The effects of car sharing on car ownership: a pseudo-panel approach

Jan-Jelle Witte

KiM Netherlands Institute for Transport Policy Analysis, The Hague, The Netherlands

Maarten Kroesen

Faculty of Technology, Policy and Management, TU Delft, The Netherlands

Abstract

Car sharing is frequently promoted as a means to reduce private car ownership, yet empirical evidence on its actual effects remains mixed. This study examines the relationship between car sharing and household car ownership using a pseudo-panel approach based on four waves (2022–2025) of the Dutch Landelijk Reizigersonderzoek (LRO). A first-order Markov transition model is estimated to capture both baseline car ownership and changes over time, while accounting for state dependence and observed heterogeneity. The results indicate that car sharing adoption is associated with lower baseline levels of car ownership. At the same time, adopters exhibit substantially higher transition rates in car ownership compared to non-adopters. Importantly, the direction of these transitions depends on initial car ownership. Among multi-car households, car sharing is associated with a higher likelihood of reducing the number of cars, whereas among car-free and single-car households it is associated with an increased likelihood of acquiring cars. Distinguishing between Business-to-Consumer (B2C) and Peer-to-Peer (P2P) car sharing reveals heterogeneous effects, with B2C car sharing showing stronger associations with both upward and downward transitions. These findings suggest that car sharing does not uniformly substitute for private car ownership, but rather contributes to increased volatility in car ownership trajectories.

Key-words: car sharing, car ownership, pseudo panel, Markov model

1. Introduction

In recent years, car sharing has emerged as a prominent element in strategies aimed at promoting more sustainable mobility systems. By enabling access to vehicles without the need for ownership, car sharing is expected to reduce the number of privately owned cars, thereby contributing to lower emissions, reduced congestion, and more efficient use of urban space (Shaheen & Cohen, 2013; Nijland & van Meerkerk, 2017). Consequently, many European governments, including the Netherlands, have incorporated shared mobility into transport and spatial planning policies.

Despite these expectations, empirical evidence on the effects of car sharing on car ownership remains inconclusive. While several studies report reductions in car ownership among users of car sharing services (Cervero and Tsai, 2004), others suggest more nuanced outcomes, including limited or even positive effects on ownership (Witte et al., 2024). A key challenge in this literature is the difficulty of establishing causal effects. Individuals who adopt car sharing may differ systematically from non-adopters, for example in terms of preferences, residential location, or initial car ownership levels, leading to potential selection bias.

Furthermore, car ownership is known to exhibit strong persistence over time due to high acquisition costs, habitual behaviour, and its embeddedness in daily activity patterns (Nolan, 2010). This implies that changes in car ownership are relatively rare and may depend on specific life events or contextual factors. As such, the impact of car sharing is likely to be conditional and heterogeneous rather than uniform across households.

This study contributes to the literature by examining how car sharing is associated with changes in car ownership over time. Using repeated cross-sectional data with retrospective information, a pseudo-panel is constructed and analysed using a Markov transition model. This approach explicitly accounts for state dependence in car ownership and allows for the identification of changes between two time points. Importantly, the analysis allows for interaction effects between car sharing adoption and initial car ownership, thereby capturing potential heterogeneity in effects. In doing so, the study aims to assess whether car sharing acts as a substitute for, or complement to, private car ownership.

2. Literature Review

A substantial body of literature has examined the relationship between car sharing and car ownership. Early contributions, often based on operator data or before–after surveys, suggest that participation in car sharing leads to reductions in private car ownership. For example, Martin et al. (2010) report that members of car sharing programs in North America reduce their vehicle holdings following adoption. Similar findings have been reported in European contexts (Nijland & van Meerkerk, 2017), reinforcing the view that car sharing can act as a substitute for private vehicles.

However, these findings have been subject to several critiques. A primary concern relates to self-selection bias: individuals who choose to participate in car sharing are typically already predisposed towards lower levels of car ownership and car use (Cervero et al., 2007; Becker et al., 2017). As a result, observed differences between users and non-users may not reflect causal effects. More recent studies employing longitudinal or aggregate (e.g. city-level) research designs highlight the importance of accounting for such selection effects and often find more modest impacts (Becker et al., 2018; Kolleck, 2021).

