The Dynamics of Metropolitan Motorization under Rapid Development: the Beijing Case

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Abstract

China is undergoing a major demographic transition of rapid and intense urbanization, coupled with high and sustained economic growth, and changes in consumer behavior and industrial and economic activity. In this paper we attempt to shed light on these recent dynamics in China's capital city, Beijing, by examining household auto ownership in 2001 and 2006. Specifically, we aim to see whether the relative influence of the underlying factors affecting household ownership decisions have been changing, even over this relatively brief period. We examine auto ownership utilizing disaggregate choice models, estimated on household surveys conducted in the two years of interest. First, we estimate separate logit models of household vehicle ownership, using traditional choice model specifications. We then combine the two datasets and use the stability of preference test to assess whether the influence of the same variables has changed over the five year period. Then, for the 2006 data, we include relative location variables to examine the degree to which these also influence household vehicle choice. Finally, we employ latent class models in an attempt to capture discrete attitude and lifestyle preference differences and see whether this improves model performance. The paper offers an example of one of the first disaggregate vehicle ownership models developed in the Chinese context. The range of models employed helps reveal how household vehicle ownership choice processes may be changing over time and, in addition, how choice models can be improved for more accurate forecasting.

1 INTRODUCTION

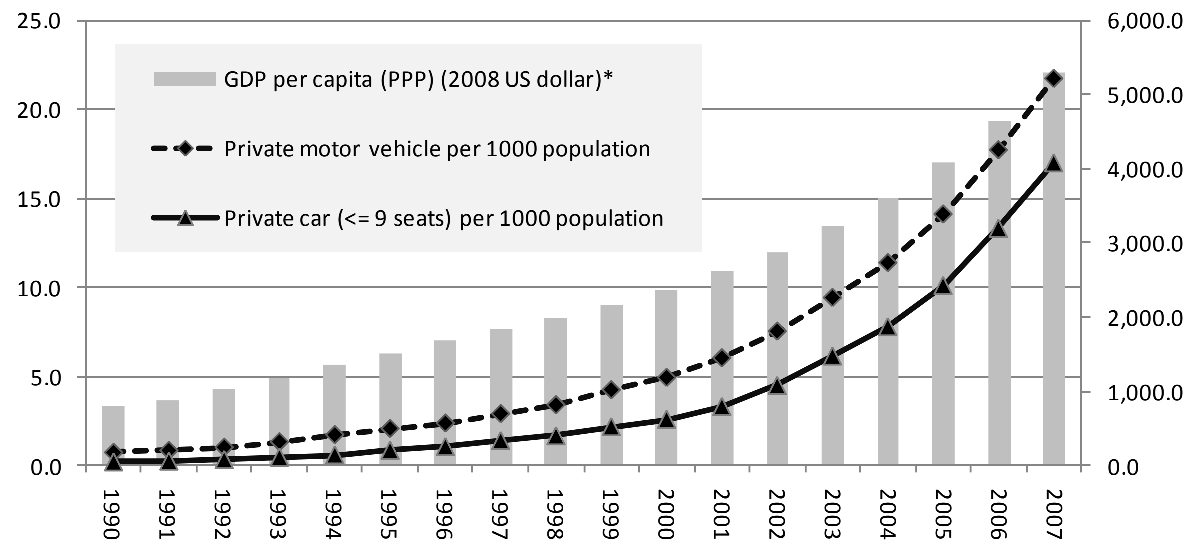
Globally, motorization – the growth in motor vehicle fleets – represents one of the most important forces driving the evolution of metropolitan-level transportation and urban development. In fact, motorization, urban development, economic and income growth, and transportation policies and investments inextricably feed each other in a complex socio-technical-economic process playing out across developing metropolitan landscapes. Income growth drives motorization, as wealthier individuals tend to prefer the privacy, speed, flexibility and status conveyed by motor vehicle ownership. Motor vehicle ownership also facilitates urban expansion, giving vehicle owners access to a greater number of potential destinations (jobs, shopping, education, etc.) and residential choices. Government transportation policies – such as road building – further enhance these dynamics, as do industrial policies promoting the motor vehicle industries. Furthermore, while motorization exacerbates roadway congestion, this may then create the perverse incentive of increasing automobile ownership and use, since congestion typically adversely impacts road-based public transportation more than private vehicles, increasing the latter's relative attractiveness. In the developing world, especially intensively in Asia, we can see the combination of these various forces in intensifying urbanization, concentration of wealth in cities, increased travel demand, and skyrocketing motor vehicle ownership. The well-known consequences may pose one of the major local, regional and global challenges of the Century.

China now looms at the vanguard of these trends. The country is undergoing a major demographic transition of rapid and intense urbanization, coupled with high and sustained economic growth, and changes in consumer behavior and industrial and economic activity. While the nation already has more than 100 cities with 1 million or more persons, just 40% of its total population currently lives in urban areas (UN, 2001). Urbanization, however, continues apace: Chinese cities will add an estimated 350 million people by 2025 and by 2030 they will be home to one billion people (Woetzel et al, 2009). At the same time, motorization intensifies; despite having national motor vehicle ownership rates just a fraction of the industrialize world, the country is already the world's fourth largest automobile producer and the third largest consumer. China's entrance into the World Trade Organization (WTO) and the rapid development in its domestic auto industry has brought about important decreases in automobile prices. In this decade, car sales have been growing by 70% per year. From 2001 to 2006, the nation's motor vehicle fleet more than doubled, reaching 37 million, approximately one-half of which were private automobiles (China Statistical Year Book, 2007). By mid-2007, the nation's private vehicle motorization rate (vehicles per 1000 persons) surpassed 24 (see Figure 1), with levels much higher in the wealthier cities. If China continues to follow the trend of motorization growth due to ongoing economic development, the nation's car fleet could exceed 100 million within the next 10 to 15 years (Schipper and Ng, 2004), presenting massive challenges in the form of congestion, infrastructure requirements, local and global air pollution, and national and international energy security.

Perhaps nowhere are these trends more on center stage than in the nation's capital, Beijing, especially with the attention generated by the 2008 Olympics. This dense city is expanding rapidly, as people in-migrate in search of jobs while the the skyrocketing housing market drives people to the outskirts. The built-up area of Beijing in 2007 is 2.6 times as large as it was in 2000. Increasing incomes and dropping automobile prices further fuel mobility demands and, in response, the city paved more than 74.6 million square meters (or more than

1800 kilometers) of new roads in five years between 1997 and 2002. The recently completed 6th ring road circumnavigates the city at approximately 15-20 kilometers from the city center. Nonetheless, traffic congestion has become the new image of Beijing, with peak hour gridlock increasingly the norm. Furthermore, Beijing's air pollution problem has become tenacious; transportation plays an important role accounting for 77% of total emissions of carbon monoxide (CO), 78% of hydrocarbons (HCs), and 40% of nitrogen oxides (NOx) in Beijing[1].

Figure 1. Growth in Motor Vehicles and Income in China: 1990-2007



Data Source: Car number and population data: China Statistical Year Book 2007 and 2008; PPP data: IMF 2008 World Economic Outlook

In this paper we attempt to shed light on the recent motorization dynamics in Beijing by examining household automobile ownership in two different, recent time-slices: 2001 and 2006. Specifically, we aim to see whether the relative influence of the underlying factors affecting household ownership decisions have been changing, even over this relatively brief period. In the next section we review the methodological literature of vehicle ownership studies and briefly describe our methodology. We then introduce the Beijing case, hypothesizing on major factors we think influence private car ownership in the city. Using two disaggregate datasets in Beijing for 2001 and 2006 we estimate a serie of models to examine these hypothesis. Based on these models we estimate income elasticities of auto ownership in Beijing and produce some initial forecasts of the vehicle fleet. We conclude with policy implications and areas for additional study.

2 LITERATURE AND METHODOLOGY

Studies on household vehicle ownership can be divided into two basic categories, those using aggregate data and those using disaggregate data. Aggregate analyses model vehicle ownership at zonal, urban, or national levels, and can be used for inputs into travel forecasting models, and/or for intra-city, inter-city, or international comparative efforts, to derive, say, the income elasticity of demand for motor vehicles, and/or develop forecasts of future vehicle fleets.

