH	1.292	4.72	–	–
Income level					
Income increase	*Base*	0.074	9.59	–	–
Income decrease	*Base*	–	–	0.051	5.61

Likelihood of buying one or more additional cars *Increases with:*	**Likelihood of discarding one or more cars *Increases with:***
Increased number of adults*	Decreased number of adults*
Residential relocation* (especially urban to rural and long distance)	Residential relocation (especially rural to urban, long distance, and household splits)
A childbirth occurs*	-
A member of the household: • Starts living with a partner*. • Enters or switches employment* • Acquires a driving licence*. • Experiences an income increase.	A member of the household: • Stops living with a partner. • Exits employment, retires, or switches jobs*. • Experiences an income decrease.

**Effects differ with current car ownership level.*

Results

- A simple illustrative example, focused on some "interesting" **baseline** cases.

$$Increase = \frac{P(j = 2|event)}{P(j = 2|no\ event)} \qquad Decrease = \frac{P(j = 2|event)}{P(j = 2|no\ event)}$$

$P(.)$ are the mean predicted probabilities.

Event	Unipersonal HH		2 adults + 1 kid HH		Car-less HH		HH w/2 or more cars	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
Residential relocation	**2.7**	1.1	1.8	0.9	**2.2**	**2.3**	1.5	1.3
Urban to rural relocation	**5.7**	1.1	**2.8**	1.0	**6.7**	**3.8**	**2.3**	1.1
Rural to urban relocation	**2.2**	**2.3**	1.7	1.4	1.2	**8.7**	0.8	0.9
Childbirth	1.3	0.9	1.0	1.1	**2.2**	1.0	0.8	1.2
Enter employment	1.8	1.2	1.3	1.0	**2.1**	1.2	1.2	1.1
Switch employment	**2.3**	1.1	1.2	1.0	**2.3**	1.5	1.2	1.4
Retire	1.0	1.7	0.8	0.8	0.8	1.0	0.8	1.3
Partner gain	**8.8**	**0.3**	**4.3**	**0.1**	**5.7**	0.5	**3.3**	1.3
Partner lost	0.6	**5.5**	0.6	**2.6**	**1.3**	**4.5**	0.8	**2.3**

**Cases when one probability is at least twice the other are highlighted.*

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Income level					
Income increase	*Base*	0.074	9.59	–	–
Income decrease	*Base*	–	–	0.051	5.61

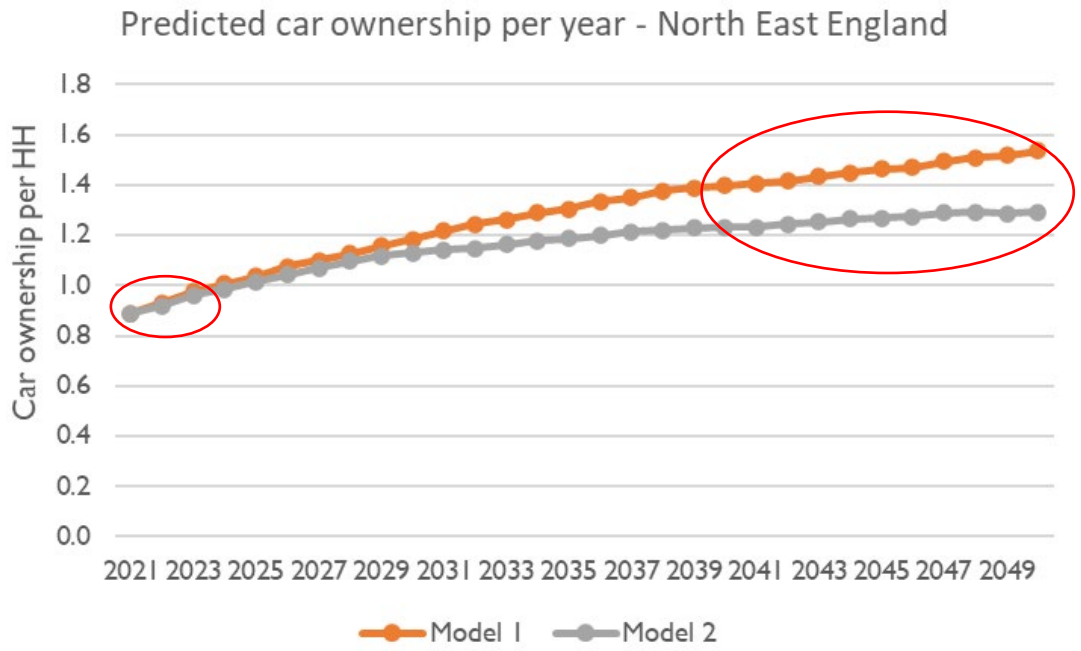
- Panel and dynamic terms:

Attribute	Model 2	
	Coef.	T-Test
Panel effect - Reference alternative	1.635	42.51
Panel effect - Increase	0.010	0.62
Panel effect - Decrease	-0.012	-1.61
Previous choice	-0.879	-13.25
First choice	-0.368	-6.65
Choice frequency	-0.803	-17.21

- Panel effect is significant for the reference alternative.
- All dynamic coefficients are significant, and their net effect is towards "stability": changing CO level is less likely if a change was previously made:
  - In the previous period.
  - In the first period.
  - Over several periods in the past.

Forecasts

- Long term prediction with an **external sample** of 2,493 households from the North East region of England (sourced from the National Travel Survey).
- Explanatory variables were predicted assuming they keep their current trends.



- Initial forecasts are similar.
- Long-term forecasts differ significantly.
- Predicted annual increases in car ownership for the region:

Model 1	Model 2	Historic (2013-2021)
2.43%	1.51%	1.54%

Conclusions

- The study illustrates the effects of life events in changes in car ownership.
- The chosen model represents a contribution as it simultaneously addresses:
  - Increases *and* decreases in car ownership level;
  - Preference heterogeneity due to *current* car ownership levels and baseline effects;
  - Dynamic effects (crucial for long-term forecasting).
- **Future work**:
  - Vehicle replacements, attitudes, spatial attributes and other information missing from the dataset?
  - Joint forecast of independent variables?

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Elisabetta Cherchi • Elisabetta.Cherchi@Newcastle.ac.uk

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