In addition, car ownership is characterized by strong inertia. Longitudinal analyses demonstrate that household car ownership exhibits high levels of stability over time, with relatively few transitions between ownership states (Nolan, 2010). This persistence is driven by financial commitments, habitual behaviour, and the role of the car in enabling daily activities. Consequently, any effect of car sharing on car ownership is likely to manifest through gradual adjustments rather than immediate changes.

Recent research further suggests that the effects of car sharing are heterogeneous. For multi-car households, car sharing may provide a viable alternative to owning a second or third car, thereby facilitating car shedding (Burghard & Dütschke, 2019). Conversely, for households without a car, car sharing may increase familiarity with car use and potentially lower the threshold for acquiring a private vehicle (Witte et al., 2024). This dual role implies that car sharing can function both as a substitute and as a complement to car ownership.

Finally, different forms of car sharing may have distinct impacts. Business-to-Consumer (B2C) systems, characterized by professionally managed fleets and high spatial availability, may support more frequent use and integration into daily mobility patterns. Peer-to-Peer (P2P) systems, in contrast, are

typically used more occasionally and may serve different user segments (Becker et al., 2017). Empirical evidence comparing these modalities remains limited.

In summary, the literature points to three key challenges: (1) disentangling causal effects from selection effects, (2) accounting for the strong persistence in car ownership, and (3) capturing heterogeneity in effects across households and car sharing types. The present study addresses these challenges by employing a pseudo-panel approach combined with a transition modelling framework.

3. Method

3.1 Statistical model

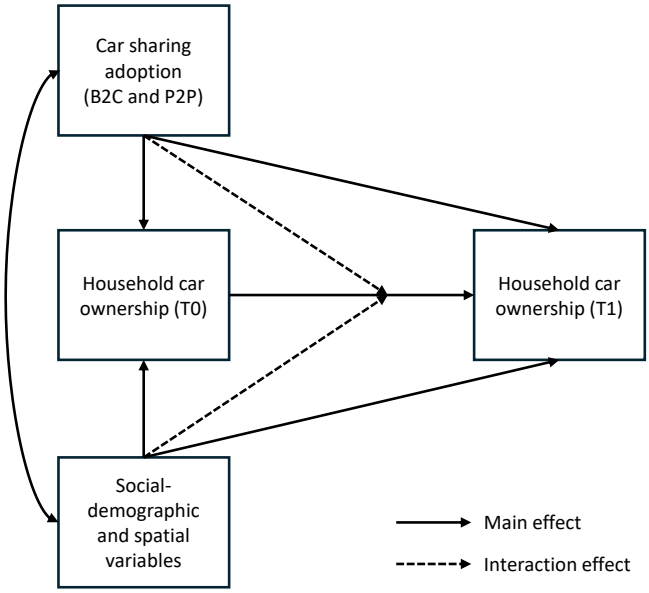
Figure 1 presents the developed statistical model. The model assumes that household car ownership at the current time point (t1) is influenced by car ownership at an earlier time point (t0). Evidence from panel studies shows that car ownership is highly stable over time, which provides theoretical support for this relationship.

The model further assumes that car sharing affects both baseline car ownership and future car ownership. The first relationship captures pre-existing causal links between car ownership and the adoption of car sharing. For instance, households with fewer cars may be more likely to adopt car sharing in the first place. By accounting for this initial overlap, the estimated relationship between car sharing adoption and car ownership at t1 reflects changes in car ownership between t0 and t1 that are associated with car sharing adoption.

This structure allows the analysis to meet an important criterion for causal inference, namely time precedence, whereby the cause precedes the effect in time. It should be noted, however, that reverse causality cannot be fully ruled out. Changes in car ownership may still influence the decision to adopt car sharing. Moreover, the model captures effects only within the observation window of the survey, which in this study spans one year (from t0 to t1). These limitations are discussed further in the discussion section.

In addition to the main effects, the model allows for interactions between car sharing adoption and initial car ownership. Rather than assuming a uniform effect of car sharing on car ownership, we hypothesize that its effects depend on the household's initial number of cars. This approach makes it possible to identify both negative and positive effects. For example, households that adopt car sharing while owning no car at t0 may be more likely to transition to owning one or two cars compared to non-adopters; for these households car sharing may function as a steppingstone to car ownership. Households with 1 or more cars, on the other hand, may be more inclined to shed a car.

