IATSS Research 42 (2018) 128–137

Contents lists available at ScienceDirect

IATSS Research

Research article

A nationwide study of factors associated with household car ownership in China

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ARTICLE INFO

Article history:
Received 16 April 2017
Received in revised form 3 October 2017
Accepted 16 October 2017
Available online 22 October 2017

Keywords:
Car ownership
China household finance survey
Motorisation
Developing country
Logistic regression

ABSTRACT

Car ownership is growing very rapidly in China; whilst this is a reflection of sustained economic growth, it presents a major challenge to Chinese transport policymakers. The consequences of China's motorization also extend beyond the national borders, however, via mechanisms such as increased demand for new automobiles produced in North America and Europe and the global atmospheric concentration of greenhouse gases. Chinese cities are also experimenting with innovative transport policies to manage increasing car ownership, which in a number of cases go beyond the menu of policy options that have traditionally been considered in the West. Despite policy interest for these reasons, China's motorization process is poorly understood, in part due to a scarcity of relevant data.

This paper contributes to the body of literature regarding this phenomenon by drawing on a unique data resource: the 2011 wave of the China Household Finance Survey ($n = 8438$ households). This is a disaggregate national-scale survey dataset developed to monitor economic conditions in China, though to the authors' knowledge the CHFS has not previously been employed to study patterns of car ownership.

We report a set of three analyses, to identify factors associated with: 1) whether a household owns at least one car, 2) multiple car ownership, and 3) whether a household owns a new car. Amongst other empirical results, we find that living in a rural area is negatively associated with car ownership, net of confounding effects, and that within towns/cities poor accessibility (i.e. long travel time) to the town/city centre is also negatively associated with car ownership. These findings regarding spatial effects are contrary to typical findings in the West, where car ownership is generally lowest in urban centres.

An earlier version of this study was presented at the 2017 Transportation Research Board conference.

1. Introduction

As of 2012, China's level of motorisation was at approximately 80 passenger cars per 1000 population, a level last seen in the United States in the year 1920 [1]. While car ownership per capita in the United States at present is approximately ten times this level, it has been broadly stable in the 2000s. China, in contrast, is motorising rapidly: car ownership per capita has grown in the 2000s at a compound rate of approximately 21% per annum, a growth rate last observed in the US also nearly 100 years ago (circa 1920) [1]. Vehicle-kilometres driven have increased There are currently more new cars being sold annually in China (21,100,000) than in either the European Union (14,300,000) or North America (9,200,000) [2]. Many informed observers expect China to continue along a trajectory of motorisation, with, for instance, Dargay et al. [3] forecasting car ownership in China to reach 270 per 1000 population by the year 2030, and the International Monetary Fund forecasting a level of 400 per 1000 population by 2050 [4].

The consequences of motorisation in China are far-reaching. In addition to local and national issues of quality-of-life and economic development for China's citizens, the impacts will be felt internationally through mechanisms such as international trade in automobiles and the global-scale climate-changing impacts of greenhouse gas emissions from China's personal-transport sector. Whilst the patterns and trajectory of car ownership in China are clearly of wider relevance outside of China, comparatively little is known in comparison to patterns in the West.

The objective of this study is to identify factors associated with car ownership in China, employing a disaggregate dataset (with individual

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Peer review under responsibility of International Association of Traffic and Safety Sciences.

https://doi.org/10.1016/j.iatssr.2017.10.001

households as the unit of observation) that is nationally-representative of Chinese households. Using logistic regression techniques, we examine three distinct dimensions of car ownership:

1. Whether or not a household owns 1 + car
2. Whether a car-owning household owns 1 car or 2 + cars (i.e. multiple car ownership)
3. Whether or not a car-owning household owns a new car (i.e. for which they are the first owner)

The first two of these dimensions can in principle be modelled via a single ordinal logistic regression model, in which the number of cars owned by a household (0 cars, 1, 2, etc.) is treated as an ordinal quantity. We chose to specify the two separate binary logistic regression models, however, in keeping with the logic of [5]. In that study Bhat and Pulugurta demonstrate that multiple independent estimations of unordered models of car ownership (e.g. 0 versus 1 +, 1 versus 2 +) more accurately capture the underlying behavioral mechanisms, because an ordered model imposes an implicit and untested assumption that the parameters governing the acquisition of a first car are identical to those of acquiring additional cars. The motivation for modeling the distinction between ownership of new versus secondhand car ownership is firstly that some car-restraint policies in China operate at the point of new-vehicle purchase (see Section 2), and that in the West there is well-established evidence that new cars are systematically driven higher annual kilometrage than older cars (cf. [6]). while the CHFS dataset does not provide the evidence required to establish whether or not this is true in China as well, it is a reason for policymakers and researchers to be interested in the correlates of new versus secondhand car ownership.

The remainder of this paper is organised as follows. Section 2 discusses this study in the context of earlier studies of car ownership in China. Section 3 describes the CHFS dataset's properties. Section 4 then presents and discusses the empirical results, and Section 5 summarises and concludes this paper.

2. Background

Within the domain of transport research, there is a long legacy of modeling car ownership, with noteworthy early studies by Mogridge [7,8], Tanner [9,10,11], and Train [12]. More recently, researchers have conceptualised a car as one type of mobility 'tool' or 'resource' that can be acquired, along with others such as a bicycle or a public transport season ticket [13,14]. In general, an important distinction in the literature is between studies in which car ownership is analysed at the *disaggregate* level (i.e. at the level of individual persons or households), or in *aggregate* form (i.e. average car ownership rates at national or subnational levels of geography). Disaggregate data provides much richer information for the analyst to work with, however it is generally more difficult to collect and expensive than aggregate data resources, and therefore less widely available to researchers.

Table 1 presents a summary of previous studies that have analysed car ownership in China. A majority of studies draw on aggregate-level data, with work by Li et al. [15] and Chamon et al. [4] being notable exceptions that have employed disaggregate data from household surveys. Neither of these two studies employed national-scale disaggregate data; Li et al. analysed data from Beijing and Chengdu, whereas Chamon et al. analysed data from 10 of China's provinces. Chamon et al. also do not report individual parameter estimates from their disaggregate modeling; the study focuses on forecasts rather than explaining existing patterns of car ownership.