[1] 2000 data (Schipper and Ng, 2004)

Examples include Beesley and Kain (1964), who use data from 45 U.S. cities in 1960 to predict automobile ownership as a function of median household income and gross city-wide population density; Button et al (1993), who develop sigmoidal car ownership models using time-series data for a number of low-income countries; and Ingram and Liu (1997), who use aggregate data for an international spectrum of cities. Holtzclaw et. al. use aggregate data from three U.S. cities and show the influence of residential density on vehicle ownership (Holtzclaw, 2002). For a more detailed categorization and complete comparison, please see De Jong et. al. (2004)

Disaggregate models typically use household level data to examine more detailed behavioral relationships at the decision-maker level. Typically, the implicit or explicit behavioral theory underlying disaggregate models is utility maximization; households or individuals are assumed to choose, from a range of possible alternatives and under income and other constraints, the alternative which provides the greatest utility. This leads to the application of Random Utility Models (RUM) of discrete choice. The "randomness" comes from the inherent stochasticity of the modeled choice processes, captured by random variables representing utilities (M. Bierlaire, 1997) and the discrete nature of the choice comes from the nominal or ordered nature of the outcome of interest (e.g., one car). For most static vehicle ownership models using only cross-sectional data, researchers have used different model structures depending upon the question asked and the characteristics of the dataset: e.g. Multinomial Logit (MNL), Nested Logit (NL), Ordered Logit (ORL), etc. Most studies reveal that the key factors influencing car ownership include income, cost of car travel, and household structure (e.g., Lerman and Ben-Akiva, 1979, Dargay, 1999). Studies have also examined, in the same basic way, the relationship between vehicle ownership and the physical and functional characteristics of the physical context, such as dwelling unit density or relative levels of transportation service. For example, using an ordered logit model, Cambridge Systematics (1997) find significant effects of population density on household vehicle availability in Philadelphia. In a binary logit sub-model of car ownership, Giuliano and Dargay (2006) find density has a negative impact on car ownership in both U.S. and U.K., while access to transit has negative impact on car ownership in the U.S. Examining the case of rapidly developing Santiago de Chile, Zegras (2010) finds that, while household income dominates the choice to own the first automobile, the decision to own additional vehicles is increasingly influenced by dwelling unit density, proximity to the central business district, and improved bus levels of service relative to the auto.

Despite numerous studies done in the developed countries, very few studies have focused on private car ownership in Chinese cities using disaggregate models, in large part due to lack of data. We might expect the behavioral patterns of private vehicle ownership in countries such as China to be different from that of the wealthier countries. As only a small fraction households, those with the highest incomes, can afford a private car, most households remain below the vehicle ownership threshold. At the same time, actual and expected income growth, lifestyle changes, etc. mean that many households soon expect to purchase a car – a decision which may carry as much symbolic value related to status, aspirations, and transition to the "modern middle class" (see, e.g., Vasconcellos, 1997) as purely utilitarian mobility value. In other words, owning a private car can have very strong psychological effects or symbolic meanings associated, or as Wu et al. (1999) assume: the utility of household vehicle ownership consists of a substantive utility and a symbolic utility. Those authors used a survey, including with questions regarding attitudes, of heads of households in Xi'an, China and find that that vehicle ownership attitudes resulting from psychological and sociological factors apparently influence vehicle ownership preference. They also find that a more expensive vehicle offers more symbolic meaning, and economic influences in the symbolic utility of a vehicle tend to diminish as "Veblen effects" (i.e. consumers exhibit a willingness to pay a higher price for vehicles that have more symbolic meanings) are declared.

2.1 Our Approach

In this paper, we utilize two cross-sectional surveys, representing two recent years, 2001 and 2006, in Beijing, to estimate automobile ownership models. The two different year surveys and their contents allow us to examine a number of different potential effects and changes in those effects, utilizing binary logit models. We compare model results across the two years to see if people's preferences – e.g. sensitivity to income or household size – have changed. For the more recent 2006 dataset, as residential locations are available, we also add those to the model to examine potential locational effects on vehicle ownership. . Finally, we estimate a latent class choice model for the 2006 case, to capture the potential effects of the heterogeneity of people's lifestyles or attitudes/preferences on car ownership decisions.

3 THE BEIJING CASE

Beijing offers an interesting case to analyze recent household automobile ownership dynamics. Not only are relatively good disaggregate household data available for the early 2000s, but the city's residents have experienced rapid income growth at the same time as vehicle ownership costs actually declined over the time period. In this section we describe the primary data source used, describe some of the most prominent relevant characteristics that the data reveal, and formulate a number of hypotheses to be tested formally in the ownership models.

3.1 Data

Like in other developing countries, original disaggregate data in China are difficult to obtain. For our analysis, we utilize surveys conducted by the *Multi-City Study of Urban China*, a collaborative project of a group of scholars from universities in China and the U.S. who have been meeting together since 2001 as a working group of the Urban China Research Network.[2] Specifically, we use two surveys done by the research group "Residential mobility and Urban restructuring under marketization" for Beijing. The first survey was conducted by the Hong Kong Baptist University research team in 2001. With the cooperation of the Population and Labor economic research group in the China Social Science Institute, a Brown University research team conducted the second survey in 2006.

The questionnaire designs for the two years are very similar in terms of contents, questions, formats, and coding. For both years, about 60 communities were selected using Probability Proportional to Size (PPS) sampling in the eight urban districts of Beijing: the number of communities surveyed is proportional to the number of urban households in each district. Then households are randomly selected and the household heads were surveyed on living condition, moving history, access to services and facilities, as well as basic socio-economic characteristics of each household member. After eliminating records without available income number, the 2001 survey has 1553 effective records, without distinguishing between local residents and migrants. The 2006 survey divides the respondents into local residents (1118 households) and migrants (266 households), so we include both to have it comparable with the 2001 survey, assuming that the 2001 survey included migrants given the sampling approach.

[2] For more details, go to the project website: http://www.s4.brown.edu/ChinaProject/

Therefore we have a total sample of 2937 households in the combined 2001-2006 dataset. While the datasets contain very rich demographic information, location data are very coarse (only the centroids of surveyed communities in 2006 are available, see Appendix Figure A1); public transportation or road conditions are unavailable.

3.2 Data Description and Hypotheses

From Table 1, we can see that the number of private cars/1000 households almost tripled from 2001 to 2006. Over the five year period between the two surveys, the share of households owning private cars tripled, from 4% to 13% (Figure 2). Although the road area per capita in the city increased from 6.11 m^2 to 7.4 m^2, road area per private car dropped from 95 m^2 to 54 m^2 (Table 1). The most prominent driver of private car ownership seems to be income. According to Beijing Statistical Year Books, the income of urban residents almost doubled in these five years (Table 1). We might expect the income or relative cost effect on car ownership to be strong.

Table 1 Motorization Rate and Related Demographic Statistics in Beijing from 2000 to 2006

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Population (million) *	13.64	14.63	14.23	14.56	14.93	15.38	15.60
Private Car (million)	0.49	0.62	0.81	1.07	1.25	1.49	1.81
Number of Private Cars/1000 Population	**35.9**	**42.4**	**56.9**	**73.5**	**83.7**	**96.9**	**116.1**
CPI (% of last year)	103.5	103.1	98.2	100.2	101.0	101.5	100.9
Disposable Income (urban residents) (yuan/year)		10,981	12,464	13,888	15,638	17,653	19,978
Road Length (km)	3,624	4,245	5,444	7,948	7,483	15,948	5,866
Road Area (10,000 sq. m)	4,199	5,917	7,645	10,570	11,213	16,227	9,858
Road Area Per Private Car (sq. m)	85	95	94	99	90	109	54
Paved Road Area Per Capita (sq.m)	3.7	6.11	7.02	9.6	9.45	10.55	7.4

