Private Vehicle Ownership in Provincial China

by Patrick McCarthy and Junda Wang

Private vehicle ownership has rapidly grown with China's economic development and increasing incomes. This paper analyzes China's provincial demands for private vehicles during the post-opening period 2000 – 2012. Based on estimates from pooled, fixed effects and Hausman-Taylor models, private vehicle ownership during this period grew at an average annual rate of over 20%, all else constant. The study focuses on the roles of economic, spatial, investment and regulatory factors in shaping private vehicle demands. The study finds that increases in GDP per capita and vehicle use cost reinforce and constrain, respectively, the strong trend toward increased ownership. And absent changes in population density, higher percentages of the population in urban areas increase the demand for private vehicles. But increasing population density provides stronger incentives for reducing vehicle demands. Municipal restrictions aimed at reducing the congestion and environmental effects of vehicle ownership and use are effective in reducing provincial demands. A separate analysis of provinces that are at least 60% urbanized identifies important differences. Vehicle demands are income elastic and infrastructure investments have stronger effects in the most urbanized provinces than in less urbanized provinces.

INTRODUCTION

With the rapid development of China's automobile industry, continuous improvements in road infrastructure, and rising disposable incomes, China entered the era of increased private vehicle consumption in 1997. During the period of China's "planned economy" (1953-1980), its vehicle sector focused on the production of vehicles for firms, government agencies, and social groups. Subsequent to the opening in 1997, the vehicle sector expanded its focus toward private vehicle consumption. In 1997, the civilian (i.e., non-government) vehicle ownership was 12 million and private vehicle ownership was 3.6 million (29%). A short 15 years later, in 2012, civilian vehicle ownership was 109 million and private vehicle ownership was 88 million, accounting for 81% of civilian vehicles. These increases in civilian and private vehicle ownership represent a staggering 808% and 2,340% increase, respectively, and a substantial change in the structure of China's vehicle industry. China continues to have one of the highest annual motorization growth rates in the world (Figure 1). The total number of private vehicles in the country increased from 9.67 million in 2002 to 123.39 million in 2014. The motorization rate rose from 7.54 vehicles per 1,000 persons to 90.21 vehicles per 1,000 persons in the same time period. Whereas some analysts had predicted that China's motorization rate would grow to 54 vehicles per 1,000 by 2020, an average increase of 7.3% annually (Energy Information Administration 2000), Figure 1 indicates that China`s motorization rate far exceeded those predictions well before 2020.

For the 2002-2014 period, Table 1 reports private vehicle ownership in total and per 1,000 persons, GDP per capita (Gu et al. 2010), and total and urban population. During this 13-year period, private vehicle ownership grew at an annual rate of 21.6%, 65% higher than the large increase in per capita GDP and nearly six times higher than annual growth in urban population. Further, due to lower birth rates that are often attributed to the overall level of socioeconomic development and to family planning programs in the 1970s and 1980s, including the government's well-known one-child policy, China's population growth remained small during this period, with an annual 0.48% increase per year. China's strong vehicle growth has also given rise to well-documented negative effects of private vehicle ownership: significantly worsening traffic congestion, air pollution and associated health effects, vehicle-related fatalities and injuries, and greater dependence on oil imports (Ministry of Environmental Protection 2012). As a highly populated developing country and with increasing urbanization, road congestion and poor air quality are common phenomena in China's megacities (e.g., Beijing, Shanghai, Guangzhou and Shenzhen). Shenzhen, for example, has the highest vehicle density in China at nearly 500 vehicles per square kilometer. Motor vehicles in China's major cities are responsible for 50% to 60% of air pollution, emitting 46.12 million tons of pollutants in 2012 (National Bureau of Statistics China (http://www.stats.gov.cn/enGliSH/)). Globally, seven of the top 20 cities with the most serious air pollution are in China (Zhang and Crooks 2012). China recognizes the importance of this. In a report on key government initiatives for 2017, the seventh initiative focuses on environmental protection. Among its strategies for improving air quality is a significant reduction in older high polluting vehicles, retrofitting pollution abatement technologies on vehicles, and encouraging the use of clean energy vehicles (Keqiang 2017). Consistent with this, a number of larger and more congested cities in China have adopted various policies to reduce these negative externalities, including restrictions on vehicle ownership and use and, more recently, congestion pricing strategies.

