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Assessing one-way carsharing's impacts on vehicle ownership: Evidence from Shanghai with an international comparison

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ABSTRACT

Carsharing is considered an important alternative to the private car. Based on the studies in Europe and North America, it is agreed that carsharing can reduce private car ownership. However, due to the differences in the development stages and characteristics of cities and transportation, it is unknown whether carsharing can also decrease car ownership in China, which results in a gap in the evaluation of carsharing in China. This paper takes the carsharing project EVCARD in Shanghai as an example. Based on survey data on vehicle ownership from users and actual operations data, the impacts of carsharing on selling cars, giving up and delaying purchasing a car in Shanghai are quantitatively analyzed. The results in Shanghai are compared with the relevant research results in different cities around the world. The results show that: (1) the carsharing project in Shanghai also has the benefit of reducing private car ownership. Each carsharing vehicle can replace 4.56 private cars. However, unlike in European and North American cities, Shanghai carsharing mainly suppresses vehicle growth by reducing individual willingness to buy a car, because the proportion of cars sold owing to carsharing is obviously lower than in Europe and North America. (2) For giving up car purchases, carsharing mainly suppresses the first car in the family. (3) Good public transport and carsharing services can substantially improve the substitution benefits of carsharing for private cars. If carsharing can reach the service level of "whenever and wherever carsharing is available", the proportion of users who sell, give up and delay buying cars will increase from 0.78%, 30% and 31% to 12%, 40% and 47% respectively. The findings in the study provide a quantitative basis for assessing the carsharing benefits on the reduction of vehicle ownership in China, and also provide a useful reference for evaluating carsharing benefits in other developing countries.

1. Introduction

With the popularization of mobile Internet technology and smart phones, an innovative travel mode - carsharing is developing rapidly all over the world. Charging users by minutes or hours and using online platforms to implement self-service, such as

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reservation, picking-up, returning and payment, carsharing changes the relationship between people and car from "owning – private" to "sharing – public". Meanwhile, carsharing avoids expensive and complicated insurance, maintenance and parking problems of private cars. It is considered a powerful alternative to private cars, and can reduce car ownership. Many studies in Europe and North America have confirmed that carsharing has a substitution effect on private cars (see the literature review below for details).

The carsharing in China started late but has developed rapidly. Since the first carsharing project "Fun car sharing" was launched in Hangzhou, China in 2011, more than 100 companies have offered carsharing, with nearly 130,000 operating vehicles and more than 8 million registered members. Unlike countries in Europe and North America, China is still in the period of rapid car ownership growth. There are widespread doubts about whether the development of carsharing in China can also reduce car ownership there. The "Guideline on Promoting the Healthy Development of Passenger Car Rental" (hereinafter referred to as the Guideline) jointly issued by the Ministry of Transport and the Ministry of Housing and Urban-Rural Development of China in 2017 clearly states that "Carsharing helps to reduce the willingness of individuals to purchase cars, and to a certain extent relieve the rapid growth of urban private car ownership and the use of road and parking resources" (Ministry of Transport of the People's Republic of China, 2017). However, due to the lack of enough empirical research, the size of the substitution effect of carsharing, if any, on private car ownership is still uncertain for China. Some cities (such as Shanghai, Shenzhen, etc.) have stopped issuing carsharing vehicle operation licenses in recent years.

To clarify whether the development of carsharing in China can produce positive benefits, such as reducing individual car purchases and decreasing car ownership, it is urgent to conduct empirical research on the impact of carsharing on car ownership based on the carsharing projects already in operation. In this context, this paper is based on Shanghai and China's largest electric carsharing firm. Based on the actual operation data of this firm and survey data focusing on user vehicle purchase intention, the substitution effect of carsharing on the private car is quantitatively evaluated in terms of vehicles sold, vehicle purchases foregone and delayed vehicles purchased. The key influencing factors are identified. The relevant results in European and North America are compared to reveal the differences in substitution benefits of carsharing on car ownership under different social environments and different stages of transportation development.

The structure of the paper is as follows: The first part discusses the research background and practical needs; The second part reviews the relevant research results and clarifies the focus and significance of this study; The third part describes the method of data collection and analysis; The fourth part analyzes the substitution effect of carsharing on the private car and identifies the key influences. The fifth part presents the international comparison of the results and policy implications. Finally, the conclusions and outlook of this paper are discussed.

2. Literature review

The direct impact of carsharing on urban transportation systems is mainly reflected in four aspects: (1) the impact on household car ownership, (2) the impact on vehicle use intensity, (3) the impact on mode choice, (4) the impact on vehicle energy consumption and emissions. Among them, the impact on household car ownership is the core indicator for evaluating the benefits of carsharing, and it is also an important decision-making factor for governments to promote the development of carsharing, thus it has attracted widespread attention from researchers.

Carsharing developed early in Europe and North America, and the relevant research results are also the most abundant there. Millard-Ball summarized 30 studies (15 in Europe and 15 in North America) on the effect of carsharing on car ownership before 2005 (Millard-Ball, 2005), and pointed out that in Europe 22% of users on average sold vehicles because of carsharing, 22% giving up purchasing a private vehicle, and each carsharing vehicle replacing 4 private cars (without considering the abandoning purchase effect). While in North America, 20% of users sold vehicles because of carsharing, 41% giving up a purchase, and each carsharing vehicle replacing 5 cars (without considering the abandoning purchase effect). Millard-Ball also conducted a survey on 1,340 carsharing members in North America and found that 11.3% of users would sell their cars because of carsharing and 49.6% of users would sell their family's second car. It was also found that 70.5% of users would postpone buying cars and that each carsharing vehicle does replace 14.9 private cars. Later, Martin and Shaheen conducted a survey of 6,281 members in 10 carsharing operators in North America (Martin et al., 2010). They found that 22% of members sold their cars because of carsharing, and 25% of the members gave up a purchase. One carsharing vehicle replaced 9–13 private cars. During 2014–2015, Martin and Shaheen also surveyed on 7,346 Car2go carsharing members in 5 cities in North America (Martin and Shaheen, 2016), and pointed out that between 2% and 5% of the car2go population sold a vehicle due to car2go and 7% to 10% of respondents (aggregate results) did not acquire a vehicle. One Car2go vehicle replaced 7–11 private cars. More studies focus on a single city. Cervero et al. conducted a survey in San Francisco, which showed 29.1% of participants sold their cars because of carsharing and 67.5% gave up buying a car owing to carsharing (Cervero and Tsai, 2004). Each carsharing vehicle replaced 6.8 cars. For cities in Canada, a survey in Quebec, 2010 found 41.2% of users could dispose a car and 72% postponed their buying (Trépanier et al., 2013). The rate of vehicles replaced by carsharing is 18. Another study in Vancouver explored the impacts of membership in different carsharing service types on vehicle ownership, which found round-trip carsharing members were five times more likely to reduce car ownership compared to free-floating carsharing users (Namazu and Dowlatabadi, 2018).

Loose summarized the development of carsharing in Europe in 2010 (Loose, 2010). Through a survey on 34 carsharing operators, it was found that each carsharing vehicle replaced an average of 7 private cars. Louvet conducted national carsharing surveys in France in 2012 and 2016 respectively (Louvet, 2017), pointing out that the number of private cars replaced by a carsharing vehicle in France increased from 6 in 2012 to 10 in 2016. Carplus has been conducting carsharing surveys in the UK since 2007, and a survey focusing on the Scottish carsharing users in 2018 showed that each carsharing vehicle replaced five private cars (Gleave, 2018). In addition, Europe has been vigorously developing free-floating carsharing since 2009, and its impact on car ownership has also received attention

in recent years. Becker et al. summarized the related research conducted in Ulm, Berlin, Munich, London, Basel and other cities during 2009–2016 (Becker et al., 2018). It was found that 4–19% of members sold vehicles because of carsharing, 8–30% of members give up buying cars, and one carsharing vehicle replacing 7–13 private cars.