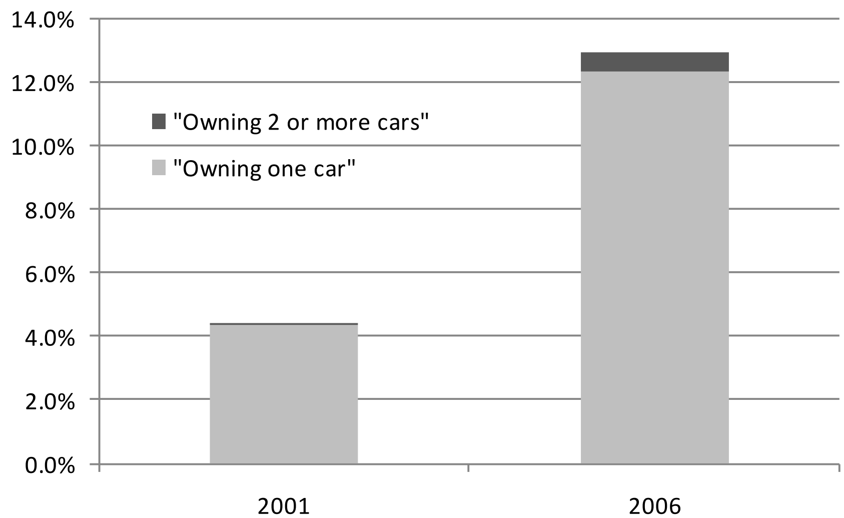
Data Source: Beijing Statistical Bureau (http://www.bjstats.gov.cn/), China Statistical Year Book 2001-2007, Beijing Statistical Year Book 2001-2007
** year end residents who have been living in Beijing for at least 6 months (chang zhu ren kou)*

The period 2001 to 2006 represents the first five-year period since China entered the World Trade Organization (WTO); during this period car prices decreased considerably. For example, one "FuKang" (a popular model of domestically-built family cars) cost 120,000 yuan ($15,000) in 2001 but only 70,000 yuan ($9,000) in 2006.[3] The average price of domestically manufactured cars dropped 40% to 50% in those five years.[4] The price of mid-and low-price family cars (100,000 yuan ~ 150,000 yuan) dropped the most and modestly priced cars in the 30,000 yuan to 70,000 yuan range emerged and also became very popular. The price drop since 2001 accelerated the rate of potential realization of many people's dream of owning a car.[5] In terms of ownership and operating costs, surveys show that currently a 100,000 yuan car costs on

[3] *Beijing News* (http://news.xinhuanet.com/auto/2006-12/11/content_5466383.htm, access date: July 21, 2007)
[4] *News Evening*, December 08, 2006 (http://www.smelz.gov.cn/news/103973.htm, access date: July 21, 2007). This is a very rough estimate. There was no passenger car average price index (CAPI) until Jan 2004 when "Online Car Market" (cheshi.com.cn) began to develop one. From Jan 2004 to July 2006, the CAPI decreased by 18%.
[5] Xinua News, http://news.xinhuanet.com/auto/2006-12/10/content_5462470.htm (Access date: July 23, 2007)

average 20,000 to 30,000 yuan per year in gas, insurance, maintenance, parking, etc.[6] We were unable to get accurate data on the costs of car use in 2001 and 2006 in Beijing, but we believe the rough trend is an increasing one.[7] However, whether these "car-use costs" increase actually offset the drop in car purchase price is unclear and we do not have enough data to test it.[8]

Figure 2 Percentages of Car-owning Household in 2001 and 2006 Surveys



Households tend to use cars for purposes other than just commuting, such as for family travel (especially weekends), household errands (kids), tending to family emergencies, etc. Indeed, the 3rd Comprehensive Household Travel Survey in 2005 shows a very different mode share (excluding walking trips) for all purposes relative to the journey-to-work; in particular, we can clearly see a much larger share of private car use for reasons other than commuting (Figure 3). Therefore we suspect that many households buy their private cars for family-related reasons, the influences of which will increase with the number of family members. Therefore besides number of employed household members (needs for commuting), household size might be a strong contributor to the utility of owning a car, as a larger family has more complicated and demanding mobility needs.

One relatively unique characteristic of passenger car growth in Chinese cities relates to the historical role of the "company car." Until the 1990s when the government relaxed the restriction on private ownership of passenger vehicles, the majority of the car fleet in China was traditionally owned by the government, state-owned enterprises, and other businesses (Riley, 2002). These government/business/company owned vehicles tended to be used for private purposes in the past, thus providing private mobility for government officials, high-rank managers, etc. in cities. In the 2001 survey, the same percentages of heads of household (1.2%) commuted with the business/company car as drove their own cars. In the 2006 survey, 3.3% of heads of household commuted by business/company cars, and 5.3% of total heads of household drive their own cars for commuting (Figure 4). Having access to a business/company car might have a two-fold effect on private car ownership: on the one hand, people get used to driving or

[6] Sina Auto News (http://auto.sina.com.cn/z/sjyanghuqgl/index.shtml, access date: July 21,2007)
[7] For example, standard 93# gasoline price in Beijing rose from 2.4 yuan/L to 5.09 yuan/L (see Appendix Figure A2), registration fee, car insurance, and parking charges also increased.
[8] People usually underestimate costs of owning and using cars when making the purchase decision.

the “lifestyle with a car,” so that company car access increases the likelihood of car ownership; on the other hand, free access to the business/company car reduces the need for car ownership. We will attempt to shed light on these effects in the models in the following section.

Figure 3 Mode Split Difference for All Purposes and Commuting Only (Excluding Walking)

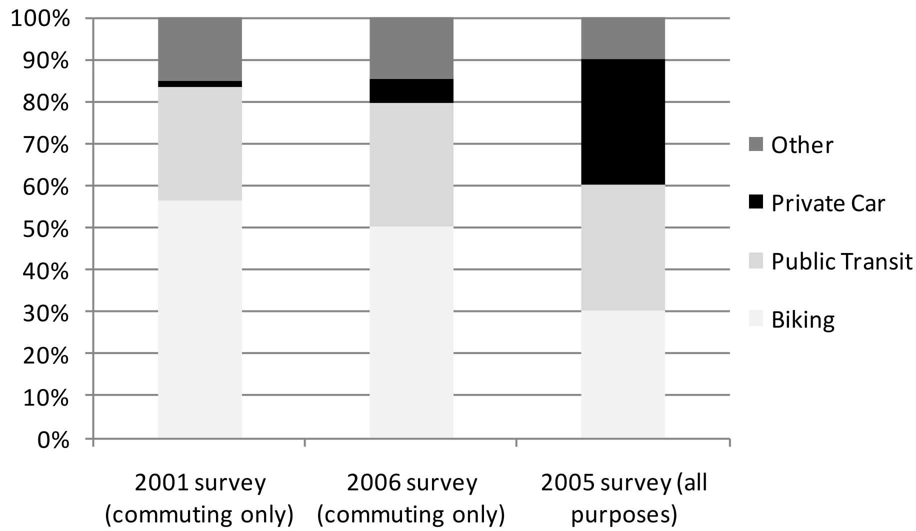
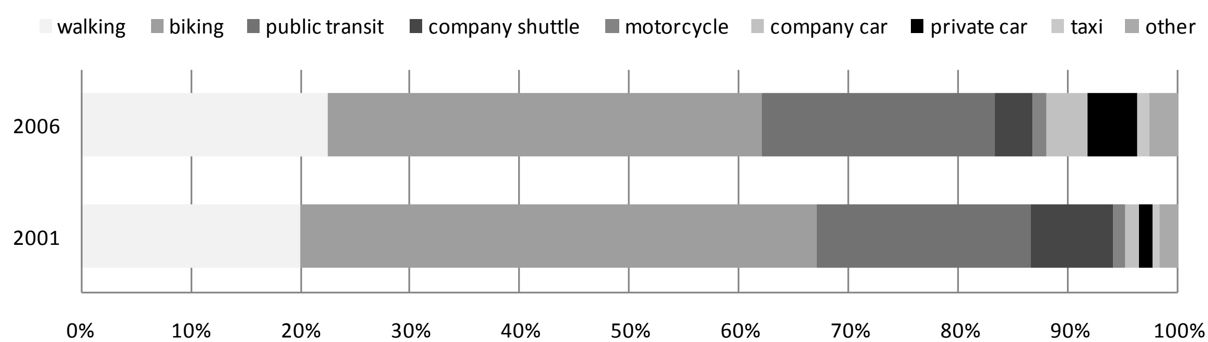


Figure 4 Commuting Mode Split for sample Beijing Residents in 2001 and 2006 survey



We also hypothesize that people’s preferences have changed over the five years analyzed. For example, while we do not have individual car price and car use costs data, we can only estimate the income elasticity for the utility of owning a car. With the drop of car purchase price, we might expect that people are less income elastic. Also family structure is changing: average household size in Beijing decreased from 2.9 in 2000 to 2.7 in 2005. We might also suspect some change in the preferences concerning household size as well.