Figure 1: Private Vehicle Ownership in China, 2002–2014

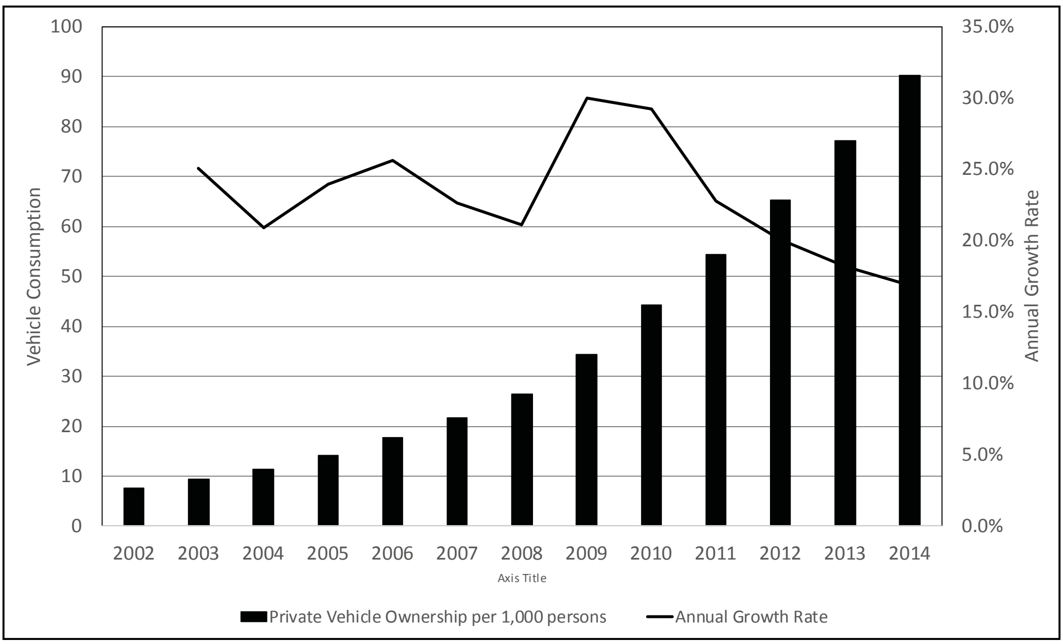

Table 1: Private Vehicle Growth in China, 2002–2014

Year	Private Vehicles (millions)	Per Capita GDP (Yuan)	Population	Urban Population (million)	Private Vehicles per 1,000 Persons
2002	9.69	9,419.94	1,284.53	502.12	7.54
2003	12.19	10,567.81	1,292.27	523.76	9.43
2004	14.82	12,363.79	1,299.88	542.83	11.4
2005	18.48	14,217.00	1,307.56	562.12	14.13
2006	23.33	16,558.38	1,314.48	582.88	17.75
2007	28.76	20,284.68	1,321.29	606.33	21.77
2008	35.01	23,851.43	1,328.02	624.03	26.37
2009	45.75	25,899.53	1,334.50	645.12	34.28
2010	59.39	30,494.44	1,340.91	669.78	44.29
2011	73.27	35,931.53	1,347.35	690.79	54.38
2012	88.39	39,446.62	1,354.04	711.82	65.28
2013	105.02	43,213.80	1,360.72	731.11	77.18
2014	123.39	46,490.77	1,367.82	749.16	90.21
Annual Growth Rate	21.62	13.07	0.48	3.13	21.04

Source: Authors' calculations. China Statistical Yearbook 2014 (National Bureau of Statistics of P.R. China, 2014).

The research reported in this paper focuses on provincial demands for private vehicles from 2000 to 2012. The paper's objectives are to identify those factors that are important determinants of private vehicle consumption in China's provinces and to explore how private vehicle ownership varies across provinces.

Relevant Literature

Reflecting the importance of motor vehicles and motor vehicle travel to a nation's economy, and mobility and a population's quality of life, there is an extensive literature on the demand for vehicles and a number of excellent studies that survey the state of knowledge on vehicle demands, including DeJong et al. (2004) and Xu (2011). Focusing on aggregate private vehicle demand across China's provinces, Table 2 reports the representative literature on aggregate vehicle demands in low income or developing countries. As is true for research on developed countries, the studies in Table 2 reflect two related aspects of car or vehicle ownership: 1) long-term forecasts that relate income growth to vehicle ownership, and that typically estimate ownership saturation at which point further increases in income have no or very little impact on ownership; and 2) analyses that focus on a broader set of determinants, including policy relevant factors.