Related studies in Asia have just started. Kim et al. (2019) conducted two cross-sectional surveys in Seoul to identify and compare factors driving carsharing users' car ownership changes. A survey based on the members of a round-trip carsharing system in Hangzhou, China found that 49.4% of respondents would postpone or give up car purchase by participating in carsharing (Hui et al., 2019). Wang et al. conducted a stated preference survey in China showing 62.1% of participants were willing to give up buying new cars if carsharing could satisfy their travel demand (Wang et al., 2017). In Singapore, a study found that people joined carsharing because public transport and carsharing together were adequate substitutes for private car ownership (Seik, 2000).

Table A.1 in the section 5.1 Impact comparison summarizes the research on the impact of carsharing on car ownership in past 20 years. We summarize the existing studies from the perspectives of research objects, locations where research was conducted, research methods, and research content:

(1) Research objects and locations where research was conducted: Most of the research was carried out focusing on carsharing projects in developed countries in Europe and North America, but research in developing countries is obviously insufficient. Due to differences in motorization rates and transportation development characteristics, research results from developed countries may not be directly applicable to developing countries. Also, because carsharing types in Europe and North America are mostly round-trip carsharing and free-floating carsharing, station-based one-way carsharing is less available. Differences in characteristics of user and vehicle caused by differences in operating mode also make research conclusions based on round-trip carsharing and free-floating carsharing not suitable for station-based one-way carsharing.
(2) Research methods: Surveys of carsharing members is a common method in the ownership impact research field. They collect the changes in household car ownership before and after members join carsharing, and obtain the proportion of members who sold their cars, give up or delay car purchasing because of carsharing. Finally, the number of private cars replaced by one carsharing vehicle can be estimated. The surveys include single cross-section surveys and continuous panel surveys. Most studies conduct single cross-section questionnaire survey because of the difficulty to obtain continuous panel data. Becker et al. used a two-wave survey approach focusing on Basel in Switzerland showing that 6% of the free-floating car-sharing members reduce their private vehicle ownership (Becker et al., 2018). Besides revealed behavior surveys, some studies are based on stated choice experiments. A survey conducted in the Netherlands indicates that 20% may forego a planned purchase or shed a current car if carsharing becomes available near to them (Liao et al., 2020). Zhou et al. found the stated availability of car-sharing has minimal impact on respondents' decision to own a vehicle or not based on a study of 1,500 private households in Australia (Zhou et al., 2020). One disadvantage of surveys is that they may contain a bias or even mistakes because of the respondents' possibly incorrect interpretation and speculation about the questions. This was also indicated by some other researchers (Klincevicius et al., 2014; Nijland and van Meerkerk, 2017; Mishra et al., 2015; Becker et al., 2018). There are also some studies using regression methods to analyze the factors, mainly using the binomial logit model. For example, users who sold cars are compared to users who did not (Cervero et al., 2007; Giesel and Nobis, 2016; Ko et al., 2019; Namazu and Dowlatabadi, 2018), or carsharing users are compared to non-users (Mishra et al., 2015). Some studies also develop multiple regression models to figure out the relationship between household car ownership and some variables such as the distance between home and the nearest carsharing station, the number of carsharing vehicles within 500 m of home, and the population density of the community (Klincevicius et al., 2014; Engel-Yan and Passmore, 2013).
(3) Research content: Most studies focus on revealing the proportion of users who sold vehicles/delay a purchase because of carsharing. However, there is a lack of research on who and why these people do so. Meanwhile, for those members who do not sell vehicles/delay their purchasing, there is also not enough research about whether their attitude would change with external factors such as the service level of carsharing.

In summary, the impact of carsharing on household car ownership is spatially diverse and temporally dynamic. Different countries, different transportation systems, different carsharing operation models, and different research methods will all lead to differences in research conclusions. Carsharing projects in China have developed rapidly in recent years, and most of them are station-based one-way carsharing systems. Whether this operation model can generate private car ownership reduction benefits during a phase of rapid motorization is worthy of special research. At the same time, it is necessary to further identify and analyze the key elements of carsharing's substitution impacts for private cars and analyze its mechanism. It can then provide a basis for maximizing the substitution benefits of car ownership.

This paper is the first empirical study on the impact of carsharing on household car ownership based on one-way carsharing in China. It is also the first to compare the results in China to those in Europe and North America. The results of this paper make up for the lack of research on car ownership reduction benefits by carsharing in developing countries, and deepen the understanding about characteristics of users affected by carsharing and some other related elements and mechanisms. The study can provide a useful reference for similar research in other cities.

3. Data and methodology

3.1. Data collection

This paper conducts a case study of the impact of carsharing on car ownership in Shanghai. Located in the South-East of China, Shanghai is a coastal city with an area of 6,340 square kilometers and ranks first in China in terms of gross domestic product (GDP). Driven by a series of policies and transportation system innovations, the city has offered a fertile environment for developing and expanding carsharing services. In 2013, Evcard, a carsharing company, was founded in Shanghai. Since its operation started in 2015, Evcard has rapidly developed into the largest carsharing company in Shanghai and in China. It was first piloted in Jiading District, Shanghai, gradually expanding to cover all of Shanghai city, and expanding to other cities in China. Evcard provides a station-based one-way carsharing service. Carsharing members can pick up a shared car from one station and return it to any station with available parking spaces. There is no membership fee for becoming an Evcard member. That is, registration to be an Evcard member is free. If a member wants to use a car, he or she needs to pay a deposit of at least 1,000 CNY, or pre-authorize the deposit with a credit card before using the service. The deposit will be returned if members have no violations of the car rental contract. The rental fee is based on the duration of use. All vehicles in operations are Pure Battery Electric Vehicles (PBEVs). As of the end of 2017, there were more than 4,000 carsharing stations covering all administrative districts in Shanghai and more than 850 thousand members registered, which accounts for 1/28 of the population in Shanghai (24 million).

This paper uses two types of data. First, survey data were collected through an online questionnaire survey among Evcard members in May 2017. Questionnaires were randomly sent to 6,932 carsharing members via email. Each respondent was promised a 60 Chinese yuan (CNY) carsharing coupon as a reward. The average 2017 disposable income in Shanghai was 4,915 CNY/month. In total, 2,203 respondents answered, and the response rate is 31.8%. The information in this survey is summarized in Table 1, including socio-economic attributes, geographical attributes of their residence, behavior and attitude to car ownership. Among these, regarding the carsharing impact on members' car ownership behavior and attitude, this paper focuses on two items: **stock benefit** and **increment benefit**. The stock benefit refers to the sale of cars that have already been purchased, while the increment benefit refers to the fact that the carsharing users give up buying cars or delay buying ones. The logic diagram of the stock benefit and increment benefit is shown in Fig. 1. Taking the stock benefit as an example, firstly, users are asked whether they had a private car when joining the membership. If owning cars, they are asked whether they have sold cars and whether this is due to the carsharing. In contrast, if the car has not been sold, there is also a question that whether they plan to sell the car when the carsharing is convenient enough in the future (members can use carsharing whenever and wherever). The future scenario is designed to further understand the potential of carsharing impacts on the car ownership. And there are also the similar questions for the increment benefit. Second is the operation data, including the booking data and registered membership attributes. The booking data, for example the time of taking and returning carsharing vehicles, from December 2016 and May 2017 were searched to match the 2,203 respondents. After data preprocessing, the usage frequency of respondents is calculated and compared with all carsharing members. Age and gender distributions of all members are also compared with the sample. It should be mentioned that all collected data is anonymized with the help of the company to protect the privacy of the participants.