Car ownership analyses in Western societies frequently employ nationally-representative travel surveys such as Britain's National Travel Survey, the United States' National Household Travel Survey, and Germany's Mobilitat in Deutschland (MiD) surveys. China does not currently have a national travel survey, however: the existing body of travel surveys typically have coverage at the geographic scale of individual districts or cities. Whereas the Western national travel surveys listed above are freely-downloadable by researchers, even the limited Chinese travel survey datasets that exist can be difficult for researchers to identify and access.

In an effort to manage the rapid pace of motorisation, Chinese cities have implemented a range of car-restraint policies that extend far beyond policies that have been employed in the West. Feng and Li [39] report that Shanghai became (in 1986) the first Chinese city with explicit policies to control car ownership. The auction-based policy has evolved over time, and is now is an open auction in which people can bid for the right to own a car via telephone and the internet. To avoid Shanghai's restrictive policies, Feng and Li report evidence of residents choosing to illicitly register their cars in other provinces. To counter this phenomenon, Shanghai's government restricts 'non-local' vehicles from entering elevated roads and the intra-city expressway system during peak hours [39]. The acceptance of the auction mechanism, the distribution of preferences across the population and its determinants are studied by Chen and Zhao [37,38]. They report that people have generally negative views on the affordability of the license, the effects on equity and the implementation process. The opacity of the disposition of the revenue and perceived inequity (e.g. government vehicles being exempt) in obtaining a license were found to exacerbate the negative view. However, Chen and Zhao demonstrate that the public believes that the auction and congestion charges are more effective than parking charges and fuel taxes. Interestingly, local car owners were found to be less opposed to the auction policy compare with non-car owners or non-local car owners, and the acceptance of the policy has increased over time.

Feng and Li also document Beijing's implementation of a lottery-mechanism car control policy in 2010. The government sets the quota based on an estimation of road capacity, emissions targets and forecast demand, and then allocate the quota to individuals, companies/organisations and operators of transportation services. The lottery processes are separate for companies and private individuals. As in Shanghai, Feng and Li report that Beijing's government also restricts non-local vehicles from entering within the fifth ring road during peak hours.

An example of a hybrid lottery/auction mechanism was implemented in Guangzhou in 2012. Feng and Li report that the system incorporates three categories: a lottery for alternative energy vehicles, a lottery for regular vehicles, and an auction for regular vehicles. Guangzhou also prevents non-local vehicles from certain parts of the road network during peak periods.

3. Description of CHFS dataset

The *China Household Finance Survey* (CHFS) dataset[1] employed in the present study follows a sampling protocol to ensure that (with the application of statistical weights to account for sampling and response biases) it is nationally-representative across China, with the exception of the following 'sensitive' regions: Tibet, Xinjiang, Inner Mongolia, Hong Kong, Macau, and Taiwan [32]. The regions that are not sampled represent 9.7% of the population of China (including Hong Kong, Macau and Taiwan).

We employ the 2011 wave of the CHFS, which includes a sample of $n = 8438$ households containing $n = 29{,}463$ household members. After removing households with missing values for any of the variables listed below, the resulting estimation sample consisted of $n = 7156$ households. The CHFS fieldwork (tablet-computer assisted personal interview) achieved a response rate of 88%, which is very high by Western standards. More recent waves of the CHFS have been performed in 2013 and 2015, however at present the 2011 data is the most recent that can

[1] The (CHFS) is provided by the Survey and Research Center of China Household Finance, Southwestern University of Finance and Economics, Chengdu, China. For additional detail regarding the dataset (beyond the summary in the present article), readers are referred to Gan et al. (32).

Table 1
Summary of earlier studies of car ownership in China.

Citation	Coverage	Data	Methods	Selected findings
(Li et al., [15])	National (aggregate analysis) & city level (disaggregate analysis)	Aggregate in city level (36 megacities, from 2006 statistical yearbooks) & disaggregate (Beijing (collected by Brown University in 2006, including 1200 households in 8 urban districts) and Chengdu (collected by Harvard University in 2005 including 1001 households))	OLS regression (aggregate analysis) & binary logit model (disaggregate analysis)	Population density at the neighbourhood level negatively associated with car ownership, whereas affluence, urban scale, and road infrastructure have positive effects on car ownership; households with private cars tend to live close to urban centres; bicycle ownership has a significant negative impact on car ownership
(Wu et al., [16])	National	Aggregate in city and region level (from China city statistical yearbook and China statistical yearbook for regional economy, 2001–2011)	Double nature logarithm model, fixed and random effect model (to capture the city-level heterogeneity)	Highway mileage per 10,000 persons, road area with pavement per capital are positively correlated with car ownership; average wage for employees dominates the growth of car ownership in metropolises; with increasing population density, car ownership will rise to a maximum level before decreasing.
(Han and Hayashi, [17])	National	Aggregate in province level (China statistical year book (1996–2006), Tabulated population census of the People's Republic of China (1993, 2002), China urban life and price yearbook (1996–2006), and China yearbook of rural household surveys (1996–2006))	Stone-Geary model	Economic conditions across regions, population migration, policies and their interactions are important factors; car ownership and pollution will reach a very high level under business-as-usual scenario
(Hao et al., [18])	National	Aggregate at national level (China statistical yearbook (2009), augmented with other data resources as noted in original study	Continuous integration model	China's vehicle population will reach 184.8, 363.8 and 606.7 million by 2020, 2030 and 2050 respectively, and will exceed the vehicle population of the U.S. by around 2025; population of urban private passenger vehicles will account for 70.1%, 81.1% and 86.1% of total vehicle population in 2020, 2030 and 2050, respectively; household income and vehicle price have significant impact on vehicle population
(Dargay and Gately, [19])	Worldwide	Aggregate at country level (Vehicle registrations and car registrations (1960–1992) from Motor Vehicle Manufacturers Association. Augmented with other data resources as noted in original study	Gompertz model	Car ownership levels will converge over the next two decades for most OECD countries; the most rapid growth within the OECD in car ownership will be in countries with low absolute incomes but high rates of income growth; for the lowest income [non-OECD] countries (i.e. China, India, and Pakistan) car ownership will grow about twice as rapidly as per-capita income.
(Huo and Wang, [20])	National	Aggregate at country level (China statistical yearbook (2005–2010)). Augmented with other data resources as noted in original study	Gompertz, logistic and Richards model	Sales of private light duty passenger vehicles in China could reach 23–42 million by 2050,with the share of new purchases representing 16–28%. The total vehicle stock may reach 530–623 million by 2050.
(Kobos et al., [21])	National	Aggregate at country level (China statistical yearbook (1990–1998)). Augmented with other data resources as noted in original study	Logistic model	Passenger vehicles per 1000 population forecast to grow from 4.22 to 54.33 from 1995 to 2025.
(Button et al., [22])	Worldwide	Aggregate at country level (the World Bank, the International Monetary Fund, the United Kingdom Society of Motor Manufacturers and Traders, the United States Department of Energy, and the International Road Federation.)	Quasi-logistic model, log-linear model	As low income countries become more prosperous, car ownership and use forecast to rise rapidly
(Chamon et al., [4])	Worldwide	Aggregate at country level (various sources, listed in original study) (1900–2006), disaggregate data (2005 Urban Household Survey covering 21,486 households in 10 provinces/municipalities, 2004 National Sample Survey Expenditure Survey covering 29,631 households)	Panel regression (aggregate analysis), ordered probit and non-parametric model (disaggregate analysis)	Number of cars will reach 2.9 billion in the world in 2050 (869 million in advanced economies, 2.0 billion in developing economies, 337 million in the U.S., 376 million in India, 573 million in China); the number of cars will reach 328.1 per 1000 population globally (824.6 in advanced economies, 261.1 in developing economies, 853.3 in the U.S., 230.7 in India, 411.6 in China); the number of cars in China will overtake the U.S. by 2031
(Wu et al., [23])	National	Aggregate at country level (Vehicle ownership data (1963–2011 from the	Gompertz model, MARMA model (GDP forecast)	China's vehicle stock growth forecast to experience an inflection point circa year