Aggregate Saturation Models. When developing forecasts and modeling saturation, studies often adopt quasi-logistic and Gompertz growth models.[1] These are probability models that generally include vehicle ownership saturation over time (as a function of gross domestic product or other measure of income). In these frameworks, vehicle ownership increases slowly at low GDP per capita, then rises more sharply, reaches an inflection point after which vehicle ownership rises more slowly. Tanner (1958) was first to construct and estimate an aggregate logistic model that provided insights on the behavior of vehicle ownership rates, marginal growth and a saturation level.

Dargay and Gatey (1999) analyzed data for 26 countries from 1960 to 1992 using Gompertz growth models with a dynamic specification in order to estimate short-run and long-run income elasticities of car and vehicle ownership. The estimated income elasticities range from 2.0+/- for some low-income and middle-income levels, down to zero, as ownership saturation nears for the highest income levels. Based on 36 countries from 1960 – 2000, Wang (2005) adopts Gompertz growth models and finds a strong relationship between motorization and per capita GDP. The study concludes that with a growth rate of per capita GDP in the 3%-7% range, the inflection point will occur between 2015 and 2042 and total vehicle ownership in China could reach nearly 260 million vehicles. Bouachera and Mazraati (2007) uses three functional forms (Gompertz, logistic and quasi-logistic) to characterize the S-curve shape of car stock evolution in India. Assuming a saturation level of 0.85, the study predicts car ownership levels, accounting for the growth of per-capita income and per-capita road density. From the study, India's vehicle stock is expected to be four times larger in 2015 than in 2002, increasing to nearly 50 million cars.

Even though vehicle ownership in developed countries is expected to increase at a declining rate with per-capita income growth and ultimately reach a saturation level, many studies` estimates do not predict real observed ownership levels well. Ingram and Liu (1999) note that there is little direct evidence that saturation levels are stationary or that they have a straightforward behavioral interpretation. And Button, Ngoe, and Hine (1993) conclude that the saturation level is a technical model feature that improves the quality of the forecasts generated. The study also notes that different countries or regions will have different levels of saturation with the growth of the economy.

Policy-Oriented Aggregate Demand Models. In Ingram and Liu's (1999) study of motorization at the national and urban levels, economic variables are important determinants, although the income effects at the urban level are somewhat weaker. Huang, Cao, and Li (2012) explore spatial variations of urban private car ownership in 235 Chinese cities from 1990 to 2009. The study finds that the extent of urbanization has a positive effect on private car ownership in general but a negative in the largest areas, metropolises, and mega-cities. The study also finds that the availability of substitutes, public transportation, and taxis limits the growth of private cars in Chinese cities to some but not to a large degree.

Chin and Smith (1997) use time series data from 1968 to 1989 in Singapore to analyze the impact of Singapore's Vehicle Quota Scheme, finding that imposing a quota is an effective policy to limit the number of private vehicles. The study concludes that vehicle intervention policies that target ownership and use are complementary. In a study on fuel consumption, Hao, Wang and Ouyang (2011) analyze the vehicle limitation policies of Beijing, which targets vehicle use, and Shanghai, whose policy focuses on vehicle ownership. The study finds that both policies reduce fuel consumption but Shanghai's policy has larger and longer lasting effects, suggesting that the most effective policies are those aimed at vehicle ownership. And in a related study, Zhou and Shu (2014) employ financial and sales data in China from 1996 to 2011 to examine the effect on traffic by using odd/even license plate numbers to restrict vehicle use. The study finds that this control had a negative impact on private car ownership.

Wu, Zhao, and Zhang (2016) estimate random and fixed effects models on a panel data of provincial capitals in China from 2001 – 2011. The authors find that, in addition to income, the extent of highway mileage and the quality of roads (i.e., paved) increased car ownership. In addition, the study finds that the number of public transit vehicles per rider, a measure of public transit comfort, significantly reduces car ownership.

The present study adds to this literature, developing and estimating panel data models of private vehicle ownership in China's provinces. The unit of analysis is a province-year comprising China's