The raw survey data was screened and processed before analysis. Duplicate and incomplete records were removed. 1,942 respondents who have lived in Shanghai for more than six months and with complete addresses of their home and workplace were retained. Among them, 22 members did not use carsharing during the half year before the survey date, and most of the 22 never used carsharing. Considering that these users are almost not affected by carsharing, they were excluded. Finally, a total of 1,920 respondents were used for analysis.

3.2. Calculating the number of vehicles replaced by each carsharing vehicle

When calculating the number of vehicles replaced by each carsharing vehicle, only the number of vehicles sold and the number of vehicles given up are considered because the users who delay the purchase might eventually buy a car. The formula for the number of carsharing vehicles replacing private vehicles (*removed*) is as follows:

Table 1
Contents of Survey and Operation Data.

Source	Category	Content
Questionnaire survey	Socioeconomic attributes	Age, gender, education background, occupation, driving age, household size, income, household car ownership, and whether living in Shanghai more than 6 months
	Geographical attributes (calculated by location of home)	Whether living in urban center/suburban areas, whether carsharing/subway is available within 800 m of home, number of carsharing stations within 1,000 m of home
	Carsharing impact on behavior and attitude of car ownership	Whether sold cars/plan to purchase cars/delay purchasing cars after joining carsharing, the characteristic of sold vehicles, the main reason to sell cars/plan to purchase cars, whether sold cars/plan to purchase cars/delay purchasing cars when carsharing is convenient enough
Operation data	Booking data	Time of taking and returning carsharing vehicle, pick-up station, drop-off station, trip mileage, trip cost, and member ID
	Registered member data	Age and gender

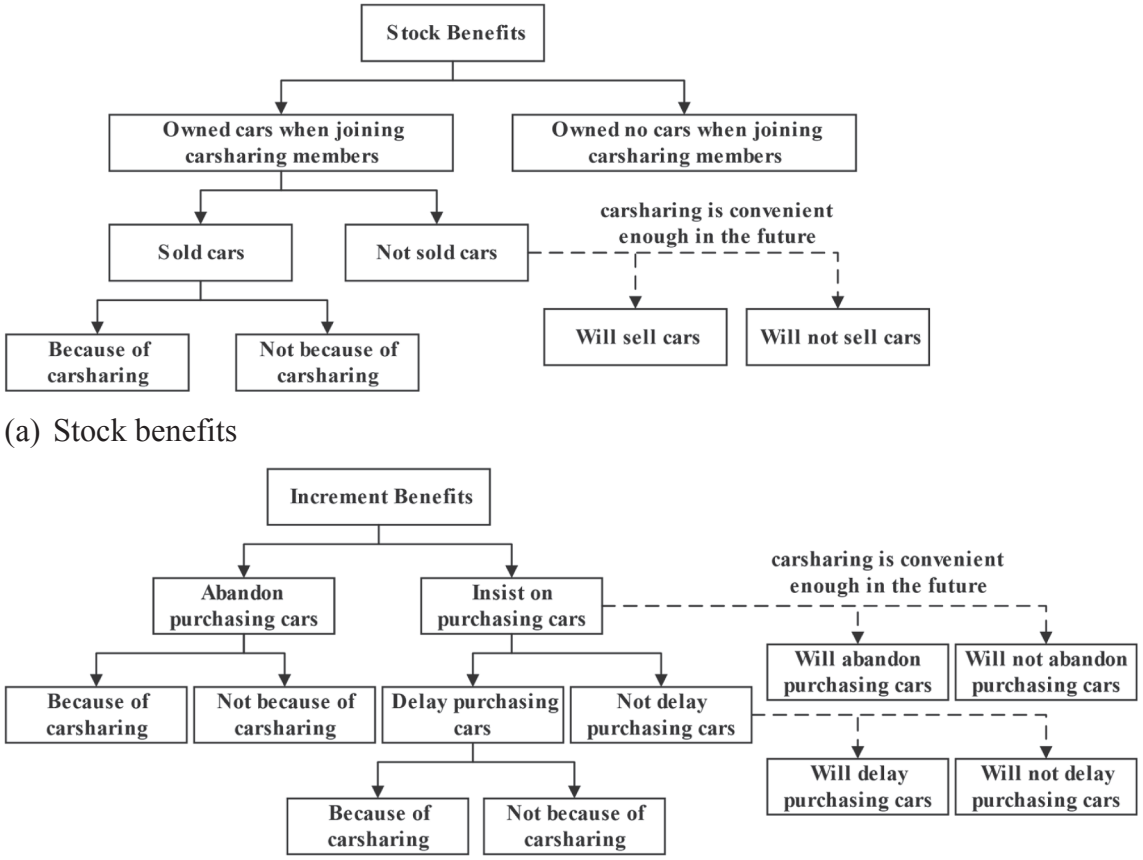

Fig. 1. Carsharing impacts on behavior and attitude of car ownership.

$$Removed = \frac{Sold + Suppression}{Sample \times Weight} \times \frac{Population}{Vehicle} \quad \text{(a)}$$

where

Sold = the number of sold vehicles owing to carsharing service,
Suppression = the number of given up vehicles owing to carsharing service,
Sample = the number of respondents who used carsharing in the last 6 months before the survey (=1,920),
Weight is a correction factor for the sample bias. This allows a weighting of the sample results by age, gender, or usage frequency. For example, the number of respondents could be corrected by the differences of usage frequency between the sample and all members,
Population = the total number of carsharing members who used carsharing in the last 6 months before the survey, which was calculated from the booking data,
Vehicle = the number of vehicles in operation.

The number of vehicles replaced by each carsharing vehicle can be calculated by the formula (a) above. Decreasing the value calculated by the above formula by one is the net reduction of the number of private vehicles per carsharing vehicle.

3.3. Logistic regression model

Logistic regression models are developed to compare the difference between carsharing members whose car ownership is affected by carsharing or not in sociodemographic attributes, geographical attributes of their home, carsharing usage frequency and carsharing satisfaction.

(Model 1 Giving-up-Purchasing-Vehicle User Model)

Firstly, a Giving-up-Purchasing-Vehicles User model is developed to estimate the probability that a carsharing user give-up pur-

Table 2
Variables considered in logistic regression modelling.

Category	Independent variable	Type	Description
Individual attributes	Age	Ordinal	18–23: 0, 24–33: 1, 34–43: 2, 44–53:3, 54+:4
	Gender	Nominal	female: 0, male: 1
	Education	Ordinal	graduated high school or grade school: 1, some college or associated degree: 2, bachelor's degree: 3, graduate or professional degree: 4
	Occupation	Nominal	civil servant: 0, teacher: 1, medical staff: 2, enterprise staff: 3, self-employed: 4, student:5, freelance: 6, farmer: 7, retiree: 8, other: 9
	Driving age	Ordinal	<6 months: 0, 6–12 months: 1, 1–2 years: 2, 3–10 years: 3, more than 10 years: 4
Household attributes	Household size	Ordinal	number of family members living in the same residence as the respondent
	Income	Ordinal	disposable income per year, <30,000 CNY: 1, 30,000–80,000 CNY: 2, 80,000–120,000 CNY: 3, 120,000–200,000 CNY: 4, 200,000–300,000 CNY: 5, 300,000–1,000,000 CNY: 6, 1,000,000 CNY and more: 7
	Car ownership	Ordinal	household car ownership
Home location attributes	Home location	Nominal	live in urban center (the area within the Shanghai outer ring road): 1, live in suburban areas (the area beyond the Shanghai outer ring road but within Shanghai): 0
	Subway-800 m	Nominal	whether subway is available within 800 m of home, yes: 1, no: 0
	Carsharing-800 m	Nominal	whether carsharing is available within 800 m of home, yes: 1, no: 0
Carsharing using attributes	Frequency	Interval	average carsharing usage frequency (per month)
	Satisfaction	Ordinal	very satisfied - very unsatisfied: 1–5

chasing a vehicle due to carsharing. Backward variable selection procedure was used in the modelling process. All the variables that have been considered are shown in Table 2. The dependent variable (Y) of this model has only two possible values, 1 and 0. Carsharing members who give up buying cars owing to carsharing is defined as $y = 1$ and for other carsharing members $y = 0$. The model is shown below:

$$\mathrm{logit}(p) = \ln\frac{P}{1-P} = b_0 + \sum_{i=1}^{n} b_i x_i$$

where $\frac{P}{1-P}$ is odds ratio which is the probability ratio of $y = 1$ to $y = 0$.