Finally, car sharing adoption and (changes in) car ownership may be influenced by possible common variables that need to be controlled for. For example, higher educated people may be more inclined to adopt car sharing while also owning more cars (on average). In addition to level of education, we included age and household composition (with partner and/or children) as relevant control variables. Next to personal characteristics, variables related to the built environment can be considered as relevant confounding factors. For example, the supply of shared cars is generally higher in denser regions, while car ownership generally decreases with increasing density. Next to density, we included public transport accessibility as a second potential confounding factor.



3.2 Data

This study uses data from the Landelijk Reizigersonderzoek (LRO), a large-scale, nationally representative survey on travel behaviour in the Netherlands. The LRO has been conducted annually since 2019 on behalf of the Dutch Ministry of Infrastructure and Water Management and is designed to monitor trends and changes in mobility, with a particular focus on commuting and work-related travel. The survey captures travel behaviour across all trip purposes, including commuting, business travel, and social-recreational travel, and links observed changes to autonomous developments, life events, employer policies, and transport system characteristics.

The LRO follows a repeated cross-sectional design with retrospective elements. Respondents report their current travel behaviour as well as their travel behaviour in the previous year, allowing for the analysis of year-to-year changes at the individual level. The questionnaire consists of a stable core that is largely unchanged across years covering travel patterns, modal choice, home and work locations, parking, teleworking, motivations and barriers.

Data collection is carried out online. In 2022, 2023, 2024 and2025, the survey achieved a net sample of 12,750, 14,966, 12,080 and 12,605 respondents respectively, after extensive data cleaning procedures, including the removal of speeders and straightliners and corrections for inconsistent responses and non-locatable postcodes. The empirical analyses presented in this study are based on a pooled dataset combining these two LRO waves, yielding 52,401 respondents in total.

Table 1 presents an overview of the sample composition in terms of social-demographic characteristics and the two spatial variables considered in the analysis. As explained in the previous section, these variables will also be used as control variables in the estimated transition model.

Table 1. Sample descriptives of social-demographic and spatial variables (N=52,401)

Variable	Category	Percentage
Age	18 t/m 30	15.7
	31 t/m 45	24.5
	46 t/m 65	35.3
	66+	24.5
	Missing	0.0
Level of education	Low	29.2
	Medium	25.8
	High	44.5
	Missing	0.5
Living situation	Living with partner without children	39.8
	Living with children (with or without partner)	28.1
	Living as single (with or without children) or other	30.4
	Missing	1.7
Level of urbanity	Not urbanised (<500 addresses per km2)	6.9
	Lightly urbanised (500 to 1.000 addresses per km2)	20.7
	Moderately urbanised (1.000 to 1.500 addresses per km2)	15.5
	Strongly urbanised (1.500 to 2.500 addresses perkm2)	30.7
	Extremely urbanised (>2.500 addresses per km2)	26.0
	Missing	0.2
Distance to transtration > 10 km	No	84.8
	Yes	14.2
	Missing	1.1

3.3 Dependent and independent variables

As discussed earlier, the main dependent variable, car ownership, is measured at the household level. Current car ownership as well as car ownership (exactly) one year earlier is measured (the latter retrospectively). Table 2 presents a cross-tabulation of both variables, indicating the transitions in car ownership over time.

As expected, car ownership levels are quite stable with most households reporting no change in car ownership from the previous year. In addition, changes towards fewer cars are slightly more prevalent than changes towards more cars. For example, only few households transition from 0 to 2 or 3+ cars (9 and 2 respondents respectively), while quite a number transition from 2 or 3+ to 0 cars (193 and 67 respondents respectively).

Table 2. Transitions in car ownership over time

		Number of cars at time of the survey (t1)				
Number of cars one year earlier (t0)		**0 cars**	**1 car**	**2 cars**	**3 or more cars**	**Total**
0 cars	Frequency	6,275	397	16	2	6,690
	Percentage	93.8	5.9	0.2	0.0	12.8
1 car	Frequency	821	28,273	998	38	30,130
	Percentage	2.7	93.8	3.3	0.1	57.5
2 cars	Frequency	193	1059	11,869	385	13,506
	Percentage	1.4	7.8	87.9	2.9	25.8
3 or more cars	Frequency	67	63	195	1,750	2,075
	Percentage	3.2	3.0	9.4	84.3	4.0
Total	Frequency	7,356	29,792	13,078	2,175	52,401
	Percentage	14.0	56.9	25.0	4.2	100.0

The main independent variable(s), car sharing adoption, is measured with multiple questions that measure the adoption of different forms of car sharing. In the present study we consider the two main forms of car sharing, namely Business-to-Consumer (B2C) car sharing, e.g. Greenwheels, MyWheels, ShareNow and Sixt Share, and Peer-to-Peer (P2P) car sharing, e.g. Snappcar. Respondents were asked whether they had used these forms of car sharing *in the past 3 years*.