Table 2: Aggregate Models of Vehicle Ownership*

Year	Author(s)	Methodology	Data	Findings
1993	Button, J., Ngoe, N. and Hine, J.	Quasi-logistic model	58 developing countries, 1968–1987, car fleet; 29 developing countries, 1968–1987, commercial vehicles	Saturation level is seen as a technical aid to improve the quality of forecasts. Given data limitations and the considerable distance of most low income countries from the saturation estimates postulated for industrialized countries, a short-term maximum level of car ownership is adopted.
1997	Chin, A. and Smith, P.	OLS	Singapore, 1968–1989	Singapore's Vehicle Quota Scheme is an effective way to regulate the number of private automobiles. Policies regulating ownership and usage are complementary.
1999	Ingram, G. and Liu, Z.	OLS	50 countries and 35 urban areas in 1970, 1980, and 1990	Income growth is the primary determinant of car ownership at the national and urban levels. Income elasticity is constant (or falling) over the range of income levels in the study.
1999	Dargay, J. and Gately, D.	Gompertz model	26 countries, 1960–1992	Strong relationship between income and vehicle ownership growth. Lower income countries estimated to have income elasticity around 2.0 and China's growth will be at a high level.
2005	Wang, Y.	Gompertz model	36 countries, some 1960–2000, some 1978–1992	Assuming 3%–7% annual per capita GDP growth, the inflection point will occur between 2015 and 2042. Total vehicle ownership in china would reach nearly 260 million vehicles.
2007	Bouachera, T. and Mazraati, M.	Gompertz, Logistic and Quasi-logistic models	7 Asian countries, 1971–2002	India's car stock expected to be 50 million cars, just under four times the level in 2002. Barring significant technological innovations, motor vehicles and the transportation sector in general will rely heavily on fossil fuels.
2010	Gu J., Qi, F. and Wu, J.	Gompertz model	31 provinces, 1998–2007	Vehicle consumption differs among eastern, central, and western regions in China. Road density has a significant effect on vehicle consumption in the three regions.
2011	Hao, H., Wang, H. and Ouyang, M.	Formula calculations, various years	Beijing and Shanghai	Beijing's policy limiting vehicle use had immediate but relatively small effect on fuel consumption; Shanghai's policy limiting ownership had larger and longer term effects.
2012	Huang, X., Cao, X., and Li. T.	OLS	235 cities in China, 1990–2009	The extent of urbanization has a strong positive effect on private car ownership in general but a negative effect in metropolises and mega-cities. public transportation and taxis inhibit the number of private cars to a small degree.
2014	Zhou, M. and Shu, W.	OLS	Financial and sales data in China, 1996–2011; 31 provinces in 2012	New government policies, such as the traffic control via odd and even license numbers and total investment in fixed assets, have a negative impact on private car ownership.
2016	Wu, N., Zhao, S. and Zhang, Q.	Fixed/random effects models	32 Provincial capital cities, 2001–2011	Gross regional product per capita (large and medium cities) and average age (smaller cities) positively related to car ownership, as was paved roads and highway mileage. A measure of public transit comfort reduced car ownership.

* OLS is ordinary least squares.

31 provinces during the 13-year period 2000 – 2012. Similar to other studies, this analysis identifies the effects of income and fuel cost on private vehicle ownership and the impact that highway and transit infrastructure investments have on private vehicle ownership. In addition, the analysis explores the extent to which private vehicle ownership in China differs from ownership patterns in the eight most highly urbanized provinces. And the study identifies the impact of two specific vehicle restraint policies: Beijing's municipal policy that restricts vehicle use versus Shanghai's municipal policy that restricts private vehicle ownership.

Hypotheses

To motivate the empirical analysis, consider China's provincial demand for private vehicles at time t in province j transportation $D_{Tj,t}$,

(1) $D_{Tj,t} = D_{Tj,t}(P_{Tj,t}, P_{zj,t}, M^a_{j,t}, \phi^a_{j,t})$

where j=1,...31, P_{Tj} is price of private vehicle use in province j, P_{zj} is the price of all other consumption in province j, $M^a_{j,t}$ is aggregate income of province j in year t and $\phi^a_{,jt}$ reflects aggregate preferences for private transportation in province j and year t.

Since public transit is a primary competing transportation mode to the private vehicle, the price of public transit $c_{PTj,t}$ is assumed to capture the price effects of all other relevant goods $P_{jz,t}$ in the model.

In this framework, the price of transportation in general includes out-of-pocket monetary cost (e.g., fuel costs, tolls, transit fare) and the opportunity cost of the time spent traveling, which is a function of the value that the traveler places on travel time. That is,

(2) $P_{jk,t} = f(c_{jk,t} , t(vot)_{jk,t} ; inf_{jk,t} , spdev_{j,t}, vr_{i,t})$

where k represents private vehicle or public transit, , $c_{ik,t}$ is the money cost and $t_{ik,t}$ is the time cost of travel on mode k in province j at time t, which depends on the value of time (vot). Further, the existing infrastructure ($inf_{jk,t}$), the province's spatial development and configuration, and vehicle restriction policies are conditioning factors that affect the monetary and time cost of travel on mode k. In China, these are of particular importance because investments on highway infrastructure and urban development have occurred at a rapid pace. In addition, seven provinces have imposed restrictions on vehicle use or vehicle ownership.