(Model 2 Delay-purchasing-Vehicle User Model)

Similar logistic regression model is also developed to calculate the probability that a carsharing user delay purchasing a vehicle because of carsharing. The explanatory variables are those shown in Table 2. The dependent variable y represents whether a user delay purchasing vehicles owing to carsharing ($y = 1$) or not delay and delay purchasing owing to other reasons ($y = 0$).

(Model 0 Selling-Vehicles User Model)

A similar selling-vehicles user model is developed to compare the difference between users who sell vehicles and users who did not sell.

(Model 3 Any-Car-Ownership-Impacts)

To comprehensively measure the stock benefits and increment benefits of carsharing on members' car ownership, a logistic regression model is developed again to calculate the probability that a carsharing member's car ownership is impacted by carsharing. All the members who sold or give up purchasing or delay purchasing vehicles is defined as $y = 1$, and other members whose car ownership is not affected is defined as $y = 0$. The explanatory variables are those shown in Table 2.

4. Results

The results consist of six parts. Part 1 describes the sociodemographic attributes of the sample and compares it with all the carsharing members. Part 2 to 4 analyze the impact of carsharing on users' car ownership for the three responses of selling cars, giving up buying cars, and delaying the purchase of cars. The characteristics of the different users are analyzed respectively. Part 5 uses logistic regression models to analyze what kind of users will be affected by carsharing. The last part considers the impact of carsharing on car ownership when the carsharing is convenient enough in the future.

4.1. Carsharing members' sociodemographic attributes, and comparison between sample and population

As shown in Table 3, the majority of respondents are male, as are the members generally. 82% are male, while the proportion of male members is slightly lower, accounting for 79%. In terms of age, although the sample has more young users aged 20–30, it is close to the overall age distribution trend. In terms of frequency, as shown in Fig. 2, the average frequency of respondents is higher than that of all members. The users in sample with 4–5 times a month are the most frequent, accounting for 18.4%. Among all members those who use the service less than or equal to once a month are most frequent, accounting for 37.9%. In general, the distribution of gender and age of sample and population is similar. However, the respondents have a higher use frequency. This is mainly because there are

Table 3
Demographic Statistics in Sample and Members.

Demographic Attribute	Sample (%)	Members (%)
Gender	N = 1,920	N = 136,739
Male	82.1%	78.9%
Female	17.9%	21.1%
Age (years)		
Younger than 20	0.8%	0.3%
20–30	47.2%	42.0%
30–40	42.2%	43.4%
40–50	8.7%	11.3%
50–60	1.0%	2.5%
60–70	0.1%	0.4%
Education		
Graduated high school or grade school	9.6%	–
Some college or associated degree	24.8%	–
Bachelor's degree	50.8%	–
Graduate or professional degree	14.7%	–
Occupation		
Civil servant	5.9%	–
Teacher	4.6%	–
Medical staff	4.3%	–
Enterprise staff	56.6%	–
Self-employed	3.3%	–
Student	12.4%	–
Freelance	5.2%	–
Farmer	0.2%	–
Retiree	0.1%	–
Other	7.3%	–
Yearly income		
<30,000 CNY	6.3%	–
30,000–80,000 CNY	11.8%	–
80,000–120,000 CNY	17.6%	–
120,000–200,000 CNY	28.8%	–
200,000–300,000 CNY	22.2%	–
300,000–1,000,000 CNY	12.2%	–
1,000,000 CNY and more	1.2%	–
Car ownership		
0	64.8%	–
1	29.9%	–
2	4.6%	–
3	0.5%	–
4	0.1%	–

coupons as rewards for answering the questionnaire, and users who use it frequently will pay more attention and be willing to answer the survey.

In addition, more than 60% of the respondents have a bachelor or higher degree. 57% are enterprise staff and more than 60% of them do not own a private car.

4.2. Selling vehicles

After the 1,920 respondents became carsharing members, 15 sold 16 cars because of carsharing, accounting for 0.78%. 56 sold their cars, but this was not caused by carsharing, accounting for 2.9%. None of the remaining users sold cars, accounting for 96.3%. This indicates that currently carsharing in Shanghai only has very limited impacts on the vehicle stock. Because the sample size is too small, it cannot support further statistical analysis.

4.3. Giving up purchasing vehicles

There are 576 (30%) respondents giving up purchasing private cars due to carsharing among 1,920 respondents. 452 (23.5%) gave up buying cars for other reasons, and 892 (46.5%) think that they will not give up and still need one. Users who give up buying cars are mainly satisfied with the services provided by the carsharing company. They think that carsharing can meet their daily travel demand, and they do not need to buy any further vehicles. As for the reasons why they still need to buy cars, they mainly think that private cars are necessities (37%, 331 people), and that the current carsharing service is not good enough to meet their needs (38%, 335 people).

The characteristics of the users who give up buying cars are shown in Table 4. The carsharing usage frequency is based on the matched booking data from December 2016 to May 2017. It refers to users' average usage frequency for this period of 6 months. If the time of the first use is after December 2016, the denominator will be the actual months counting from the beginning month of the first usage to May 2017. The share of using carsharing three or more times a week refers a usage frequency of more than 12 times a month.

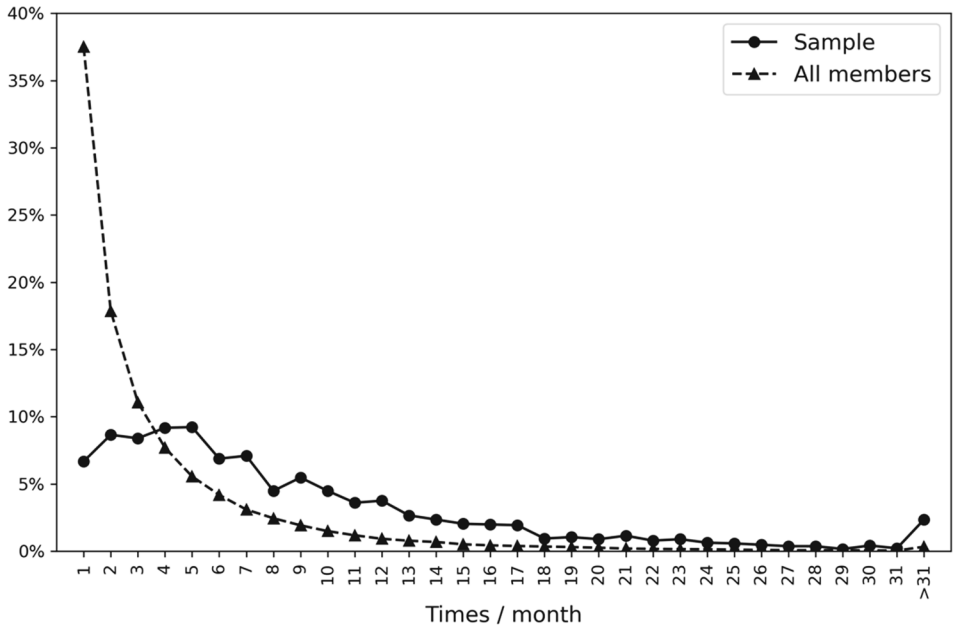

Fig. 2. Distribution of carsharing use frequency of sample and all members.