We also suspect that the distance of residential location to center city will have effect on the utility of owning a car, as the further away from city activity center, the more utility a car will bring. We also hypothesize that discrete lifestyle preferences exist, that these lifestyles are not directly identifiable from the data, and that people with different lifestyles will exhibit different car ownership choice behavior. We test this hypothesis via application of a latent class model with lifestyle segments. Such a model may help us better understand different car ownership mechanisms within population groups, make stronger policy implications, and will produce better prediction as well.

4 Model Specification and Results

Household vehicle ownership represents a categorical variable, so disaggregate auto ownership models typically take the discrete choice form. This choice could be represented by an ordered (e.g., ordered-response logit, ORL) or unordered (e.g., multinomial logit, MNL) mechanism and both forms have been used in other research (e.g., Cambridge Systematics 1997; Cambridge Systematics, 2002). Bhat and Pulugurta (1998), however, based on analysis of four different data sets, find the unordered (i.e., MNL) model to outperform the ORL model (according to several measures of fit), leading them to conclude that the unordered response choice mechanism better represents the household auto ownership decision. In our case, however, due to the very small share of households with more than one car (0.06% in 2001 and 0.7% in 2006), we simply use the binary logit approach, modeling the household's choice "to own a car" or "not to own a car."

Most car ownership studies in the literature find the relationship between car ownership and household resource variables such as income to have the logarithmic form. The logarithm of per capita income turns out to have the best fit in our case. In terms of company car effects, the Sydney Strategic Transport Model (Hague Consulting Group, 2000) showed modeling private car ownership conditional on company car access to be the best structure. We therefore use access to company car directly as exogenous explanatory variable in our models.

First we estimate the models for 2001 and 2006 separately, testing different variables and model specifications. We then combine the datasets to examine whether people's preferences have changed. In the 2006 model, we then add location variables and, finally, estimate a latent class choice model structure to capture the heterogeneity of lifestyle/attitudes.

4.1 Variables Tested in the Car Ownership Models

Table 2 presents the variables of interest in the various vehicle ownership models and our hypothesized effects. Table 3 presents the average values for those variables for the 2001 and 2006 datasets.

Table 2 Variables Tested and Hypothesized Effect on Car Ownership

Variables	Hypothesized Effect on Car Ownership
Household Demographics	
Number of household members	Positive, as big family has larger mobility needs
Couple with kid	Positive, as having a kid has larger mobility needs
Young household head (a)	Positive, as young people tend to like speed and modern lifestyle
Single-person family	Negative, as single person has much smaller mobility needs
Household Resources	
Household Income	Positive, as more resource to spend
Ln (per capita Income in 1,000 yuan)	Positive, as more resource to spend
Access to a Company Car (b)	Unclear, two-fold effects might exist
Number of employed household members	Positive, as commuting needs increase
Home Owner	Positive, as homeowners have less financial burden
Residential Location	
Living Outside the 3rd Ring (c)	Unclear
Living Close to Subway (d)	Negative, as people have better transit accessibility
Living in House built after 1990	Positive, as those houses have better parking and driving condition
Living in House built after 2000	Positive, as those houses have better parking and driving condition

(a) Dummy variable: whether the household head is younger than 40 years old;
(b) Dummy variable: whether the household head or the spouse of household head use company/business car for commuting;
(c) Dummy variable: whether the household lives outside the 3rd ring road, chosen from a set of dummy variables representing the location by between which two ring roads. Interestingly (see table 3), people living within the 3rd ring road (near the city center) are more likely to own more cars while the average income is relatively low and more accessible to subway.
(d) Dummy variable: whether the household lives in community located within 800 meters of the subway line.

Table 3 Descriptive Statistics (Means, Proportions) of Variables in 2001 and 2006 datasets

Variables	2001	2006	
Count	1544	1381	
Owning at Least One Car	4.4%	13.0%	**
Household Demographics			
Number of household members	3.26	2.80	**
Single-person Family	6%	10%	**
Couple Family	16%	20%	**
Couple-with-Kid Family	47%	50%	
Age of Household Head	58.5	47.8	**
Household Resources			
Household Income	26,540	34,355	**
Per Capita Income	9,414	13,633	**
Access to a Company Car	1.9%	3.8%	**
Number of Employed Household Members	1.49	1.51	
Home Owner	64%	60%	**
Female Household Head	38%	37%	
Residential Location			
Living within the 2nd Ring		11.3%	
Living outside the 2nd but inside the 3rd Ring		26.1%	
Living outside the 3rd but inside the 4th Ring		20.5%	
Living outside the 4th but inside the 5th Ring		27.6%	
Living outside the 5th Ring		14.6%	
Living Close to Subway		26.2%	
Living in House built after 2000		4.4%	

Note: ***Dummy Variables are shown in percentages***
*****Indicates Two Means/Proportions are different at the 99% level***

4.2 Preference Change from 2001 to 2006

Table 4 presents the model results for the choice models of vehicle ownership: binary logit models for the 2001 and 2006 datasets estimated separately, and a nested logit for the combined 2001 and 2006 cases. Starting with the separate models, we can see that the 2001 model has stronger explanatory power (adjusted rho-square for the 2001 model is 0.735 versus 0.525 for the 2006 model). In both cases, the coefficient for ln(per capita income) is positive as expected and significant at the 5% level, showing, as expected, that urban households have a higher likelihood of owning a car as income increases. The coefficient for household size is also positive and significant at the 5% level in both models, showing a that ownership likelihood increases with more people in the household. Homeownership increases the relatively utility of car ownership in the 2006 case; this may be the case because: 1) housing purchase is still the first priority of households in Beijing, and homeowners have less burden; 2) renters have more flexibility in residential location (e.g., choosing to be close to their working places, transit stations, or other frequently-visited activity centers and therefore less in need of cars; 3) the symbolic utility of owning a car is more cherished by homeowners. We do not have the data necessary to validate these reasons but the results suggest an area for further exploration.

Table 4 Model Estimation Results (Binary Logit for 2001, 2006, and Nested Logit for the combined)

	2001		2006		Combined		
Variables	β	*robust-t*	β	*robust-t*	β	*robust-t*	
Alternative Specific Constant 2001	**-5.91**	**(-8.51)**			**-10.34**	**(-7.60)**	
Alternative Specific Constant 2006			**-7.44**	**(-12.06)**	**-7.35**	**(-11.77)**	
Ln (per capita Income in 1,000 yuan)	**0.85**	**(4.12)**	**1.53**	**(8.48)**	**1.52**	**(8.54)**	
Number of household members	**0.23**	**(2.50)**	**0.51**	**(6.22)**	**0.48**	**(6.34)**	
Access to a Company Car	**1.03**	**(1.91)**	**1.21**	**(3.92)**	**1.26**	**(4.28)**	
Home Owner	0.45	(1.54)	**0.55**	**(2.65)**	**0.59**	**(3.09)**	
Living Outside the 3rd Ring			**-0.42**	**(-2.27)**	**-0.42**	**(-2.29)**	
Living Close to Subway			-0.31	(-1.60)	-0.32	(-1.65)	
Living in House built after 2000			0.52	(1.31)	0.52	(1.30)	
scale parameter for 2001 dataset					**0.59**	**(-3.37)**	*
L(β)	-279.26		-447.04		-726.68		
Adjusted ρ^2	0.735		0.525		0.637		
Number of observations	1550		1381		2931		

* robust-t to test whether the scale parameter is significantly different from 1

Note: In the parentheses are the robust t statistics of the coefficient; coefficient estimation is bold if it is significant at the 5% level.