Table 2 presents the cross-tabulation between the two types of car sharing. The results show that the forms are dependent on each other (as also indicated by a significant chi-squared test, χ^2=1814.7, df=1, p<0.001), if a person made use of B2C car sharing the probability is substantially higher (15.1% compared to 1.6%) that this person also engaged in P2P car sharing. Still, the groups that only make use of one form of car sharing and not the other are substantial in size, and larger than the group that uses both forms.

Table 3. Adoption of B2C and P2P car sharing

			Adopted P2P car sharing		
			No	**Yes**	**Total**
Adopted B2C car sharing	No	Frequency	49,276	827	50,103
		Percentage	94.0	1.6	95.6
	Yes	Frequency	1,951	347	2,298
		Percentage	84.9	15.1	4.4
Total		Frequency	51,227	1,174	52,401
		Percentage	97.8	2.2	100.0

In the analysis two separate models are estimated, one in which we include a combined dummy variable indicating 0 when one a person has adopted neither types of car sharing and 1 when the person has adopted at least one type, and a second model in which we include both types of car sharing as separate dummy variables.

3.4 Model specification and estimation

The model in Figure 1 is estimated as standard Markov model in which the states are measured without measurement error. The model simultaneously captures the effects of the explanatory variables on initial and future car ownership, while also accounting for the state dependency in car ownership (i.e. the first-order Markov assumption). To give maximum flexibility to the model, car ownership is treated as a nominal outcome (instead of an ordinal or count variable), and so all relationships in the model are estimated using logistic regression functions. The models are estimated using Latent Gold 6.1.

4. Results

Table 4 presents the logit coefficients and associated Wald test statistics of the estimated Markov model. All explanatory variables significantly influence car ownership at t0 and t1, except for public transport accessibility, for which the effect on car ownership at t1 does not reach non-significance. This means that the explanatory variables can explain differences in initial car ownership as well as changes in car ownership over time.

Turning first to the effects on car ownership at t1, the adoption of car sharing is associated with a higher probability of owning zero cars, and decreases the chances of owning 1, 2 or 3 or more cars. As discussed in section 3.1, this association has likely resulted from causal effects operating in both directions, i.e. people who engage in car sharing may have shredded a car in the past or people with a low number of cars may be more inclined to adopt car sharing (to satisfy their mobility needs).

The effects of the other explanatory/control variables are also intuitively plausible. Increasing age is associated with a higher probability of having 1 car (compared to zero), but decreases the probability of owning 2 or 3 or more cars, indicating that people at older ages are less likely to have more than 1 car. Higher education and living with either partner and/or children are associated with higher probabilities of owning 1 car or more. Finally, increasing urban density increases the likelihood of owning zero cars, while households living further away from a train station generally have higher chances of owning 1 car or more.

While these effects on car ownership at t0 are already interesting, the primary findings relate to the effects of the explanatory variable on car ownership at t1. As discussed in section 3.1 these effects are interacted with initial car ownership, allowing us to separately identify the effects of the explanatory variables on each cell in the transition matrix (i.e. each transition combination). To ease interpretation, Latent Gold uses a so-called transition logit specification, in which the logit related to the probability of staying in the same class is treated as the reference and fixed to zero. Hence, positive logits indicate that people are more likely to switch to a different class, while negative logits indicate that people are more likely to stay in the same class.