Table 1 (*continued*)

Citation	Coverage	Data	Methods	Selected findings
		International Road Federation; GDP (1963–2011) from World Bank; population (1963–2011) from World Bank		2030. The annual growth rate increases from 6.1% to 9.5% before the inflection point and drops to 0.5% by 2050
(Jiang and Zhao, [24])	National	Aggregate at country level (1986, 1999, and 2009 China statistic yearbook)	Logistic model (fitted by genetic algorithm and non-linear least square)	Logistic model predicts more precisely than BP neural network, grey prediction model and econometric models; logistic model fitted by genetic algorithm is suitable for long-term and maximum vehicle stock prediction, whereas logistic model fitted by nonlinear least square is suitable for short-term prediction
(Bao, [25])	National	Aggregate at country level (Provided by the National Bureau of statistics of China)	Gompertz model	The inflection point of car ownership increase curve of the highest income-level population will be in 2010, whereas the other income-level populations have not reach the inflection point; the number of cars per 100 population will be 9.2 and 14.7, respectively. Around 1/3 of households own cars, and this ratio will be 1/2 in 2020; higher income elasticity of car ownership for lower income populations.
(Wang, [26])	National	Aggregate at country level (World Development Indicators, 2002)	Gompertz model	Developed countries have already passed the inflection point of car ownership curve, but developing countries have not; developed countries have lower income elasticity of car ownership; the inflection point of China will be between 2015 and 2042, and the inflection point for high income population will be around 2015
(Sun et al., [27])	National	Aggregate at country-level (Chinese statistical yearbook)	Principal component analysis (PCA), linear regression, and hidden Markov model (HMM)	PCA with HMM approach is suitable for short term car ownership prediction

be downloaded. The CHFS interview collects data on the following themes:

- Expenditure and Income
- Non-Financial Assets
- Insurance and Social Welfare
- Household Financial Assets
- Household Demographics and Work Characteristics
- Household Debts

The questionnaire employed to generate the CHFS dataset can be accessed via [33] in both English and the original Mandarin. The variables from the CHFS that were employed in the present study are as follows:

- Number of cars owned by the household
- Whether the household owns any ‘new’ cars (i.e. a car for which the household is the first owner)
- Number of working (employed) adults
- Number of non-working adults
- Number of children
- Whether the household owns their primary residence
- Whether the household owns two or more residences
- Household income (RMB/year)[2]
- Whether the household lives in a rural (or urban) area
- Whether the household lives in an urban area and contains any member who does not have an urban *hukou* status (explained further below)
- Size (square meters) of primary residence
- Self-reported travel time (minutes) from the household's primary residence to the city/town centre, by whichever mode of transport of quickest
- Which of the following bands the age of the oldest household member falls within: Up to 39 years; 40 to 59 years old; 60 + years old
- Which of the following categories describes the highest level of education attained by any member of the household: High school or less; Secondary/College/Vocational; University (including graduate degrees)
- An indicator for optimism regarding the Chinese economy: which of the following categories the household's respondent self-reports regarding their expectation for the performance of China's economy in the next 3–5 years: “Better” or “Much Better”; “Almost no change”; “Worse” or “Much Worse”
- An indicator for subjective well-being: which of the following categories the household's respondent self-reports regarding their ‘Happiness’: “Happy” or “Extremely happy”; “Normal”; “Unhappy” or “Extremely Unhappy”

Hukou is a “system of population registration and control…[that is]…the central institutional mechanism defining the city-countryside relationship and shaping important elements of state-society relations…without registration, one cannot establish eligibility for food, clothing or shelter, obtain employment, go to school, marry or enlist in the army” [34,p. 644]. We included in the analysis a variable to identify households that are resident in an urban area but have at least one member whose hukou is rural. This characterises internal migrant workers, who may live in urban areas without access to public services that are available to neighbours with urban hukou status.

Table 2 reports the sets of independent variables employed in previous studies of car ownership (mainly, though not exclusively from the

[2] At the time of writing (Spring 2017), the exchange rate between US dollars and Chinese RMB is approximately $1: RMB ¥6.9.

Table 2
Variables and goodness-of-fit from earlier studies of car ownership using disaggregate data.