Access to a company car shows a positive effect on private car ownership, with the coefficient significant at the 10% level for the 2001 data and at the 5% level for the 2006 data. The reasons why access to a business/company car may actually increase the utility of owning a private car might include: 1) people use the company car must obtain a drivers license and learn to drive, thus inducing vehicle ownership propensities; 2) using a company car gives people the experience of owning cars, getting used to a car-owning lifestyle, and therefore further increasing the likelihood of car ownership; and/or 3) access to a company car influences people's sense of "status," such that the company car provides the first taste of the "symbolic utility" of private car ownership. In any case, we see that the company car is associated with higher car ownership likelihood among Beijing households.[9]

From Table 4, for 2006 we can see that households living within the 3rd ring road are more inclined to own private cars than those who live outside the 3rd ring road, after controlling for income, household size, homeownership, access to company car, housing type, and subway access. This result seems counter-intuitive as we might expect a positive sign due to shorter commuting distance and worse road condition (presumably more congestion) for people living closer to the city center. However, identifying household location at this aggregate spatial scale may mask more complex information, especially when there are many possible omitted variables

[9] We might suspect that people employed at the level of "manager" (i.e., with the title of manager) might have a higher likelihood of vehicle ownership even after controlling for income, as such individuals might have a higher value of time; however a dummy variable indicating whether the household head has a "manager" title, does not have a significant effect in either model. The correlations between manager title and access to a company car are small in both datasets (Ideally we would use a variable indicating whether the household head *or* the spouse of household head has a manager title, but such information is not available in the data.

leading to other directions as in this case. Nonetheless, it is worth pointing out that other recent analyses of vehicle ownership in Chinese cities have found a similar negative relationship between distance to city center and vehicle ownership (e.g., Li et al, 2010; Jiang, 2010). Again, these results, which run counter to studies in the West, suggest an area worth further study.

In our models, the data limitations suggest that we may still have a number of possible omitted characteristics of relevance including: 1) other income-related effects not captured by ln(per capita income) such as "symbolic utility" and lifestyle effect; 2) public transport conditions and levels of service; 3) driving conditions such as available road area (e.g., more road area within the 3rd ring might increase the utility of car ownership; 4) employment location, e.g. there are self-sufficient and job-housing balanced new towns outside the 3rd ring road, however, the variable we tested "whether living in the working-unit community" is not significant enough to support this argument; 5) availability of company shuttles; 6) school location; etc. With the available data we cannot narrow down the range of possible explanations, but one thing is clear: factors influencing private car ownership go beyond socioeconomic and demographic variables like income, and crude land use-related variables like inner-city vs. suburban do not seem to have a simple relationship with private car ownership in Beijing.

Now, to see if households have stable preferences with respect to these variables from 2001 to 2006, we combine the two datasets and account for the scale difference, as different samples usually result in different variances in the error terms. We hypothesize that people's preferences vis-à-vis ownership effects of income, household size, or other variables might change over time. To test whether these coefficients have changed over this brief five-year period, we employ the stability of preference test, which is essentially a likelihood ratio test, enabling us to compare two separate models: the restricted model, in which coefficients for both datasets are set to be the same, and an unrestricted model, with a scale parameter for one dataset. Surprisingly, the model passes the stability of preference test strongly.[10] The result indicates that households' preferences with respect to income, household size, homeownership, and access to business/company car did not change from 2001 to 2006. However, the estimated coefficients on the alternative specific constants are significantly different, which implies some missing variables, as discussed above; therefore the combined model should not be used for forecasting.

Returning to the differences in the explanatory power of the two models, the adjusted rho-square for the 2006, while still high, is still smaller than the 2001 model. This suggests that more factors, outside of our models, influenced private car ownership in 2006 than in 2001. However, we might also suspect that the survey and data collection process brought more "noise" in the 2006 data. However, the estimated scale parameter for the 2001 dataset is significantly less than 1 at the 5% level (while the scale parameter for the 2006 dataset is set to be 1), meaning that the variance of the error terms in the 2001 dataset is bigger than that of the error terms in the 2006 dataset, so it seems that the latter has less "random noise" in the data. Given that, as the same four variables account for less variance in private car ownership choice in 2006 than in 2001 (adjusted rho-square is much smaller even with three more additional explanatory

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[10] The stability of preference test is:

H_0: $\beta^{2001} = \beta^{2006}$ (stability of preference)

H_1: $\beta^{2001} = \beta^{2006}$ (there is no stability of preference)

Degrees of Freedom = (# of parameters in unrestricted model) - (# of parameters in combined restricted model) = 3
$LR = -2 * (L_{restricted} - L_{unrestricted}) = -2 * (-726.68 - (-279.26-447.04)) = 0.39 < \chi^2_{0.05,3} = 7.82$, therefore we cannot reject the null hypothesis that there is stability of preference at the 5% significance level. Therefore we can use the combined model for estimation and forecasting.

variables), we can somewhat confidently conclude that in the five years between 2001 and 2006 an increasing number of factors have begun influencing private car ownership among Beijing's households.

4.3 Latent Class Choice Model for 2006

As we hypothesize that discrete lifestyle preferences exist, and that people with different lifestyles will exhibit different car ownership choice behavior, we now employ a latent class choice model structure in an attempt to develop a more informative model.

The latent class choice model is comprised of two components: a class membership model and a class-specific choice model as shown in Appendix Figure A3. The class-specific choice model represents the choice behavior of each class and varies across latent classes. This class-specific choice probability is written as $P(i \mid X_n, s)$: the probability of decision maker *n* selecting alternative *i*, conditional on its own attributes or alternative attributes X_n and conditional on *n* belonging to latent class *s*. The class membership probability is $P(i \mid X_n)$: the probability of decision maker *n* with attributes X_n belonging to latent class *s*. Since the class of each decision-maker is unknown, neither of the above equations can be estimated individually. Rather, the two components are estimated simultaneously via a latent class choice model (for additional details see Walker and Li, 2006):

$$P(i \mid X_n) = \sum_{i=1}^{s} P(i \mid X_n, s) P(s \mid X_n) \quad (1)$$

We specify the class-specific choice model as:

$$U_{ns}^{Car} = \beta_s X_n + \varepsilon_{ns}^{Car} \quad (2)$$

$$U_{ns}^{Non-Car} = \varepsilon_{ns}^{Non-Car} \quad (3)$$

Where n = 1,2,…N (N = 1381 households), s = 1,2,…, S (S = number of latent classes). ε_{ns}^{Car} and $\varepsilon_{ns}^{Non-Car}$ are iid extreme value across all household *n*.

It is somewhat tricky to distinguish which variables should enter the choice model and which ones should be in the membership model, especially when alternative specific characteristics are limited. Intuitively, when certain households with similar lifestyles, attitudes, and sensitivity (i.e., in one latent class) make the choice of owning a car, the direct utility/disutility should contain the direct costs, total motor vehicle travel demand (activities, trip rates, and travel distance), time saving, comfort, and other benefits of owning a car. All other socioeconomic characteristics should be in the membership model to predict which latent class this household belongs to. Therefore, the model specification is different from the binary logit model discussed above, where all variables enter the utility function in one layer through either direct or indirect influence. Here in the class-specific choice model: Ln(per capita income) is an approximation for relative costs of owning a car for each household, as individual car costs are not available so identical Ln(costs)'s cancel out; the number of employed household members is a proxy for the commuting demand of the household; and residential location variables are aggregate accessibility measures, including proximity to subway. All other socio-demographic attributes of households are used in the class membership model, including access to company car, home ownership, household structure, and income level, which we assume influences car ownership indirectly through household lifestyle and attitude.

We estimated the model using LatentGold Choice 4.0, obtaining results for s = 1, 2, 3, 4. Considering AIC, AIC3, BIC,[11] as well as the coefficient estimation results, one 3-class model is chosen as the best model specification (see shaded row in Appendix Table A1).