Table 4
Comparison between respondents whose car ownership is affected by carsharing.

Characteristic (Average)	Giving up purchasing vehicles		Delaying purchasing vehicles	
	394 car-free users	182 car-owning users	211 car-free users	68 car-owning users
Age	30.8	33.5	28.9	28.7
Household size	3.0	3.6	2.8	3.5
Household ownership	–	1.1	–	1.2
Living in suburban areas	64.7%	80.8%	60.7%	75.0%
Subway is available within 800 m of home	29.7%	19.2%	36.0%	23.5%
Carsharing station is available within 800 m of home	78.9%	83.0%	73.9%	80.9%
Number of carsharing stations within 1,000 m of home	3.1	3.6	3.0	2.9
Carsharing usage frequency per month	10.3	8.5	10.3	7.5
Using carsharing 3 or more times a week	28%	20%	30%	16%
Using carsharing for commuting	6.6%	20.9%	13.7%	10.3%

The proportion of using carsharing for commuting refers to the proportion of carsharing commuters. The carsharing commuter is judged by origin and destination of carsharing trips and user's home and working locations together. For more details about this method see (Ye et al., 2019). Most of the users still have no cars (68.4%). Therefore, carsharing mainly replaces the first car in the family instead of the second car. 64.7% of these car-free users live in the suburban areas, which is lower than that of the car-owning users (80.8% resident in the suburban area). The car-free users use carsharing more frequently, but the main purpose is not to commute. The car-owning users will commute by carsharing more frequently.

4.4. Delay purchasing vehicles

The 892 respondents who still want to buy a car in the above answer are asked whether they can delay buying a car. Among these users, 279 (31%) think that they can delay the purchase of a car because of carsharing, and 256 (29%) think that they will not delay and go ahead with buying a car.

As shown in Table 4, 75.6% of carsharing members who delay purchasing have no cars. The proportion of car-free users living in the suburban area is lower than that of car-owning users. Meanwhile, the carsharing usage frequency of car-free users is higher than that of car-owning users. 13.7% of car-free users and 10.3% of car-owning users use carsharing for commuting respectively.

Comparing car-owning users the average age of delaying buying cars users is lower, and the household size is also smaller. In terms of accessibility around the residence, carsharing accessibility of giving up buying cars users is better, with more users covered by carsharing stations. The carsharing usage frequency of giving up buying cars users is higher than that of delaying buying cars users. For the car-free users, the users who give up buying cars are older and have more family members and giving up users have better carsharing accessibility from their residences.

4.5. Ownership model results

The logistic regression models have been developed and only the significant variables (p-value <0.10) were included in the final models. The results for Model 1 Giving-up-Purchasing-Vehicle User Model, Model 2 Delay-purchasing-Vehicle User Mode, and Model 3 Any-Car-Ownership-Impacts User Model are shown in Table 5. Model 0 Selling-Vehicles User Model is not developed because the number of selling car uses is too small.

In the Model 1 Giving-up-Purchasing-Vehicle User Model, the significant variables are age, income, car ownership, whether living in urban center, carsharing usage frequency and carsharing using satisfaction. The results indicate that the carsharing members who are older, have a lower income and fewer car ownership will be more likely to give up buying cars because of carsharing. In addition, the carsharing members living in suburban areas, usually use carsharing for a trip, and are satisfied with current carsharing service tend to be more likely to give up buying a car. Other variables such as gender, education, occupation, etc. were not found to be influential. In the Model 2 Delay-purchasing-Vehicle User Model, the driving age, whether subway is available within 800 m of home, carsharing usage frequency and satisfaction are significant. The results show that users with lower driving age live in suburban areas with accessible subway service, and have higher carsharing use frequency and satisfaction are willing to delay the purchase of private cars.

Finally, in the Model 3 Any-Car-Ownership-Impacts User Model, the car ownership of users with lower car ownership, living in suburban areas and close to subway stations are more impacted by carsharing. The same factors are carsharing usage frequency and satisfaction with the same function.

Compared with car-owning members, car-free members may consider different factors when deciding whether to give-up or to postpone buying a car. To test whether this kind of heterogeneity exists in the above models, the data are split into two groups according to car ownership status. One group is carsharing members without a private car, the other is members with one or more cars. The models are developed separately and the results are shown in the Tables 6–8.

As shown in the Table 6, when considering whether to give up buying a car, it is the same for car-free and car-owning members that older users who are more satisfied with carsharing and use it more frequently will give-up purchasing a car. Besides, car-free members are more likely to give up buying their first private cars because of lower income. And usually, they may be less educated. However, for car-owning members, the income and education are not significant. They care more about the built environment of their places of residence. If living in the suburbs but with subway stations nearby, the car-owning members are more likely to give-up purchasing their second or third cars. The same phenomenon also exists in the model 2 and model 3, that car ownership of car-owning members is more likely impacted by their home location and accessibility to surrounding public transport. For the model 2, delay purchasing vehicle model, in addition to the differences above, car-free members who use carsharing more frequently are more likely to postpone buying their first car. But for car-owning members, the users with lower driving age are more likely to delay the purchase of additional cars.

4.6. Potential

Fig. 3 shows the current impact and potential analysis of carsharing on car ownership. The solid arrow represents the current impact caused by carsharing. The dotted arrow represents change in ownership attitude of the uninfluenced user when carsharing service is improved greatly in the future (basically everyone can get access to carsharing whenever and wherever they want to use it). Among them, the question of whether to give up buying a car in an ideal situation is to ask the 335 of the 892 people who insist on buying a car and think that the current carsharing is not good enough. When calculating the proportion of users who delay purchasing cars, the denominator is the number of users who insist on buying a car also (892).

In this ideal situation, the number of users who sell vehicles will increase the most, from 0.78% to 12.0%. The number of users who give up buying vehicles will increase from 30% to 40%, and the number of users who delay buying vehicles will increase from 31% to 47%. A selling rate that increases from 0.78% to 12.0% seems rather optimistic, so we want to know which users would behave like

Table 5
Results of the Logistic Regression Models.

	Model 1: Giving-up purchasing vehicle		Model 2: Delay purchasing vehicle		Model 3: Any car ownership impacts	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
Constant	0.01	0.99	1.35***	0.00	1.69***	0.00
Age	0.04***	0.00	–	–	–	–
Driving age	–	–	−0.21***	0.00	–	–
Income	−0.10**	0.02	–	–	–	–
Car ownership	−0.19**	0.04	–	–	−0.35***	0.00
Home location	−0.29**	0.01	−0.45**	0.02	−0.39***	0.00
Subway – 800 m	–	–	0.34*	0.09	0.24*	0.07
Frequency	0.02***	0.00	0.04***	0.00	0.03***	0.00
Satisfaction	−0.78***	0.00	−0.80***	0.00	−0.81***	0.00
McFadden's pseudo R^2	0.09		0.09		0.09	
Adjusted McFadden's pseudo R^2	0.09		0.08		0.09	
Sample size	n = 1,920		n = 892		n = 1,920	

***p < 0.01, **p < 0.05, *p < 0.10.

Table 6
Heterogeneity in Model 1.