Citation	Independent variables analysed	Range of pseudo-r^2 (goodness-of-fit) values reported
(Bhat et al., [6])	Number of working adults; Number of non-working adults; Household income; Residential location; Dwelling unit type	0.166 to 0.275
(Giuliano & Dargay, [28])	Gender; Age; Employment; Number of adults; Household with pensioner; Presence of children; Household income; Population density; Metropolitan region population; Access to transit; Housing type; Car ownership	Car ownership correctly predicted for 71% of sample
(Potoglou & Susilo, [29])	Type of dwelling; Number of workers; Household income; Household life cycle (single, couple, single parent, couple with children, extended family, retired); Race; Residential density Location of residential area	0.111 to 0.356
(Gómez-Gélvez & Obando, [30])	Household income; Number of working adults and distance-to-workplace; Number of non-working adults; Number of children; Population density; Number of company cars;	0.20 to 0.21
(Clark et al., [31])	Life events (residential relocation, household gained partner, etc.); Household size; Cohabiting relationship in household; Presence of children; Age of the eldest householder; Age of children; Household income; Highest household education qualification; Socio-economic classification; Residential area type; Access to transit; Travel time to the nearest place of interest (food store, town center, etc.); Population density; Proportion of economically active in neighbourhood	0.045 to 0.342
Present study	*Household income; Number of working adults; Number of non-working adults; Number of children; Tenure of residence; Ownership of multiple residences; Location of residence; Travel time to city centre; Hukou status; Size of residence; Age of eldest household member; Highest education qualification; Expectations of economic growth; Self-reported happiness*	*0.072 to 0.202*

West; cf. [30]) that have employed disaggregate data, as well as the goodness-of-fit reported in each study. Notable differences with variables previously employed are that the present study employs two attitudinal variables (expectations of economic growth and self-reported happiness) as well as hukou status (which does not have a direct analog in Western countries). For comparability with the earlier literature, we report in Table 7 results with the attitudinal variables excluded.

Table 3 contains a summary of descriptive statistics for the CHFS sample, with Table 4 presenting a subset of indicators for each province. Large geographic differences in average household income can be seen, with incomes in Guangdong (a coastal province bordering Hong Kong) approximately eight times the average in Guizhou (a landlocked province in the southwest). The close correlation (Pearson's r of $+0.58$) between income and per capita car ownership can also be clearly seen; this effect is reflected in the correspondingly large differences in car ownership levels across provinces.

Prior to performing the logistic regression analyses described in the next section, we first investigated the possibility of collinearity by performing a bivariate correlation analysis between each pair of independent variables. Table 5 presents this correlation matrix; on the basis of the maximum observed absolute value of any correlation coefficient of 0.51, we determined that it would not be necessary to remove any variables due to collinearity.

4. Results

As noted in the introduction, we employed a set of binary logistic regression models [35] to evaluate three distinct dimensions of car ownership:

1. Whether or not a household owns 1 + car
   ○ The estimation sample for this model contained all households
2. Whether a car-owning household owns 1 car or 2 + cars (i.e. multiple car ownership)
   ○ The estimation sample for this model contained only car-owning households
3. Whether or not a car-owning household owns a new car (i.e. for which they are the first owner)
   ○ The estimation sample for this model contained only car-owning households

Table 3
Descriptive statistics of estimation sample ($n = 7156$ households) (Source: CHFS).

Statistic	Value
Household income in RMB (Mean)	¥60,375
Household income in RMB (Median)	¥30,225
Size of residence in square meters (Mean)	108.2
Distance from residence to city/town centre (Minutes)	40.4
Percentage of households that…	
…do not own a car	83.7%
…own 1 car	14.6%
…own 2 + cars	1.7%
…own 1 + new car(s)	13.4%
…have 0 working adults	12.4%
…have 1 working adult	19.8%
…have 2 + working adults	67.8%
…have 0 non-working adults	42.2%
…have 1 non-working adult	30.8%
…have 2 + non-working adults	27.0%
…have 0 children (age under 18)	50.9%
…have 1 child	34.0%
…have 2 + children	15.1%
…own their residence	84.7%
…own 2 + residences	15.3%
…live in an urban area and have 1 + members without an urban 'hukou' status	21.7%
…live in a rural area	48.1%
…oldest household member is aged 60 +	38.1%
…oldest household member is aged 40–59	46.4%
…oldest household member is aged 39 or less	16.9%
…no household member is educated beyond high school	62.2%
…highest level of educational attainment of any household member is secondary/college/vocational	21.0%
…highest level of educational attainment of any household member is university or above	16.9%
…household respondent indicates that they expect the Chinese economy to perform 'Better' or 'Much Better' in the next 3–5 years	79.8%
…household respondent indicates that they expect 'Almost No Change' in the performance of the Chinese economy in the next 3–5 years	7.0%
…household respondent indicates that they expect the Chinese economy to perform 'Worse' or 'Much Worse' in the next 3–5 years	13.2%
…household respondent reports generally feeling 'Happy' or 'Extremely Happy'	65.4%
…household respondent reports generally feeling 'Normal' (i.e. neither 'Happy' nor 'Unhappy')	29.1%
…household respondent reports generally feeling 'Unhappy' or 'Extremely Unhappy'	5.5%

Table 4
Summary descriptive statistics by province, using full CHFS sample (including cases with partially missing data) (Source: CHFS).

Province name	Cars per household	Cars per 1000 population	Average household income	Of all households, the percentage that live in rural areas	Unweighted sample size (households)	Unweighted sample size (persons)
Guangdong	0.45	119	¥ 152,209	31%	737	3031
Zhejiang	0.31	209	¥ 71,055	45%	567	1812
Beijing	0.29	163	¥ 92,415	0%	411	1004
Tianjin	0.27	63	¥ 60,156	0%	200	548
Shanghai	0.24	25	¥ 87,932	15%	494	1484
Shandong	0.22	85	¥ 30,834	31%	447	1345
Qinghai	0.15	34	¥ 79,112	0%	100	315
Jiangxi	0.13	17	¥ 32,078	71%	185	695
Hunan	0.12	35	¥ 39,979	27%	491	1829
Hebei	0.11	23	¥ 20,872	67%	396	1331
Henan	0.11	21	¥ 30,820	62%	646	2468
Hubei	0.10	17	¥ 33,726	69%	620	2340
Shanxi	0.10	30	¥ 33,731	53%	200	753
Heilongjiang	0.09	22	¥ 40,746	15%	427	1262
Liaoning	0.09	16	¥ 36,544	41%	321	930
Gansu	0.08	11	¥ 27,798	89%	190	830
Guangxi	0.08	26	¥ 25,970	100%	80	324
Jilin	0.08	37	¥ 32,809	59%	292	942
Jiangsu	0.08	23	¥ 55,449	52%	407	1503
Sichuan	0.06	10	¥ 33,601	75%	272	995
Yunan	0.06	15	¥ 20,331	98%	245	899
Chongqing	0.06	23	¥ 22,035	67%	175	642
Anhui	0.05	11	¥ 34,724	75%	375	1369
Guizhou	0.04	4	¥ 20,054	100%	80	332
Shaanxi	0.01	2	¥ 28,715	100%	80	341
China	***0.18***	***45***	***¥ 57,693***	***46%***	***8438***	***29,324***

Tables 6 and 7 contain estimation results for two alternative specifications of each of these three dimensions. Table 6 reports estimation results where all independent variables are included, and Table 7 reports results with attitudinal variables excluded and all other variables retained only under a criterion of $p < 0.15$ following a stepwise-with-backwards-removal specification search. Except as noted otherwise, the discussion of results in the remainder of this section refers to the reduced-specification results reported in Table 7; all effects reported in Table 7 are within ±25% of the effects in the full-specification model (Table 6).