Table 4 Class Membership Estimation Result (3-class model)

	Class1	z-value	Class2	z-value	Class3	z-value
Intercept	**9.64**	**(2.93)**	5.07	(1.70)	**-14.71**	**(-2.48)**
Household structure						
single	**4.23**	**(2.03)**	**5.34**	**(2.28)**	**-9.58**	**(-2.31)**
couple	**2.96**	**(2.19)**	2.9	(1.86)	**-5.86**	**(-2.21)**
couple with kid	0.43	(0.66)	**2.07**	**(2.60)**	**-2.5**	**(-2.13)**
number of household members	**-1.04**	**(-2.13)**	-0.01	(-0.03)	1.05	(1.47)
Household Head Characteristics						
whether household head is female	1.12	(1.86)	**1.71**	**(2.53)**	**-2.83**	**(-2.47)**
whether household head is under 30 years old	**-4.39**	**(-2.88)**	**-3.7**	**(-2.41)**	**8.09**	**(2.82)**
whether household head is aged between 30-50 years old	-0.9	(-1.45)	1.71	(1.84)	-0.81	(-0.70)
whether household head is floating population (not permanent citizen)	1.07	(0.86)	0.06	(0.05)	-1.13	(-0.48)
Household Resources						
whether annual household income is less than 30k RMB	-1.05	(-1.07)	**-3.97**	**(-3.43)**	**5.02**	**(2.69)**
whether annual household income is more than 100k RMB	-4.09	(-1.40)	**-9.78**	**(-2.14)**	**13.87**	**(2.92)**
whether household head or spouse has access to a company car	-3.84	(-1.49)	**-8.87**	**(-2.26)**	**12.71**	**(3.08)**
whether household owns the housing they live	**-4.48**	**(-2.76)**	**-4.51**	**(-2.73)**	**8.99**	**(2.82)**

**** Coefficients significant at the 10% level are marked bold.***

From the class membership model results (Table 4 and Appendix Table A2), we can generalize the characteristics of these three membership classes. Households are divided into three segments: one group of them (class 3) is characterized by high-income, large family, male-headed, relatively young, permanent resident, homeowner, and very noticeably, having access to a company car (almost all households with access to a company car are in this group). This result is consistent with our proposition that access to a company car positively influences car ownership through changing people's lifestyle. This group of households has very high propensity to own a car (41%) compared to the rest of the population (see Table). We call them "big, young, and affluent, with pro-car lifestyle" households. Class 2 is a group of households characterized by traditional core family structure of "a couple with kid," middle-aged household head, with mid-level household income, primarily not homeowners. This group has a more modest propensity, 20%, to own a car. We call this group the "traditional core family." A little over than half of total households belong to the third group (class 1), characterized by old and small-sized families with low household income, with a large number "floating population" (i.e.,

[11] See Vermunt and Magidson's Technical Guide for Latent Gold Choice 4.0, the AIC (Akaike Information Criterion) in Latent Gold Choice 4.0 is equal to *-2*(LL(β)+ 2K*. K is the number of parameters estimated. Akaike Information Criterion 3 (AIC3) is equal to *-2*(LL(β)+ 3K.* The adjusted rho-squared is equal to *1-(LL(β)-K)/LL(0)* where *LL(0)* is the log-likelihood of a naive model with no parameters. The BIC (Bayesian Information Criterion) imposes a harsher penalty on the number of parameters than the AIC and adjusted rho-squared; the BIC formula is -*2*LL(β)+ln(N)*K* where N is the number of respondents. Results by Andrews and Currim (2003) and Dias (2004) suggest that AIC3 is a better criterion than BIC and AIC in determining the number of latent classes in choice models.

not formally residents of Beijing) belonging to this group. They have the lowest car ownership propensity. We call them "incomplete and unstable" households. Overall, we find that household structure, age and gender of household head, household income, homeownership and access to a company car are major predictors of class membership.

Table 5 Estimated Propensity of Car Ownership Choice in Each Class

Set Average (n=1381)	Class 1 (54%) *Incomplete and unstable*	Class 2 (35%) *Traditional core family*	Class 3 (10%) *Big, young, affluent, pro-car lifestyle*	overall
Own a car	3%	20%	41%	13%
Not own a car	97%	80%	59%	87%

Although only 10% of all households fall into the "big, young, and affluent" class, it might be expected that its proportion will increase in the future in Beijing as income continues to rise steadily and higher educated young people move to the capital city for higher-paying jobs, and to establish their family. The "traditional core family" class will remain a stable share while the "incomplete and unstable" class membership is expected to fall. This possible membership trend poses a great challenge of private car ownership in Beijing.

Table 6 Class-specific Model Estimation Results (3-class model)

		Class1		Class 2		Class 3	
	Variables	***coefficient***	*robust-t*	***coefficient***	*robust-t*	***coefficient***	*robust-t*
	Alternative Specific Constant	**-19.26**	**(-2.74)**	**-4.72**	**(-4.20)**	**-4.02**	**(-4.43)**
Relative cost	Ln (per capita Income)	**3.12**	**(3.93)**	**1.46**	**(3.62)**	**1.14**	**(4.09)**
Commuting demand	Number of household members employed	**1.18**	**(2.50)**	-0.02	(-0.13)	**0.72**	**(2.31)**
Road condition	Living Outside the 3rd Ring	**-2.16**	**(-2.40)**	-0.14	(-0.49)	-0.42	(-0.91)
Alternative utility	Living Close to Subway	7.44	(1.19)	**-1.74**	**(-3.02)**	-0.54	(-0.96)
Parking availability	Living in House built after 2000	-5.6	(-0.30)	0.30	(0.44)	1.72	(1.43)

**** Coefficients significant at the 5% level are marked bold.***
***** Coefficients that are significantly different across classes at the 10% level (Wald test) are shaded grey***

The detailed results in Table 6 allow us to see how the car ownership behavior varies across these three classes. It makes sense that, considering the relative costs of owning a car, the "big, young, and affluent" class has the lowest income elasticity, while the low-income "incomplete and unstable" group is more sensitive to income changes. When income rises, each group increases car ownership probability with the largest change in the "incomplete and unstable" group in the short term; in the longer term, households move into the other two groups with a higher car ownership propensity. The low-income "incomplete and unstable" group also has the highest sensitivity to increased commuting demand – reflected by an increase in the number of household members employed – because cars are mainly used for commuting for this group. The other two groups with much higher propensity of car ownership are less sensitive to commuting needs. Especially for the "traditional core family" group, the increase of commuting demand does not have a significant ownership effect. This is consistent with our previous proposition that the greatest demand for private cars comes from activities other than commuting. Living close to the subway has significantly negative effects on car ownership only for the "traditional core family" group, indicating a possible target group when developing public transportation facilities. It seems that living in a newly built home has a positive effect on "big, young, and affluent" households as well.

In terms of policy implications, it is important to be aware of the different preferences of different groups. The growing "big, young, and affluent" households with pro-car lifestyle will continue to account for the majority of car ownership increase in the future. We suspect that access to a company car helps these households establish a pro-car or pro-driving lifestyle, which has much stronger effect on increasing private car ownership rather than serving as an alternative. Job-housing balance might not be an effective measure to reduce car ownership because the groups with the strongest car ownership propensities are not as sensitive to commuting demand as the low-income "unstable" group. Newly built housing with better parking availability seems to matter only to home owners. Traditional core families are sensitive to subway availability, but it does not mean that other groups are not. Additional data and analysis would help to make more accurate vehicle ownership predictions and thereby enable better assessments of various policy options.