Again, turning first to the effects of car sharing adoption, it can be observed that, with one exception (the transition from 2 to 3 cars), the logits are all positive, indicating that car sharing adoption generally increases the probability of switching to another class compared to remaining in the same class. Hence, people engaged in car sharing and owning zero cars, are more likely to switch to owning 1, 2 or 3 or more cars, and, similarly, those owning one car are also more likely to switch to 2 or 3 or more cars. Compared to non-adopters, the transition from 2 to 3 or more cars becomes less likely among adopters, indicating that for households with two cars car sharing can ‘prevent’ the purchase of a third car. The logits in the lower left triangle are also all positive, indicating that households who adopted

car sharing are more likely to shed a car compared to non-adopters. In general, the expectation that car sharing has both positive and negative effects on car ownership is confirmed.

The effects of the other variables on changes in car ownership are generally in line with the effects on baseline car ownership. For example, being higher educated and living with either partner and/or children increases the likelihood of switching to higher car ownership levels, while decreasing the likelihood of switching to lower car ownership levels. Increasing urbanity, on the other hand, is associated with lower chances of switching to states with more cars, and higher chances of switching to states with fewer cars.

Table 4. Logit coefficients and Wald test statistics of the Markov model

		Car ownership at t0			
		0 cars (ref.)	**1**	**2**	**3+**
Intercept (Wald=303.1, df=3, p<0.001)		0	1.672	1.389	0.917
Shared car user (Wald=341.5, df=3, p<0.001)		0	-0.747	-1.265	-0.856
Age (Wald=1443.0, df=3, p<0.001)		0	0.012	-0.015	-0.012
Level of education (Wald=128.0, df=3, p<0.001)		0	0.053	0.128	0.071
Living with partner without children (Wald=3796.2, df=3, p<0.001)		0	1.399	2.788	1.449
Living with children (Wald=4724.4, df=3, p<0.001)		0	1.805	3.511	2.781
Level of urbanity (Wald=2058.6, df=3, p<0.001)		0	-0.455	-0.715	-0.844
Distance to train station > 10 km (Wald=62.1, df=3, p<0.001)		0	0.257	0.426	0.505
		Car ownership at t1			
	Car ownership at t0	**0**	**1**	**2**	**3+**
Intercept (Wald=350,8, df=12, p<0.001)	0	0	-1.191	-1.586	-21.756
	1	-1.644	0	-1.663	-4.338
	2	-1.448	-2.494	0	-1.276
	3+	-0.850	-3.687	-1.836	0
Shared car user (Wald=313,5, df=12, p<0.001)	0	0	0.480	0.509	1.808
	1	1.190	0	0.321	1.158
	2	1.942	0.676	0	-0.311
	3+	2.145	1.030	0.348	0
Age (Wald=754, df=12, p<0.001)	0	0	-0.044	-0.114	-0.025
	1	-0.020	0	-0.051	-0.042
	2	-0.041	0.010	0	-0.011
	3+	-0.071	-0.034	-0.022	0
Level of education (Wald=170,2, df=12, p<0.001)	0	0	0.152	0.328	2.279
	1	-0.236	0	0.056	-0.148
	2	-0.245	-0.014	0	-0.061
	3+	-0.263	0.258	0.018	0
Living with partner without children (Wald=534,1, df=12, p<0.001)	0	0	1.354	1.672	2.574
	1	-0.710	0	1.122	0.273
	2	-1.304	-0.860	0	-1.945
	3+	-0.393	-0.939	0.896	0
Living with children (Wald=498,9, df=12, p<0.001)	0	0	1.058	1.282	2.000
	1	-0.606	0	1.330	1.732
	2	-0.963	-1.084	0	-0.753
	3+	0.909	-1.214	0.338	0
Level of urbanity (Wald=165,5, df=12, p<0.001)	0	0	-0.309	-0.819	-0.817
	1	0.183	0	-0.163	-0.148
	2	0.289	0.148	0	-0.101
	3+	0.312	0.238	0.046	0
Distance to train station > 10 km (Wald=12, df=12, p=0.45)	0	0	-0.579	0.238	2.957
	1	0.123	0	-0.040	0.385
	2	-0.089	-0.103	0	-0.148
	3+	-0.242	-0.015	-0.183	0

To provide a more intuitive picture of how car sharing affects (changes in) car ownership, we can use the model to compute baseline and transition probabilities for those who adopted car sharing and those who did not, while holding all other covariates at their mean values. Table 5 presents these probabilities.