In Models 1a, 2a, and 3a, household income is introduced directly into the set of independent variables. The parameter values can be interpreted as the elasticity of the odds of the dependent dimension (i.e. whether or not a household owns any cars, in the case of Model 1a) in response to an absolute change of ¥10,000/year. In Model 1b, 2b, and 3b, household income is introduced after taking its natural logarithm. For these models, the parameter values can be interpreted as unitless elasticities (i.e. percentage change in dependent variable in response to a 1% change in household income).

4.1. Models 1a and 1b: car-less versus car-owning households

On the basis of relative goodness-of-fit,[3] we identify Model 1b as statistically preferred over Model 1a; from Model 1b it can be inferred that the income elasticity of being a car-owning household is approximately 0.48.

Car ownership was found to be independently positively linked, ceteris paribus, with the number of working adults, the number of non-working adults, and the number of children. Of these three variables, the largest elasticity is with respect to the presence of children.

Owning one's residence is strongly positively associated with car ownership, as is owning multiple residences. Living in an urban area also correlates positively with car ownership, net of confounding effects, as does proximity (measures in travel time) to the city/town centre. The same applies for the size of one's residence.

We found no significant effect for the ‘migrant’ hukou status variable. In Table 6, we report finding that being optimistic about the future performance of the Chinese economy was *negatively* linked with car ownership; we do not have an immediate explanation for this result. Reporting that one is generally ‘Happy’ is found to be positively associated with car ownership.

Net of confounding effects, we found that households with only younger members (all under age 40) and households with highly-educated members were more likely to own cars, under ceteris paribus conditions.

Models 2a and 2b: multiple car ownership

Amongst the two models of multiple-car-ownership, Model 2a is statistically preferred. We note that the goodness-of-fit (McFadden's pseudo-r^2) of these Models (and also Models 3a and 3b) are in the range 0.10–0.12 and adjusted pseudo-r^2 values are in the range 0.07–0.08, which is substantially worse fit than Models 1a and 1b. In other words, the models we specified are much better able to explain a household's car-owning status (yes/no) than they are able to explain patterns of multiple-car-ownership or new-car-ownership.

In the models of multiple-car-ownership, no 2 + −car-owning households were observed for which the household respondent reported feeling ‘Unhappy’ or ‘Extremely Unhappy’; we therefore exclude this variable from Models 2a and 2b (See Table 6).

With one exception, all parameters in the models of single versus multiple-car-ownership (Models 2a and 2b) that are statistically significant have the same signs as the corresponding parameters in the model of car ownership versus non-car-ownership (Models 1a and 1b). The exception is that in Model 2a, households with members aged 40–59 are found to be more likely to own multiple cars than households with all members under age 40. By comparing Model 2a/2b to 1a/1b,

[3] As each Model contains the same number of variables, one method of selecting the statistically preferred specification for each of the three dimensions is to prefer the specification with the larger value of McFadden's pseudo-r^2 statistic. Other methods involve McFadden's adjusted-pseudo-r^2 statistic and the Akaike Information Criteria, though these methods are not necessary when the number of parameters in competing specifications are identical.

Table 5
Bivariate correlation between independent variables.

	Number of working adults	Number of non-working adults	Number of children	Residence is owned (dummy)	Owns 2+ residences (dummy)	Residence located in a rural area (dummy)	Household income	Indicator for urban-resident household with 1+ members without an urban hukou status (dummy)	Size of [primary] residence (m2)	Distance from residence to city/town centre (minutes)	Highest education level attained by any household member	Expectation for performance of Chinese economy in next 3–5 years (1 = 'Worse', 2 = 'Neutral', 3 = 'Better')	Self-reported 'happiness' (1 = 'Unhappy', 2 = 'Neutral', 3 = 'Happy')
Age of oldest household member	0.008	−0.362	0.164	−0.154	−0.017	−0.166	0.095	0.150	−0.092	−0.085	0.146	0.091	0.077
Number of working adults		−0.417	0.244	0.111	0.085	0.333	0.004	0.019	0.271	0.158	−0.005	−0.055	−0.005
Number of non-working adults			−0.074	0.063	0.014	−0.197	−0.016	−0.019	−0.005	−0.078	0.133	0.000	0.009
Number of children				0.035	0.043	0.090	−0.016	0.086	0.140	0.065	−0.163	−0.012	0.013
Residence is owned (dummy)					0.081	0.108	0.002	−0.115	0.174	0.003	0.004	−0.038	−0.075
Owns 2+ residences (dummy)						−0.073	0.158	0.019	0.022	−0.128	0.122	0.018	−0.065
Residence located in a rural area (dummy)							−0.127	−0.507	0.137	0.354	−0.300	−0.158	−0.011
Household income								−0.020	0.039	−0.118	0.217	0.067	−0.024
Indicator for urban-resident household with 1+ members without an urban hukou status (dummy)									0.029	−0.133	−0.077	0.018	0.017
Size of [primary] residence (m^2)										0.044	−0.038	−0.048	−0.074
Distance from residence to city/town centre (minutes)											−0.183	−0.033	0.001
Highest education level attained by any household member												0.138	0.005
Expectation for performance of Chinese economy in next 3–5 years (1 = 'Worse', 2 = 'Neutral', 3 = 'Better')													0.146

Table 6
Parameter estimates from binary logistic regression models (all independent variables retained).