5 BEIJING'S MOTORIZATION IN CONTEXT

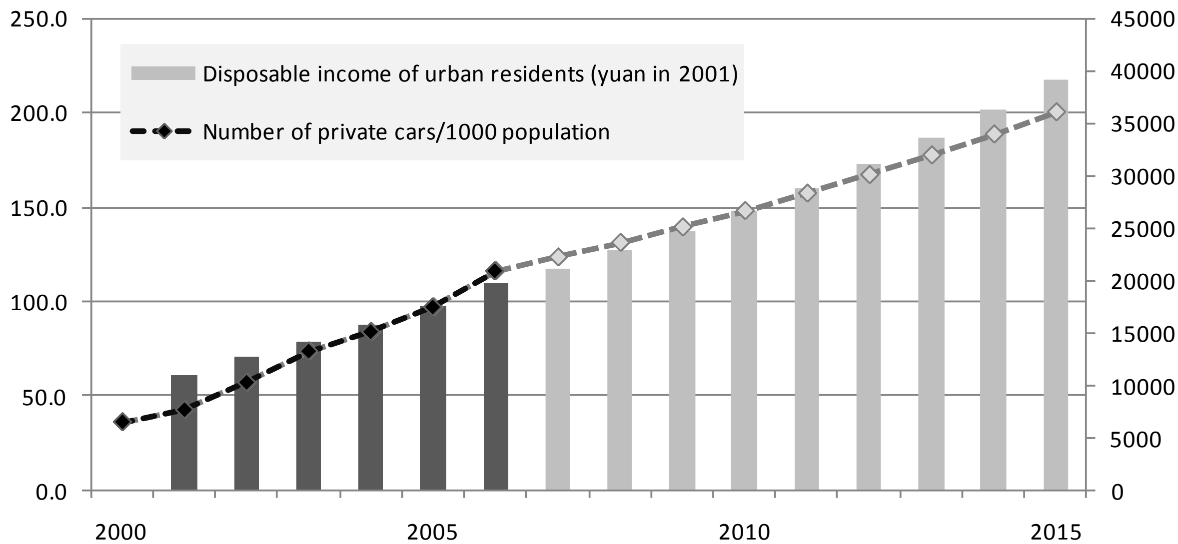
Since increasing income seems to be the major driving force of motorization, the elasticity of car ownership with respect to income is one of the most important factors when we make forecasts. We can find various examples in the literature. Using aggregate 1980 data from 35 large cities around the world (29 in the developed countries and 6 in the developing countries), Ingram and Liu (1997) found the income elasticity for private car ownership to be 0.5,[12] while Kain and Liu (1994) found it to be 1.02, using 1980 data from 60 world cities (see Ingram and Liu (1999) for a more complete list of aggregate income elasticity estimates). Using pseudo-panel data for the UK, Dargay and Vythoulkas (1999) estimated the income elasticity for car ownership to be 0.3 in the short run and 0.7 in the long run. The change of income elasticity over time seems to have different directions for countries or cities at different motorization stages. Button et al (1993) used country-level data from most developing nations from 1968 to 1987 and found income elasticity for car ownership to increase as one nation's economic development progresses (from 0.5 to 1.1). Dargay (2001) shows cross-section income elasticity for car ownership in UK cities to have declined from well above unity in 1970, to significantly below unity in 1995. Using disaggregate household survey data, Matas and Raymond (2007) also found income elasticity for car ownership in large cities of Spain to be declining (0.676, 0.590, and 0.548 for the year 1980, 1990, and 2000, respectively), showing that income's effect in driving up car ownership diminishes as the level of motorization increases and saturation approaches.

Disaggregate elasticities represent the sensitivity of an individual's choice probability to a change in the value of some attribute (Ben-Akiva and Lerman, 1985). Our study provides another case of large urban area in the developing world for which we can examine the income effect on motorization. Specifically, we calculate the income elasticity using sample enumeration and weighted by household's estimated probability of owning cars. For the year 2001, the income elasticity for car ownership is 0.781; and for the year 2006, the income elasticity is 1.141 using the binary logit model, or 0.854 using the latent class model. The increasing income elasticity over time indicates that at this early motorization stage, large urban areas like Beijing will continue to see more rapid rises in car ownership, driven by income, if other factors do not change – a result consistent with global experience. However, as the aforementioned preference stability test shows, people's income sensibility toward car ownership does not seem to have

[12] Due to lack of data, they used country-level income data for city-level income.

changed from 2001 to 2006, after correcting for differences in the error term variance – it is very likely that the larger random noise in the 2001 dataset makes its elasticity estimations smaller in magnitude than those in the 2006 dataset. Using the 2001 elasticity to be conservative, we still expect Beijing to face serious urban transportation challenge due to increasing private car ownership driven by income increase alone, all else equal. One car in every five resident means at least 4 million private cars on street for Beijing in 2015 (conservatively assuming a population of 20 million in Beijing; see Figure 5). This scenario already seems to be too conservative – as in 2009, Beijing already has over 3 million private cars and on average, 171 persons in a thousand has their own cars[13].

Figure 5 Car Ownership Increase Driven by Income Increase--Conservative Scenario



Ultimately, concerns about motorization relate not only to the overall magnitude – that is, a city's total motor vehicle fleet size – but also the rate of increase, as this rate tends to outpace relevant physical and institutional capabilities. Motorisation is a fundamental driving force behind increases in transportation greenhouse gas emissions, pressures for land conversion to urban uses, dependency on petroleum, and demands for infrastructure expansion.

CONCLUSIONS

using binary logit models to analyze factors affecting private car ownership in Beijing in 2001 and 2006, we found that: access to business/company car has a positive effect on private car ownership. Households seem to have very stable preferences in terms of income, household size, homeownership, and access to company car toward owning private cars. However, during the fast changing period of urbanization, motorization, and urban transformation, factors influencing private car ownership in Beijing are much more than just socioeconomic and demographic variables like income or household size. Crude relative location variables like inner-city vs. suburb do not seem to have simple relationship with private car ownership. Heterogeneity in lifestyle/attitude does exist in car ownership decisions as captured by the latent class models

[13] Calculation based on Beijing Economic and Social Development Report for 2009, Beijing Bureau of Statistics, 2010

estimated. Three groups of households are identified in Beijing: "big, young, affluent families with pro-car lifestyle," "traditional core families," and low-income "incomplete and unstable" households. The growing "big, young, and affluent" households will continue to account for the majority of car ownership increase in the future, and we suspect that access to a company car helps them establish a pro-car or pro-driving lifestyle. Job-housing balance policies might not be an effective measure to reduce car ownership because the groups with strongest car ownership propensities are not as sensitive to commuting demand as the low-income unstable group.

More studies should continue the effort to help us understand the behavioral mechanisms underlying private car ownership in Chinese cities, and more rigorous data collection and models should be developed to improve our forecasting capabilities and policy relevance.