Model 1: Giving-up purchasing vehicle					
	Car-free users		Car-owning users		All
	Coefficient	Sig.	Coefficient	Sig.	Coefficient
Satisfaction	−0.76***	0.00	−0.85***	0.00	−0.78***
Frequency	0.01*	0.07	0.05***	0.00	0.02***
Age	0.03***	0.00	0.05***	0.00	0.04***
Income	−0.11**	0.02	–	–	−0.10**
Education	−0.16**	0.04	–	–	–
Home location	–	–	−1.02***	0.00	−0.29**
Subway – 800 m	–	–	0.64**	0.04	–
Constant	0.67	0.14	−0.80	0.13	0.01
McFadden's pseudo R^2	0.09		0.12		0.09
Adjusted McFadden's pseudo R^2	0.08		0.10		0.09
Sample size	1,245		675		1,920

***p < 0.01, **p < 0.05, *p < 0.10.

Table 7
Heterogeneity in Model 2.

Model 2: Delay purchasing vehicle					
	Car-free users		Car-owning users		All
	Coefficient	Sig.	Coefficient	Sig.	Coefficient
Satisfaction	−0.81***	0.00	−0.80***	0.00	−0.80***
Frequency	0.04***	0.00	–	–	0.04***
Driving age	–	–	−0.25**	0.04	−0.21***
Home location	–	–	−1.00**	0.02	−0.45**
Subway – 800 m	–	–	0.79*	0.09	0.34*
Constant	1.10***	0.00	1.53**	0.01	1.35***
McFadden's pseudo R^2	0.08		0.09		0.09
Adjusted McFadden's pseudo R^2	0.07		0.06		0.08
Sample size	603		289		892

***p < 0.01, **p < 0.05, *p < 0.10.

Table 8
Heterogeneity in Model 3.

Model 3: Any car ownership impacts					
	Car-free users		Car-owning users		All
	Coefficient	Sig.	Coefficient	Sig.	Coefficient
Satisfaction	−0.81***	0.00	−0.84***	0.00	−0.81***
Frequency	0.02***	0.00	0.04***	0.00	0.03***
Home location	–	–	−1.03***	0.00	−0.39***
Subway – 800 m	–	–	0.65**	0.02	0.24*
Constant	1.68***	0.00	1.27***	0.00	1.69***
McFadden's pseudo R^2	0.08		0.11		0.09
Adjusted McFadden's pseudo R^2	0.08		0.10		0.09
Sample size	1,245		675		1,920

***p < 0.01, **p < 0.05, *p < 0.10.

that and the reasons for selling cars in the ideal situation. Based on the survey results, the 623 users who did not sell cars currently are divided into two categories. One is, although they did not sell cars, they have had the intention to sell cars. The other is those who do not have the intention to sell cars. There are 81 users having the intention to sell cars and 542 users without that intension. Among them, 77.8% of users having the intention would sell cars if carsharing service is improved greatly, while only 28.0% of the users without intension would have the potential to sell cars. In addition, a binary logit model was further developed to find out who would like to sell cars in the hypothetical scenario. Comparing users who will sell cars and those who will not sell cars in the ideal situation, it is found the car ownership, living in the suburban areas, being able to use carsharing within 800 m of home and being a student are significant factors. That means the users, usually not students, own more private cars, living in the suburban areas without carsharing services nearby currently are more likely to sell their cars if the carsharing service is improved greatly.

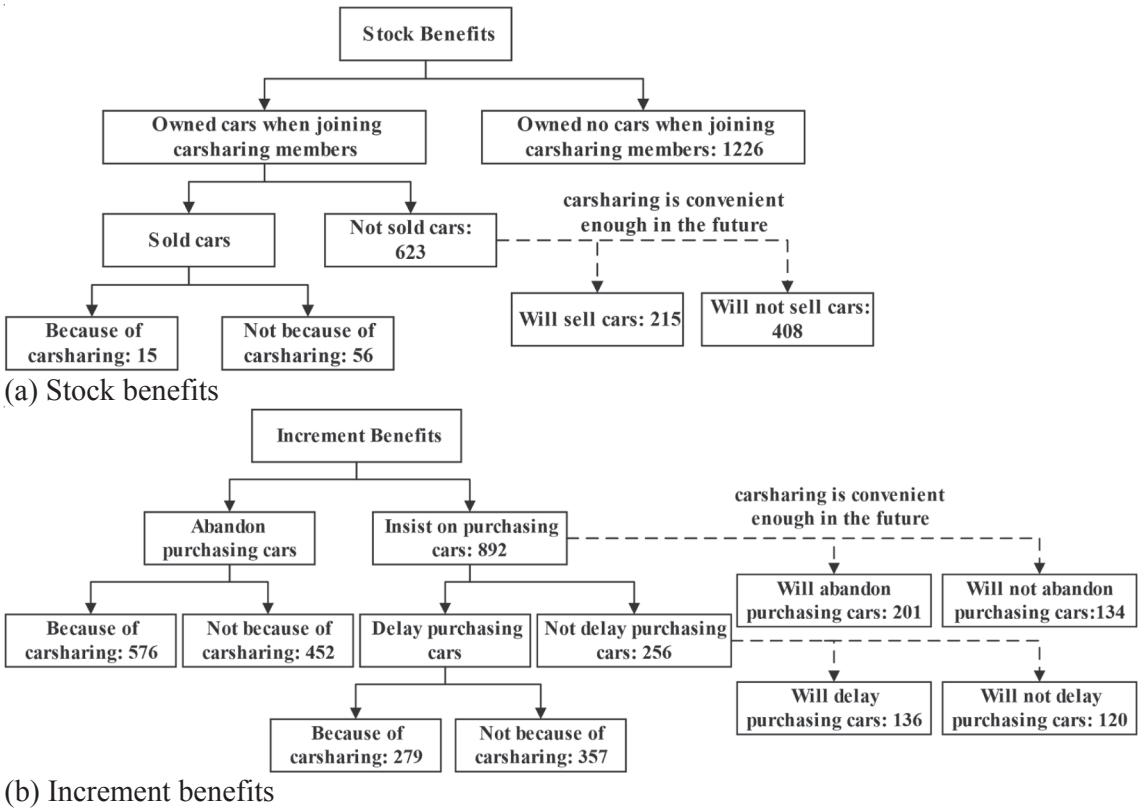

Fig. 3. Current impact and potential analysis of carsharing on car ownership.

5. International comparison and policy implications

This section compares the carsharing impact on car ownership in Shanghai with other cities' cases, including the comparison of impacts and factors. Some policies are suggested from this discussion. With literature review, 27 cases around the world in the last 20 years have been selected for impacts comparison. In terms of factors, due to the lack of relevant research, 4 cases which further consider the factors above and an additional Montreal case are compared with Shanghai.

5.1. Impact comparison

Table A.1 shows the proportion of car selling users and proportion of giving up purchase users, as well as the stock benefits, increment benefits and final replacement amount per carsharing vehicle. The results show that the proportion of car selling users in Shanghai is only 0.78%, which is lower than other cases. In terms of restraining purchase, up to 30% of users in Shanghai will give up buying cars because of carsharing, which is higher than most cases. Only 3 of the 18 cases with this data are higher than Shanghai.

When calculating the number of cars replaced by each shared car, the respondents tend to be high-frequency users because coupons were most useful to them. Therefore, the number of the respondents is corrected based on the use frequency distribution of sample and all members. The number changes from 1,920 to 4,095 after correction. By formula (a), the following figures can be calculated: the car stock reduced by each shared car in Shanghai is 0.12, and the car increment restrained by each shared car is 4.44. In total, each shared car can replace 4.56 cars, with a net decrease of 3.56 cars. It can be found from the Table A.1 that the reduction of car stock per shared car is still lower than that of other cases. The number of increments restrained is between the results in North America (4–15.3). Finally, in terms of the number of cars replaced by carsharing (stock benefits + increment benefits), the number in Shanghai is lower than that in North America (6.8–22.8) and among those in Europe (3–13).