	Model #1a: HH owns car(s) or not (with household income entered directly)		Model 1b: HH owns car(s) or not (with natural logarithm of household income)		Model 2a: HH owns 1 or 2+ cars (with household income entered directly)		Model 2b: HH owns 1 or 2+ cars (with natural logarithm of household income)		Model 3a: HH owns 1+ new car(s) (with household income entered directly)		Model 3b: HH owns 1+ new car(s) (with the logarithm of household income)	
Sample size (unweighted)	7156		7156		1169		1169		1169		1169	
McFadden's pseudo-r^2	0.208		0.209		0.129		0.118		0.118		0.115	
McFadden's adjusted pseudo-r^2	0.202		0.203		0.088		0.077		0.084		0.082	
	β	p	β	p	β	p	β	p	β	p	β	p
Constant	−3.489	<0.01	−7.855	<0.01	−1.780	0.158	−5.062	<0.01	0.733	0.407	0.774	0.515
Household income (¥, divided by 10,000)	0.396	<0.01	–	–	0.0915	<0.01	–	–	0.0679	0.138	–	–
Natural logarithm of household income	–	–	0.460	<0.01	–	–	0.291	<0.01	–	–	0.009	0.896
Number of working adults	0.167	<0.01	0.109	<0.01	0.271	0.025	0.205	0.087	−0.197	0.038	−0.211	0.026
Number of non-working adults	0.221	<0.01	0.199	<0.01	0.123	0.373	0.124	0.369	−0.095	0.406	−0.107	0.350
Number of children	0.345	<0.01	0.351	<0.01	0.193	0.240	0.167	0.308	0.158	0.197	0.154	0.207
Residence is owned (dummy)	1.898	<0.01	1.667	<0.01	−1.502	0.215	−1.305	0.288	1.473	0.075	1.478	0.074
Owns 2+ residences (dummy)	0.847	<0.01	0.816	<0.01	0.740	<0.01	0.753	<0.01	−0.066	0.727	−0.031	0.870
Residence located in a rural area (dummy)	−0.627	<0.01	−0.469	<0.01	−1.107	<0.01	−1.072	<0.01	−0.376	0.114	−0.384	0.107
Travel time from residence to city/town centre (minutes)	−0.011	<0.01	−0.011	<0.01	−0.005	0.360	−0.005	0.325	−0.017	<0.01	−0.018	<0.01
Indicator for urban-resident households with 1+ members without an urban hukou status (dummy)	−0.070	0.492	0.009	0.928	0.070	0.807	0.084	0.769	−0.422	0.068	−0.428	0.065
Size of [main] residence (m^2)	0.003	<0.01	0.003	<0.01	0.002	0.067	0.002	0.042	−0.001	0.294	−0.001	0.332
Age of the oldest household member is 60+	−0.959	<0.01	−0.856	<0.01	0.560	0.178	0.635	0.121	1.122	<0.01	1.141	<0.01
Age of the oldest household member is 40–59	−0.458	<0.01	−0.385	<0.01	0.614	0.067	0.629	0.057	0.801	<0.01	0.808	<0.01
Age of the oldest household member is under age 40	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–
No household member educated beyond high school level	−0.801	<0.01	−0.707	<0.01	−0.440	0.158	−0.267	0.393	−0.790	<0.01	−0.847	<0.01
Highest education level of any household member is secondary/college/vocational	−0.318	<0.01	−0.326	<0.01	−0.193	0.470	−0.091	0.727	−0.740	<0.01	−0.772	<0.01
Highest education level of any household member is university or above	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–
Expectation is that Chinese economy will perform 'Better' or 'Much Better' in next 3–5 years	−0.388	<0.01	−0.382	<0.01	−0.603	0.016	−0.589	0.017	−0.005	0.983	−0.004	0.987
Expectation is that Chinese economy will perform 'A Little Worse' or 'Much Worse' in next 3–5 years	−0.243	0.111	−0.207	0.167	−0.912	0.021	−0.770	0.042	−0.136	0.696	−0.076	0.826
Expectation is for 'Almost No Change' in performance of the Chinese economy in next 3–5 years	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–	0[b]	–
Respondent reports generally feeling 'Happy' or 'Extremely Happy'	0.536	<0.01	0.491	<0.01	–	–	–	–	0.638	<0.01	0.636	<0.01
Respondent reports generally feeling 'Unhappy' or 'Extremely Unhappy'	−0.695	<0.01	−0.578	0.017	–	–	–	–	−0.410	0.448	−0.392	0.464
Respondent reports generally 'Normal' (i.e. neither 'happy' nor 'unhappy')	0[b]	–	0[b]	–	–	–	–	–	0[b]	–	0[b]	–

Note: [b] indicates parameters fixed at zero for normalisation purposes.

our results suggest that, net of confounding effects, older households are less likely to own cars, but amongst car-owning households older households are more likely to own multiple cars rather than a single car.

We note that the estimated income elasticity of multiple-car-ownership (Models 2a/2b) is lower than that for car ownership (Models 1a/1b). Also, for Models 2a/2b the effect due to the number of working adults is larger than the effect due to the number of working adults, whereas the opposite was found in Models 1a/1b.

4.2. Models 3a and 3b: new car ownership

The final set of Models (3a and 3b) evaluated patterns of new car ownership amongst car-owning households. As noted above, explanatory power was rather low (0.08); we interpret this as likely due, at least in part, to the fact that only a small minority (16.3%) of households own cars, and that of this group a relatively small proportion (18%) own a used car. In other words, most cars owned by CHFS respondents are

Table 7
Parameter estimates from binary logistic regression models (stepwise variable selection with backward variable elimination at $p > 0.15$ criterion, and attitudinal variables excluded).