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APPENDIX

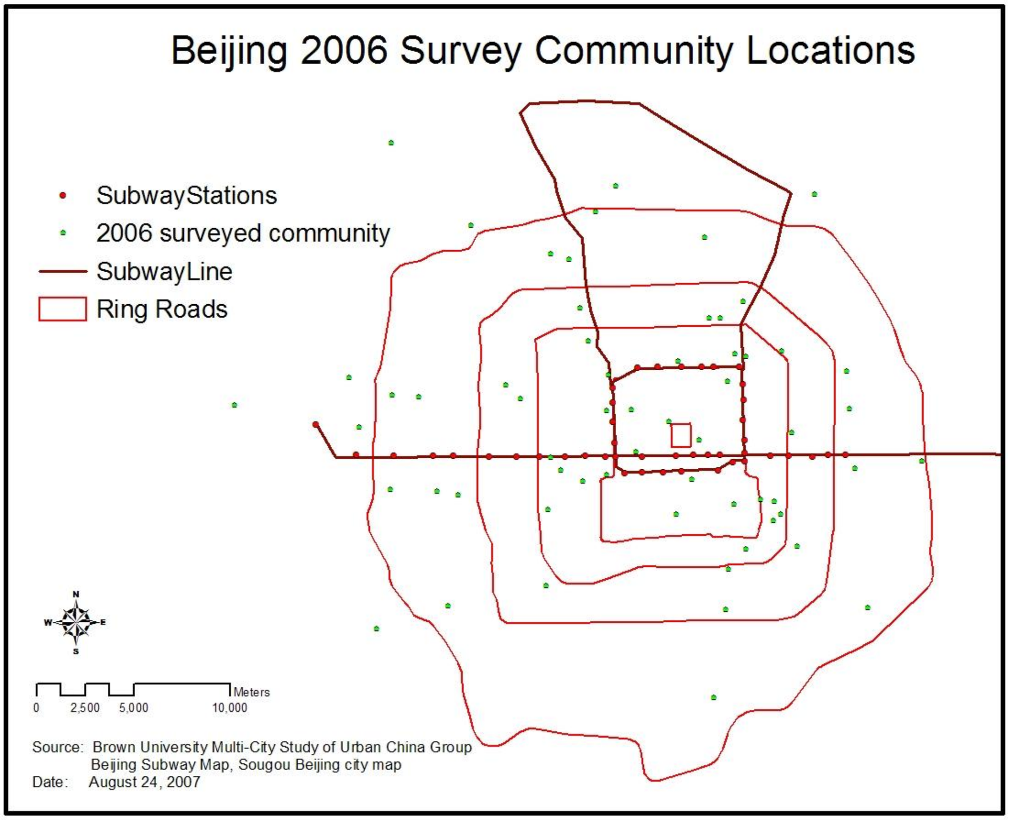

Figure A1 Beijing 2006 Surveyed Community Locations

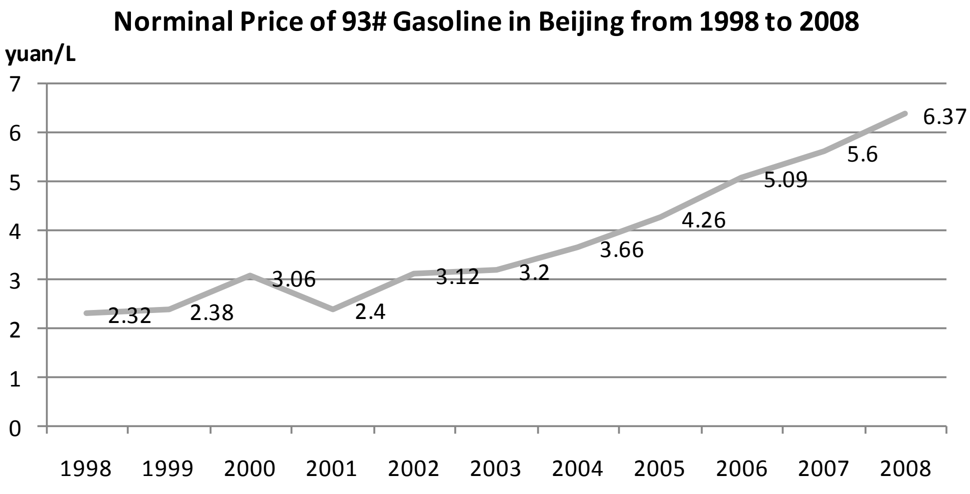

Figure A2 Gasoline Price in Beijing from 1998 to 2008 (nominal price yuan/L)

Source: original data collected from http://auto.sina.com.cn

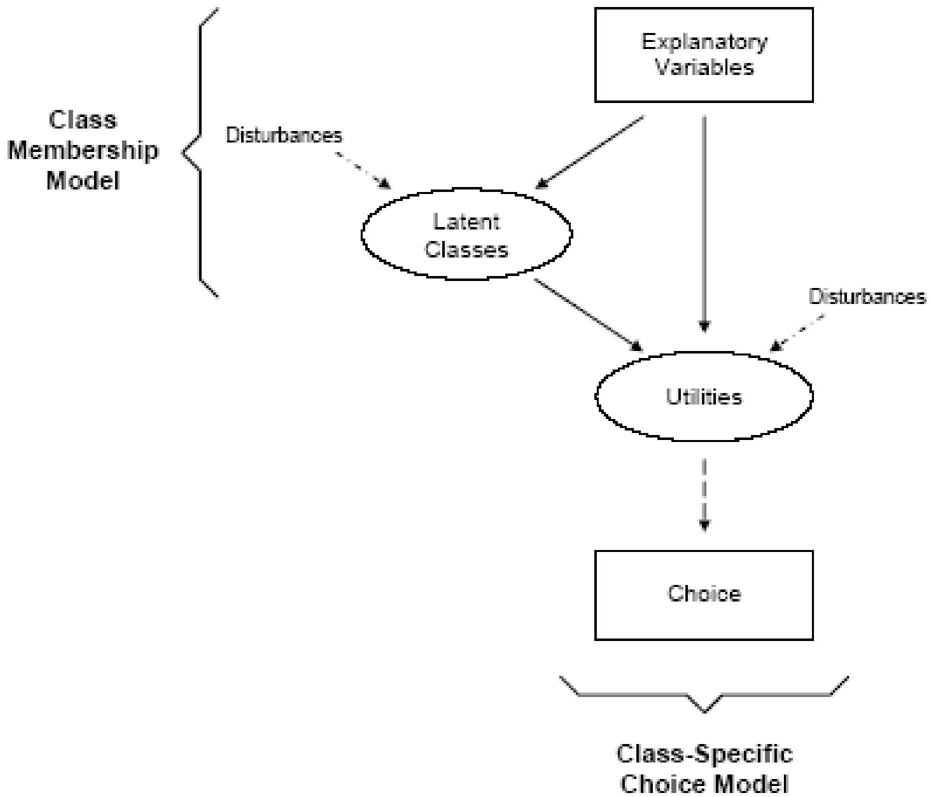

Figure A3 Latent Class Choice Model Structure (Walker and Li, 2006)

Table A1 Sample Latent Class Choice Model Results Comparison

		LL	BIC(LL)	AIC(LL)	AIC3(LL)	Npar	df	Class.Err.	$R^2(0)$	R^2	Adjusted ρ^2
Model15	1-Class Choice	-460	970.6	933.99	940.99	7	1175	0	0.6	0.12	0.51213703
Model2	2-Class Choice	-427.65	1036.05	905.29	930.29	25	1157	0.11	0.82	0.6	0.52712811
Model3	3-Class Choice	-396.96	1112.06	881.91	925.91	44	1138	0.09	0.69	0.31	0.53934035
Model5	3-Class Choice	-392.02	1102.19	872.04	916.04	44	1138	0.17	0.72	0.38	0.54450104
Model6	3-Class Choice	-402.7	1094.62	885.4	925.4	40	1142	0.1	0.71	0.36	0.53752262
Model17	3-Class Choice	-393.82	1113.02	877.65	922.65	45	1137	0.13	0.9	0.78	0.54157595
Model20	4-Class Choice	-372.64	1208.03	873.27	937.27	64	1118	0.15	0.87	0.71	0.54385334

Table A2 Class Membership Profile (3-class model)

		Class1	Class2	Class3
Class Size		54%	35%	10%
whether household owns the housing they live				
	0	0.52	0.33	0.04
	1	0.48	0.67	0.96
Mean		0.48	0.67	0.96
whether household head is female				
	0	0.65	0.56	0.78
	1	0.35	0.44	0.22
Mean		0.35	0.44	0.22
single				
	0	0.83	0.97	0.99
	1	0.17	0.03	0.01
Mean		0.17	0.03	0.01
couple				
	0	0.7	0.93	0.92
	1	0.3	0.07	0.08
Mean		0.3	0.07	0.08
couple with kid				
	0	0.64	0.28	0.52
	1	0.36	0.72	0.48
Mean		0.36	0.72	0.48
whether household head is floating population (not permanent citizen)				
	0	0.71	0.91	0.98
	1	0.29	0.09	0.02
Mean		0.29	0.09	0.02
whether household head is under 30 years old				
	0	0.85	0.97	0.88
	1	0.15	0.03	0.12
Mean		0.15	0.03	0.12
whether household head is aged between 30-50 years old				
	0	0.65	0.33	0.57
	1	0.35	0.67	0.43
Mean		0.35	0.67	0.43
whether annual household income is less than 30k RMB				
	0	0.35	0.81	0.5
	1	0.65	0.19	0.5
Mean		0.65	0.19	0.5
whether annual household income is more than 100k RMB				
	0	0.99	1	0.8
	1	0.01	0	0.2
Mean		0.01	0	0.2
number of household members				
	1	0.16	0.02	0.01
	2	0.38	0.11	0.11
	3	0.37	0.65	0.53
	4-8	0.09	0.22	0.35
Mean		2.41	3.18	3.54
access to a company car				
	0	0.98	1	0.72
	1	0.02	0	0.28
Mean		0.02	0	0.28