In line with expectations, car sharing is associated with lower baseline car ownership; people who adopted car sharing have a higher probability of owning zero cars (16.1%) than people who did not adopt car sharing (7.5%). Reversely, the probability of owning 2 cars among adopters (14.7%) is much lower compared to non-adopters (24.2%).

While controlling for the association on baseline car ownership, the transition probabilities show how car sharing influences changes in car ownership over time. The results show strong persistence in car ownership between t0 and t1, but the degree of stability differs markedly between non-adopters and adopters of car sharing. In all cases, most households remain in the same car-ownership category, confirming the well-known inertia in car ownership decisions. However, adopters of car sharing display substantially higher transition rates—both upward and downward—than non-adopters.

For households that did not adopt car sharing, car ownership is highly stable; 0-car households are very persistent: 94.7% remain car-free, and only 5.2% acquire one car. 1-car households show the highest stability overall, with 95.3% remaining in the same category. 2-car households are also largely stable (87.0%), with limited downward movement to one car (9.4%) and small upward movement to three or more cars (2.9%). Households with three or more cars remain in this category in 88.7% of cases, with modest reductions to two cars (8.6%). Overall, transitions are rare and, when they occur, typically involve small changes between adjacent ownership levels. This pattern reflects strong path dependence in car ownership among non-adopters.

Households that adopted car sharing show noticeably more mobility in car ownership: 0-car households are less stable than among non-adopters: 91.7% remain car-free, while 8.2% move to owning one car. 1-car households are also less stable, with only 89.9% remaining in the same category and a higher likelihood of both shedding their car (6.6%) or increasing ownership (3.2%). 2-car households exhibit substantial downward mobility: 16.3% reduce to one car and 4.9% to zero cars, compared to much lower rates among non-adopters. However, the probability of switching to 3 cars is lower, indicating that car sharing forestalls the purchase of an extra car for 2-car households. Households with three or more cars are considerably more likely to downsize, with 10.7% moving to two cars and 4.6% to one car and 6.2% to no car at all.

Comparing the two transition matrices suggests that car sharing adoption is associated with greater volatility in car ownership over the one-year period. Downward transitions (car shedding) are consistently more common among adopters, especially for households with two or more cars. Upward transitions are also more frequent among adopters, notably from zero to one car, suggesting that car sharing may sometimes function as a complement to car ownership rather than a pure substitute.

Taken together, these patterns imply that car sharing does not have a uniform effect on car ownership. Instead, its association with car ownership transitions depends on the household's initial number of cars. While car sharing appears to facilitate car reduction among multi-car households, it may simultaneously act as a prelude to car ownership for car-free households and increasing car ownership

for 1-car households. This heterogeneity underscores the importance of modeling interaction effects between car sharing adoption and initial car ownership.

Table 5. Baseline and transition probabilities of (non-)adopters of car sharing

			Car ownership at t1			
	Car ownership at t0		**0**	**1**	**2**	**3+**
Non-adopters	0	7.5	94.7	5.2	0.1	0.0
	1	64.3	2.1	95.3	2.5	0.1
	2	24.2	0.8	9.4	87.0	2.9
	3+	4.0	0.8	1.9	8.6	88.7
	Car ownership at t0		**0**	**1**	**2**	**3+**
Adopters	0	16.1	91.7	8.2	0.1	0.0
	1	65.5	6.6	89.9	3.2	0.3
	2	14.7	4.9	16.3	77.0	1.9
	3+	3.7	6.2	4.6	10.7	78.4

Tables 6 and 7 respectively present the logit coefficients and the baseline/transition probabilities of the second model in which we used separate dummies for B2C and P2P car sharing adoption. Both dummies significantly influence the baseline and transition probabilities. Interestingly, the association between B2C car sharing and initial car ownership is much stronger than the association between P2P car sharing and initial car ownership. People only engaged in P2P car sharing have only slightly lower car ownership levels compared to non-adopters.

In addition, while both B2C and P2P car sharing have independent effects on the transition probabilities, the pattern of effects is different. B2C car sharing positively influences transitions from lower to higher car-states, but this is much less the case for P2P car sharing. B2C seems to act more as a steppingstone to private car ownership than P2P car sharing. In addition, the reverse effect of B2C car sharing on the transition from 2 to 1 car is stronger than the respective effect of P2P car sharing on this transition probability. P2P car sharing, on the other hand, seems to induce more extreme transitions from 3 or more cars to 1 car or zero cars and from 2 cars to zero cars.