5.2. Factor comparison

This section further compares the factors between Shanghai and other cases. Because survey and data analysis methods focusing on factors are quite different in every research, these results are classified to compare the factors, which is shown in Table A.2. The p value of all included results is less than 0.10, and most of the p values are less than 0.05.

Firstly, in terms of personal sociodemographic attributes: (1) Age. In addition to Shanghai, there are two studies showing that among the older, carsharing will have a more positive impact on the reduction of car ownership (Cervero et al., 2007; Ko et al., 2019);

(2) Gender, (3) Education background. Both are not significant in Shanghai; (4) Driving age. Except Shanghai, no other research has considered it.

Secondly, in terms of family attributes: (5) Household size. Although some other cases show that family structure and size are significant (Cervero et al., 2007; Giesel and Nobis, 2016; Klincevicius et al., 2014; Ko et al., 2019; Le Vine and Polak, 2019), which mainly indicate larger families are more likely to keep or plan to buy cars, this factor is not significant in Shanghai case; (6) Income. The results of Shanghai case are basically consistent with the results of the other three cases (Klincevicius et al., 2014; Ko et al., 2019; Le Vine and Polak, 2019), which show that the lower the income is, carsharing will have a more positive impact on the reduction of car ownership; (7) Car ownership. Seoul's case shows that users owning fewer cars will be more likely to give up and delay the purchase, but it is not significant in selling cars (Ko et al., 2019). Although the Shanghai case has no result about selling car users, we show that those with low car ownership are more likely to give up car buying. This result is consistent with the Seoul result. This may be mainly due to the high carsharing use frequency and high carsharing satisfaction of members in Shanghai. And there are maybe not too many scenarios requiring cars in their daily trips, or they use more public transport because of income constraints. If there is an occasional trip needing a car, carsharing can meet it well.

In terms of home location: (8) Whether living in the urban center. Shanghai case shows that carsharing will have a positive impact on the ownership reduction of users who live in the suburban areas, while Montreal case indicates that users who live closer to the urban center will have lower car ownership (Klincevicius et al., 2014). These results can be analyzed combining them with (9) Public transport accessibility. Montreal research shows that the subway is more convenient when users live closer to the urban center, and users will have lower car ownership (Klincevicius et al., 2014). Although the Shanghai case suggests that the more likely impacted users live in the suburban areas, they are more likely to live in the areas with better subway accessibility. Their residences can be reached within 800 m of the subway stations, so they can use the fast and punctual subway for their daily trips, suggesting a low demand for the private car. There is also a case indicating that users owning a transit pass tend to sell cars (Cervero et al., 2007). (10) Carsharing accessibility. This factor is not significant in the Shanghai case. The other two cases suggest that carsharing will have more positive impact on the car ownership of users who have better carsharing accessibility (Cervero et al., 2007; Ko et al., 2019).

In terms of carsharing usage, there are two factors, (11) Carsharing use frequency and (12) Carsharing satisfaction. The Shanghai case leads to the same conclusion as other cases, that is the carsharing members who uses carsharing more frequently and are more satisfied with the current carsharing service will be more likely to sell cars, give up buying cars and delay buying cars (Giesel and Nobis, 2016; Ko et al., 2019; Le Vine and Polak, 2019; Hui et al., 2019). The study in Hangzhou found the willingness to postpone car purchase was related to more carsharing usage characteristics, such as having activity points in their round-trip carsharing trips and the most common travel purpose of carsharing is work-related (Hui et al., 2019).

According to the 2018 Shanghai Comprehensive Transportation Annual Report, the ownership rate of private cars registered in Shanghai in 2017 is 111 vehicles per 1,000 people (Shanghai Urban Rural Construction and Transportation Development Research Institute, 2018), which is still far behind the cities in North America and Europe. The motorization in Shanghai is still growing. The demand to buy private cars is still very high. Against this background, although the proportion of car selling users is not high, 30% of users will give up buying cars because of carsharing. This is a positive signal for the control of car ownership in the future. The government or urban traffic management department should encourage residents to try and use carsharing as much as possible, while reasonably controlling the total number of carsharing vehicles. In particular, they could increase the publicity to the target groups who are elderly, low-income, low-car-ownership, and live in the suburban areas with access to the subway, so that more residents in the city can experience the convenience of carsharing. It will promote to residents a change from the traditional concept of private car ownership, and let residents' attitude change from "car owning" to "car sharing" gradually.

6. Conclusions and outlook

Based on the questionnaire data and carsharing operations data, this paper quantitatively analyzes the influence of carsharing on the stock benefits and increment benefits of car ownership in Shanghai, and further finds the factors affecting users to change their car ownership. Further, the results in Shanghai are compared with 27 cases all around the world. The results indicate that carsharing in Shanghai also has the benefit of decreasing car ownership. Each carsharing vehicle can replace 4.56 private cars. However, Shanghai carsharing mainly suppresses growth in vehicle numbers by reducing individual willingness to buy a car. Only 0.78% of the users sold cars because of carsharing, while 30% of users will give up buying vehicles owing to carsharing. Though the proportion of users selling cars is obviously lower than that in Europe and North America, the higher increment benefits will help to control car ownership in the future. Secondly, for giving-up car purchases, carsharing mainly suppresses the first car in the family instead of the second one. Thirdly, better carsharing services can substantially improve the stock benefits and increment benefits of carsharing. If carsharing is available whenever and wherever in the future, the proportion of users who sell, give up and delay buying cars will increase from 0.78%, 30% and 31% to 12%, 40% and 47% respectively. Finally, the results suggest that the users who are more likely to sell cars or give up or delay buying a car are usually older and lower-income. Although having lower car ownership and living in the suburban areas far away from the urban center, they prefer to live near the subway station and can use the subway for convenient travel which can meet most of their daily travel needs. Meanwhile they use the carsharing more frequently, and they are satisfied with current carsharing. Carsharing can meet their occasional car travel demand. Therefore, after introducing carsharing service, these members hold a more negative attitude towards owning private cars.

There are some limitations which need to be studied further. (1) It should be pointed out that the impacts of carsharing are dynamically changing with the change of user behavior, fleet supply and service quality of carsharing. In this paper, a cross-section survey, focusing on a specific time was conducted. Further continuous panel surveys should be conducted in the future to capture

Table A1
International Comparison in the Influence Value.