	Model #1a: HH owns car(s) or not (with household income entered directly)		Model 1b: HH owns car(s) or not (with natural logarithm of household income)		Model 2a: HH owns 1 or 2+ cars (with household income entered directly)		Model 2b: HH owns 1 or 2+ cars (with natural logarithm of household income)		Model 3a: HH owns 1+ new car(s) (with household income entered directly)		Model 3b: HH owns 1+ new car(s) (with the logarithm of household income)	
Sample size (unweighted)	7156		7156		1169		1169		1169		1169	
McFadden's pseudo-r^2	0.197		0.199		0.119		0.110		0.104		0.102	
McFadden's adjusted pseudo-r^2	0.191		0.194		0.078		0.069		0.072		0.069	
	β	p	β	p	β	p	β	p	β	p	β	p
Constant	−3.527	<0.001	−8.044	<0.001	−3.769	<0.001	−7.016	<0.001	1.231	0.140	1.231	0.140
Household income (¥, divided by 10,000)	0.405	<0.001	–	–	0.089	<0.001	–	–	–	–	–	–
Natural logarithm of household income	–	–	0.477	<0.001	–	–	0.311	<0.001	–	–	–	–
Number of working adults	0.151	<0.001	0.098	0.010	0.219	0.024	0.166	0.088	−0.179	0.018	−0.179	0.018
Number of non-working adults	0.194	<0.001	0.178	<0.001	–	–	–	–	–	–	–	–
Number of children	0.352	<0.001	0.363	<0.001	–	–	–	–	–	–	–	–
Residence is owned (dummy)	1.991	<0.001	1.711	<0.001	–	–	–	–	1.421	0.078	1.421	0.078
Owns 2+ residences (dummy)	0.869	<0.001	0.825	<0.001	0.812	<0.001	0.773	<0.001				
Residence located in a rural area (dummy)	−0.614	<0.001	−0.495	<0.001	−1.281	<0.001	−1.225	<0.001	−0.423	0.067	−0.423	0.067
Travel time from residence to city/town centre (minutes)	−0.011	<0.001	−0.011	<0.001	–	–	–	–	−0.017	<0.001	−0.017	<0.001
Indicator for urban-resident households with 1+ members without an urban hukou status (dummy)	–	–	–	–	–	–	–	–	−0.435	0.055	−0.435	0.055
Size of [main] residence (m^2)	0.003	<0.001	0.003	<0.001	0.002	0.053	0.002	0.033	–	–	–	–
Age of the oldest household member is 60+	−0.903	<0.001	−0.814	<0.001	0.694	0.030	0.794	0.016	0.968	<0.001	0.968	<0.001
Age of the oldest household member is 40–59	−0.444	<0.001	−0.382	<0.001	0.749	0.014	0.746	0.012	0.677	0.001	0.677	0.001
Age of the oldest household member is under age 40	0[b]		0[b]		0[b]		0[b]		0[b]		0[b]	
No household member educated beyond high school level	−0.859	<0.001	−0.726	<0.001	–	–	–	–	−0.713	0.003	−0.713	0.003
Highest education level of any household member is												

secondary/college/vocational−0.3410.001−0.3330.001––––−0.7110.003−0.7110.003Highest education level of any household member is university or above0[b]0[b]0[b]0[b]Note: [b] indicates parameters fixed at zero for normalisation purposes.

new cars, which reflects the rapid growth in motorisation in recent years.

A counterintuitive result from Models 3a/3b is that the effect of income on ownership of new cars versus used cars is insignificant in both specifications (Table 6 shows that it is close to significant when entered directly in Model 3a, and not close in Model 3b when entered after taking its natural logarithm). The estimated effects are positive, but the fact that they are not significant is contrary to our a priori expectations.

The effect due to living in a rural (versus urban) area is negative ($p = 0.07$), and the effect of travel time to the city/town centre is also negative. Thus households in urban areas, and specifically the central areas of urban areas, appear to be more likely to own new (versus used) cars, ceteris paribus. It is worth noting that one hypothesis of Chamon et al. [4] for the period 2008–2030 is consistent with this finding: that "*trickle-down effects, whereby used cars are sold from the richer urban areas to the poorer rural ones could also help equalize ownership rates*" [4,p. 269].

Models 3a/3b identified the only effect due to the hukou variable that is significant ($p = 0.06$). Urban car-owning households with rural-hukou-status members are, net of countervailing effects, less likely to have purchased their car(s) new.

We found (ceteris paribus) that car-owning households with older members are more likely to own a new car, that households with more-highly educated members are more likely to own a new car. Finally, we found no significant effect due to economic expectations, however reporting being 'Happy' is positively associated with having bought a new car.

5. Conclusions

In this study we present an analysis of car ownership in China that employs a novel nationally-representative household survey. A particularly noteworthy finding is that the negative association between car ownership and living in a rural area of China remains after accounting for confounding effects including income differences. This finding was robust across both specifications of income effects that we tested (with household income entered directly, or via the natural logarithm of household income). Chamon et al. [4] report that car ownership in rural areas of China is lower than in urban areas; however the authors suggest that this result is primarily an income effect ("…*mainly because several rural areas remain on average poor in absolute terms*") [4,p. 268]. Therefore, further research will be needed to determine the reasons for the divergent results on this issue (is lower rural car ownership due primarily to lower incomes, or other mechanisms?) between the present study and Chamon et al. [4], and the consequences for the future as China continues to both urbanise and motorise.

It is also worth noting that there is historical precedent for the fact that car ownership is linked positively with living in urban areas and particularly places nearest to the centres of cities/towns. Cornut et al. [36], for instance, document that in France car ownership was higher in the Paris conurbation (France's largest metropolitan region) than elsewhere in the country until the 1960s. Given that car ownership in China is now at levels experienced in the United States in the early 20th century, it will be of interest to observe whether car ownership in China's countryside in time catches up to urban areas; this is the working hypothesis behind the forecasts of Chamon et al. [4], for instance.

The pace of motorisation in China means that the number of cars owned by Chinese households may have more than doubled between the fieldwork of the 2011 wave of the CHFS and the time of writing (Spring 2017); this highlights the need for ongoing research using data resources generated more recently, and perhaps a 'backcasting' effort to determine whether changes to car ownership in China in the 2010s are consistent with the changes predicted by studies such as Dargay et al. [3], Chamon et al. [4], Hao et al. [18], and Huo et al. [20]. The far-reaching consequences of China's motorisation process mean that research to understand and document its trajectory is likely to be of wide interest to transport researchers and policymakers for many years to come.

Acknowledgments

An earlier version of this study was presented at the 2017 Transportation Research Board conference; the authors thank attendees for helpful questions/feedback which have strengthened the analysis. The authors thank two anonymous peer reviewers for useful feedback. The usual disclaimer applies: any errors in this paper are the authors' sole responsibility.