Table 6. Logit coefficients and Wald test statistics associated with B2C and P2P car sharing

		Car ownership at t0			
		0 (ref.)	**1**	**2**	**3+**
Adopted B2C car sharing (Wald=405.6, df=3, p<0.001)		0.000	-0.943	-1.546	-1.405
Adopted P2P car sharing (Wald=15.5, df=3, p=0.002)		0.000	-0.017	-0.145	0.402
		Car ownership at t1			
	Car ownership at t0	**0**	**1**	**2**	**3+**
Adopted B2C car sharing (Wald=96.6, df=12, p<0.001)	0	0	0.431	0.676	2.026
	1	0.940	0	0.232	1.128
	2	0.948	0.667	0	0.089
	3+	1.026	0.319	0.548	0
Adopted P2P car sharing (Wald=152.8, df=12, p<0.001)	0	0	0.101	0.053	-3.433
	1	0.981	0	0.421	0.697
	2	1.812	0.363	0	-1.107
	3+	2.060	1.017	0.066	0

Note: only the logit coefficients related to car sharing are reported. The other estimates do not deviate strongly from those presented in table 4.

Table 7. Baseline and transition probabilities of B2C and P2P car sharing adoption

			Car ownership at t1			
	Car ownership at t0		**0**	**1**	**2**	**3+**
Non-adopters	0	7.5	94.7	5.2	0.1	0.0
	1	64.2	2.1	95.3	2.5	0.1
	2	24.2	0.8	9.4	87.0	2.9
	3+	4	0.8	1.9	8.6	88.7
	Car ownership at t0		**0**	**1**	**2**	**3+**
Adopted B2C car sharing	0	19.4	92.0	7.9	0.1	0.0
	1	64.7	5.3	91.4	3.0	0.3
	2	13.4	1.9	16.5	78.7	2.9
	3+	2.6	2.2	2.4	13.6	81.8
	Car ownership at t0		**0**	**1**	**2**	**3+**
Adopted P2P car sharing	0	7.7	94.2	5.8	0.1	0.0
	1	64.7	5.5	90.7	3.6	0.2
	2	21.5	4.8	12.6	81.7	0.9
	3+	6.2	6.1	4.8	8.3	80.8

5. Conclusion and discussion

This study examined the relationship between car sharing and household car ownership using a pseudo-panel approach and a Markov transition model. The results confirm the strong persistence of car ownership over time, consistent with previous research. At the same time, car sharing adoption is associated with significantly higher transition rates between ownership states, indicating increased dynamics in car ownership trajectories.

Importantly, the findings reveal that the effects of car sharing are heterogeneous and depend on initial car ownership levels. Among households with multiple cars, car sharing is associated with a higher likelihood of reducing car ownership, supporting its role as a substitute for private vehicles. In contrast, among car-free and single-car households, car sharing is associated with an increased likelihood of acquiring cars, suggesting that it may also function as a complement or steppingstone to ownership. These results help reconcile previously conflicting findings in the literature by demonstrating that both substitution and complementarity effects can occur simultaneously.

The distinction between B2C and P2P car sharing provides further insight. B2C car sharing appears to have a broader impact, being associated with both upward and downward transitions in car ownership. P2P car sharing, on the other hand, is more strongly associated with reductions among households with higher levels of car ownership. This suggests that different car sharing modalities may serve different roles within the mobility system.

Several limitations should be acknowledged. First, although the modelling approach accounts for time precedence and baseline differences, reverse causality cannot be fully ruled out. Second, the analysis is limited to a one-year observation window, which may not capture longer-term behavioural adjustments. Third, unobserved factors, such as attitudes and preferences, may still influence both car sharing adoption and car ownership decisions.

From a policy perspective, the findings suggest that car sharing should not be viewed as a uniform solution for reducing car ownership. Its effects are contingent on household characteristics and initial conditions. Policies aiming to reduce car ownership may therefore benefit from targeting multi-car households and combining car sharing with complementary measures, such as improvements in public transport accessibility.

Future research could extend this analysis by incorporating longer time horizons, richer behavioural variables, and more detailed measures of car sharing use intensity. In particular, examining how life events and residential context interact with car sharing adoption may provide further insight into the mechanisms underlying changes in car ownership.

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