Area	City	Published year	Survey year	Carsharing type	Operator	Sample size	Selling vehicles users	Giving up purchasing vehicles	Vehicles sold	Vehicles suppressed	Total vehicles removed per carsharing vehicle	Reference
Asia	Shanghai	2021	2017	station-based one-way	EVCARD	1,920	0.78%	30.00%	0.12	4.44	4.56	(this paper)
	Hangzhou	2019	2017	station-based round-trip	Fun Carsharing	627	–	20.6%	–	–	–	(Hui et al., 2019)
	Seoul	2019	2018	station-based round-trip & one-way	Nanum Car	9,498	4.3%	7.3%	13.2	–	–	(Kim et al., 2019)
	Seoul	2019	2014	station-based round-trip	Nanum Car	5,597	2.3%	3.6%	3.3	–	–	(Ko et al., 2019)
North America	Calgary	2016	2015	free-floating	Car2go	1,246	2%[a]	9%[a]	2	9	11	(Martin and Shaheen, 2016)
	San Diego					643	2%[a]	10%[a]	1	6	7	
	Seattle					2,463	3%[a]	9%[a]	3	7	10	
	Vancouver					863	2%[a]	10%[a]	2	7	9	
	Washington D.C.					952	5%[a]	7%[a]	3	4	7	
	(North America)	2010	2008	(-)	(10 organizations)	6,281	22%[b]	25%	4–6	5–7	9–13	(Martin et al., 2010)
	Vancouver	2018	2013	station-based round-trip	Modo	823	35%	–	–	–	–	(Namazu and Dowlatabadi, 2018)
	Vancouver	2018	2013	free-floating	Car2go	1,227	12%	–	–	–	–	(Namazu and Dowlatabadi, 2018)
	Ithaca, NY	2013	2011	station-based round-trip	Ithaca Carshare	253	–	18%[b]	–	15.3	–	(Stasko et al., 2013)
	San Francisco	2007	2005	station-based round-trip	City CarShare	527	24.2%	–	–	–	–	(Cervero et al., 2007)
	San Francisco	2004	2003	station-based round-trip	City CarShare	462	29.1%	67.5%	–	–	6.8	(Cervero and Tsai, 2004)
	Philadelphia	2005	2003	(station-based)	PhillyCarShare	262	24.5%	29.1%	10.8	12	22.8	(Lane, 2005)
	Portland	2003	1999	(station-based)	Carsharing Portland	64	26%	53%	–	–	–	(Katzev, 2003)
	Portland	2000	2000	(station-based)	Carsharing Portland	89	22.5%	24.7%	–	–	–	(Cooper et al., 2000))
Europe	London	2019	2015	free-floating	Drivenow	298	4%	30%	–	–	–	(Le Vine and Polak, 2019)
	London	2017	2016	station-based round-trip	(5 car club operators)	2,901	14%	34%	10.5	–	–	(Gleave, 2017)
	London	2017	2016	free-floating	DriveNow	1,122	19%	27%	13	–	–	(Gleave, 2017)
	Basel	2018	2015	free-floating	Mobility	224	6%	–	–	–	–	(Becker et al., 2018)
	Berlin and Munich	2016	2015	free-floating	DriveNow	819	6.5%	–	–	–	–	(Giesel and Nobis, 2016)
	Berlin and Munich	2016	2014	station-based round-trip	Flinkster	227	15.3%	–	–	–	–	(Giesel and Nobis, 2016)
	Paris	2014	2014	station-based one-way	Autolib	644	–	–	–	–	3	(Louvet, 2014)
	Paris	2014	2014	station-based round-trip	Mobizen	525	–	–	–	–	7	(Louvet, 2014)
	Ulm	2011	2009	free-floating	Car2go	256	3.8%	9.7%	–	–	–	(Firnkorn and Müller, 2011)

[a] The proportion data has been re-weighted the effects to consider the distribution of usage frequency in the activity data.
[b] Own calculation based on numbers in the respective paper.

Table A2
International Comparison in the Influence Factor.

Case	City	Shanghai (this paper)	London	Seoul	San Francisco	Berlin and Munich	Montreal
	Published year	2019	2019	2019	2007	2016	2014
	Data source	Cross-section, online survey	Cross-section, online survey	Cross-section, online survey	Panel, survey & tracking	Cross-section, online survey	Panel, origin–destination surveys
	Carsharing type	station-based round-trip	free-floating	station-based round-trip	station-based round-trip	free-floating & station-based round-trip	station-based round-trip
Influence factor	Age	The older users are more likely to give up buying a car		The older users are more likely to sell cars and give up or delay buying a car	The older users are more likely to sell cars		
	Gender			The female members are more likely give up or delay buying a car			
	Education		The users with higher education level are more likely to keep cars			The users with high school degree or above are more likely to give up purchasing a car	
	Driving age	The users with lower driving age are more likely to delay a purchase					
	Household size		The users' families with more children under 16 are more likely to be impacted by carsharing and are more likely to give up a purchase instead of selling cars	The users with lower household size are more likely to sell cars	The users who don't have children in their family are more likely to sell cars and users with lower household size are less likely to keep cars	The users with larger household size are more likely to buy a car	The families with more adults and children will have more cars
	Income	The users with lower income are more likely to give up purchasing a car	The users with lower income are more likely to sell cars instead of giving up a purchase and their car ownership are more likely to be impacted by carsharing	The users with lower income are more likely to sell cars and are less likely to give up and delay a purchase			The users with higher income will have more cars
	Car ownership	The users with lower car ownership are more likely to be impacted by carsharing and more likely to give up a purchase	The users with larger car ownership are more likely to give up a purchase instead of selling cars	The users with lower car ownership are more likely to give up or delay a purchase			
	Home location	The users living in suburban are more likely to be impacted by carsharing and more likely to give up a purchase			The users living in San Francisco are more likely to sell cars	The users living in Berlin instead of Munich are more likely to give up a purchase	The users living closer to the city center will have less cars
	Public transport accessibility	The users living with better public transport			The users owning a transit pass are more		The users living with better subway

(*continued on next page*)

Table A2 (*continued*)

Case	City Published year	Shanghai (this paper)	London 2019	Seoul 2019	San Francisco 2007	Berlin and Munich 2016	Montreal 2014
	Data source	Cross-section, online survey	Cross-section, online survey	Cross-section, online survey	Panel, survey & tracking	Cross-section, online survey	Panel, origin–destination surveys
	Carsharing type	station-based round-trip	free-floating	station-based round-trip	station-based round-trip	free-floating & station-based round-trip	station-based round-trip
		accessibility are more likely to be impacted by carsharing and are more likely to give up a purchase			likely to sell cars		accessibility will have less cars
	Carsharing accessibility			The users who can get to a carsharing station in 3 min are more likely to sell cars, and give up or delay a purchase	The users who have a carsharing station within 0.5 mile of their home are more likely to sell cars		
	Carsharing usage frequency	The users with higher carsharing usage frequency are more likely to be impacted by carsharing and are more likely to give up or delay a purchase	The users with higher carsharing usage frequency are more likely to be impacted by carsharing and are more likely to give up a purchase instead of selling cars	The users using carsharing at least once a month are more likely to sell cars and give up or delay a purchase than users who never use		The users with higher carsharing usage frequency are more likely to sell cars	
	Carsharing satisfaction	The users with higher satisfaction are more likely to be impacted by carsharing and are more likely to give up or delay a purchase		The users with higher satisfaction are more likely to sell cars and give up or delay a purchase			
	Other		The users with higher public transport usage frequency and less car usage frequency are more likely to be impacted by carsharing; users with less car usage frequency are more likely to give up a purchase instead of selling cars	The users living in multifamily housing with a lack of parking space are more likely to sell cars; users thinking carsharing can save money are more likely to sell cars, and give up or delay a purchase	The users who don't drive to work are more likely to sell cars	The users with less car usage frequency are more likely to sell cars; users thinking that private car is important and carsharing is more convenient than public transport are more likely to buy cars; users thinking carsharing is economic and bus and riding are not complicated and usually taking public transport are more likely to give up a purchase	The users living in higher population density will have less cars

Note: "be more likely to be impacted by carsharing" means they are more likely to sell cars or give up or delay buying a car.

the evolution characteristics of carsharing's impacts. Questionnaire survey is one way to evaluate the impacts of carsharing directly based on the answers from respondents. Though these surveys may contain a bias because of the members' interpretation of reality, we are able to understand the motivations or reasons why they are impacted by carsharing in details and ask further questions by telephone interview. Another method to assess the impacts is by objective data analysis instead of subjective questions and answers. Through this way, more data are needed to estimate the strength of the factors. For example, Klincevicius et al. (2014) developed multiple regression models to study the relationship between car ownership and exposure to carsharing while controlling for other variables known to also influence ownership. In addition, DID (differences in differences) is also a good way to evaluate the net impacts of policies. For example, the areas served by carsharing can be compared to the areas without carsharing in Shanghai. However, the panel data are necessary for before-and-after comparisons in these models. (2) This paper only conducts a case study for Shanghai. Case analysis in more cities need to be carried out in the future. (3) Due to the limitation of current data, some factors have not been considered in this study, for example, whether there is an available parking space at home. More variables can be introduced in the impact mechanism research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2021.05.012.

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