References

[1] US Department of Energy, Vehicles per thousand People: US Versus Other World Regions, Retrieved 15 April 2017 Via, 2014http://energy.gov/eere/vehicles/fact-841-october-6-2014-vehicles-thousand-people-us-vs-other-world-regions.
[2] OICA, Sales of New Passenger CarsRetrieved 15 April 2017 via http://www.oica.net/category/sales-statistics/ 2016.
[3] J. Dargay, D. Gately, M. Sommer, Vehicle ownership and income growth, worldwide: 1960-2030, Energy J. 28 (4) (2007) 143–170.
[4] M. Chamon, P. Mauro, Y. Okawa, Mass car ownership in the emerging market giants, Econ. Policy 23 (4) (2008) 243–296.
[5] C.R. Bhat, V. Pulugurta, A comparison of two alternative behavioral choice mechanisms for household auto ownership decisions, Transp. Res. B 32 (1) (1998) 61–75.
[6] England National Travel Survey Table NTS0903, Annual Mileage of 4-wheeled Cars by Fuel Type, Age and Trip Purpose, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/550502/nts0903.xls Retrieved 1 October 2017.
[7] M.J.H. Mogridge, The prediction of car ownership, JTEP 1 (1) (1967) 52–73.
[8] M. Mogridge, The Car Market, 1983.
[9] J.C. Tanner, Car ownership trends and forecasts, Transport and Road Research Laboratory Report, 799, 1977.
[10] J.C. Tanner, Long-term forecasting of vehicle ownership and road traffic, J. R. Stat. Soc. 141A (1978) 14–63.
[11] J.C. Tanner, Choice of model structure for car ownership forecasting, Transport and Road Research Laboratory Supplementary Report, 523, 1979.
[12] K. Train, A structured logit model of auto ownership and mode choice, Rev. Econ. Stud. 47 (2) (1980) 357–370.
[13] C. Weis, K.W. Axhausen, R. Schlich, R. Zbinden, Models of mode choice and mobility tool ownership beyond 2008 fuel prices, Transp. Res. Rec. 2157 (2010) 86–94.
[14] S. Le Vine, A. Sivakumar, M.E.H. Lee-Gosselin, J. Polak, A new concept of accessibility to personal activities: development of theory and application to an empirical study of mobility resource holdings, J. Transp. Geogr. (2013).
[15] J. Li, J.L. Walker, S. Srinivasan, W.P. Anderson, Modeling Private Car Ownership in China: Investigation of Urban Form Impact across Megacities, Transportation Research Record: Journal of the Transportation Research Board, Vol. 2193, Transportation Research Board of the National Academies, Washington, D.C. 2010, pp. 76–84.
[16] N. Wu, S. Zhao, Q. Zhang, A study on the determinants of private car ownership in china: findings from the panel data, Transp. Res. A 85 (2016) 186–195.
[17] J. Han, Y. Hayashi, Assessment of private car stock and its environmental impacts in China from 2000 to 2020, Transp. Res. D 13 (2008) 471–478.
[18] H. Hao, H. Wang, R. Yi, Hybrid modeling of China's vehicle ownership and projection through 2050, Energy 36 (2011) 1351–1361.
[19] J. Dargay, D. Gately, Income's effect on car and vehicle ownership, worldwide: 1960-2015, Transp. Res. A 33 (1999) 101–138.
[20] H. Huo, M. Wang, Modeling future vehicle sales and stock in China, Energy Policy 43 (2012) 17–29.
[21] P.H. Kobos, J.D. Erikson, T.E. Drennen, Scenario analysis of Chinese passenger vehicle growth, Contemp. Econ. Policy 21 (2) (2003) 200–217.
[22] K. Button, N. Ngoe, J. Hine, Modelling vehicle ownership and use in low income countries, JTEP 27 (1) (1993) 51–67.
[23] T. Wu, H. Zhao, X. Ou, Vehicle ownership analysis based on GDP per capita in China: 1963–2050, Sustainability 6 (8) (2014) 4877–4899.
[24] W. Jiang, Y. Zhao, Application Research of Logistic Model in Private Car Ownership Prediction in China, J. Indust. Technol. Econ. 11 (2010) 99–104 (in Mandarin).
[25] Y. Bao, Integrated Forecast on Car Ownership Rate of Urban Dwellers in China: Based on different income levels, Technol. Econ. 30 (3) (2011) 87–90 (in Mandarin).
[26] Y. Wang, Car ownership forecast in China-an analysis based on Gompertz equation, Research on Financial and Economic Issues, 11, 2005, pp. 43–50 (in Mandarin).
[27] L. Sun, Y. Yu, W. Gu, Car ownership prediction method based on principal component analysis and hidden Markov model, J. Traffic Transport. Eng. 13 (2) (2013) 92–98 (in Mandarin).
[28] G. Giuliano, J. Dargay, Car ownership, travel and land use: a comparison of the US and Great Britain, Transp. Res. A Policy Pract. 40 (2) (2006) 106–124.
[29] D. Potoglou, Y. Susilo, Comparison of vehicle ownership models, Transportation Research Record #2076, 2008.
[30] J. Gómez-Gélvez, C. Obando, Modeling car ownership in urban areas of developing countries: case study of Bogotá, Colombia, Transportation Research Record #2394, 2013.
[31] B. Clark, K. Chatterjee, S. Melia, Changes in level of household car ownership: the role of life events and spatial context, Transportation 43 (4) (2016) 565–599.
[32] L. Gan, Z. Yin, N. Jia, S. Xu, S. Ma, L. Zheng, Data you Need to Know about China: Research Report of China Household Finance Survey 2012, Springer, 2013.
[33] L. Gan, CHFS Questionnaire-CAPIRetrieved 15 April 2017 via http://www.chfsdata.org/intro-14.html .
[34] T. Cheng, M. Selden, The origins and social consequences of China's Hukou system, China J. 139 (1994) 644–688.
[35] M. Ben-Akiva, S.R. Lerman, Discrete Choice Analysis: Theory and Application to Travel Demand, The MIT Press, Cambridge, Massachusetts, 1985.
[36] B. Cornut, J.L. Madre, E. Boucq, L. Hivert, Diffusion of Car Ownership and Use in Paris Metropolitan Area Since the Mid-70's, PANAM - XVIII Congreso Panamericano de Ingenieria de Transito Transporte y Logistica, June 2014, Spain, 2014.
[37] X. Chen, Zhao J. Bidding to drive, Car license auction policy in Shanghai and its public acceptance, Transp. Policy 27 (2013) 39–52.
[38] X. Chen, J. Zhao, Car owners as a supporting constituency of car-deterring policies: preference variations in Shanghai's car licensing policy, Transportation Research Board 92nd Annual Meeting 2013, pp. 13–4374 Washington, D.C.
[39] S. Feng, Q. Li, Car ownership control in Chinese mega cities: Shanghai, Beijing and Guangzhou, Journeys (2013) 40–49, https://www.lta.gov.sg/ltaacademy/doc/13Sep040-Feng_CarOwnershipControl.pdf.