Thus, for this analysis, China's demand for private transportation in province j at time t is:

(3) $D_{Tj,t} = D_{Tj,t}(c_{jk,t} , vot_{jk,t} , c_{PTj,t}; inf_{jk,t} , inf_{PTj,t}\ spev_{j,t}, vr_{i,t}, M^a_{j,t}, \phi^a_{j,t})$ j = 1, 31

This framework motivates four sets of testable hypotheses related to the effects of economic factors, infrastructure, spatial form, and regulation on private vehicle ownership.

Hypothesis 1 – Economic Environment

- *1a. Per-capita GDP*: Holding all else constant, an increase in provincial per-capita income increases the demand for vehicle ownership.
- *1b. Price of vehicle* and *vehicle use cost*: Holding all else constant, an increase in the price of private vehicle ownership and cost of vehicle use reduces the demand for private vehicles.
- *1c. Public transit fare*: This is a substitute for private vehicles, which implies that an increase in public transit fares increases the demand for private vehicles.
- *1d. Average wage*: Through its effect on the value of time, increasing wages increase the

generalized (time and money) cost of travel. All else being constant, this increases the demand for modes that offer faster travel, the private vehicle.[2]

Hypothesis 2 – Infrastructure Investment

- *2a. Real Investments on roads and bridges*: Holding all else constant, an increase in the supply and quality of infrastructure for private transportation reduces the cost of traveling by private vehicle and increases the demand for private vehicles.
- *2b. Real Investments on public transit*: Holding all else constant, an increase in public transit infrastructure reduces the overall cost of taking public transit, increasing the demand for public transit and reducing the demand for private vehicles.
- *2c. Road density:* Holding all else constant, an increase in the number of highway kilometers per square mile increases capacity for transportation, reduces time costs, and stimulates the demand for private vehicles.

Hypothesis 3 – Spatial Environment

- *3a. Population density*: Increases in population density (persons per square kilometer) reduce travel speeds, increasing travel times and the time cost of highway travel. All else being constant, this reduces the demand for private vehicles.[3]
- *3b. Urbanization level*: Urbanization is a broader concept than population density and typically reflects areas with higher population densities and built environments. In contrast to rural areas, urban areas are typically more prosperous economically, have greater accessibility to resources, and benefit from various agglomeration economies. Holding constant economic factors, infrastructure, and population density, higher urbanization through larger built urban environments increases average distances traveled, which argues for increased vehicle ownership.

Hypothesis 4 – Regulatory Environment

- *4a. Vehicle limitations*: Policies that restrict vehicle ownership and use are negatively associated with private vehicle ownership. Holding all else constant, vehicle limitations increase the generalized cost of private vehicles (e.g. having to make other arrangements, inconvenience), which reduces the demand for private vehicles.

Data

Our empirical analysis uses data from a panel of 31 provinces in China for the period 2000 – 2012. The main data sources are the National Bureau of Statistics of the People`s Republic of China (NBS) and EPS China Data (EPS).[4] Table 3 defines the variables used in analysis. There were several problems encountered in collecting the data. Urban populations for several provinces are missing in certain years. For these provinces we assume that urban population grew at the same rate as in the previous year. Also, data are not available for vehicle use cost so we use the consumer price index (CPI) for transportation as a proxy.[5] All price and cost variables are converted to real or constant yuan with 2000 as the base year.

Limitations on vehicle purchasing and use reflect three types of limited quotas: a lottery for license plates, bidding for plates, and odd and even number rules on license plates. In order to account for these limitations on purchasing and using vehicles, we created a dummy variable that equals 1 if a municipality in the province adopted any of these restrictions and 0 if no restrictions were adopted.[6]

Table 3: Variable Definitions[a]

Private Vehicle Ownership Per Capita	Provincial per capita private vehicle ownership (vehicles/person)
Independent Variables	**Definition**
Economic environment	
GDP Per Capita	Provincial per capita GDP
Vehicle Price	Provincial vehicle purchase taxes per vehicle divided by the tax rate
Wage Rate	Provincial average hourly wage
Vehicle Use Cost Index	Provincial Transportation Consumer Price Index
Infrastructure	
Highway Investments Per Capita	Provincial real per capita investment on roads and bridges (100 million yuan)
Public Transit Investments Per Capita	Provincial real per capita investment on public transit (100 million yuan)
Road Density	provincial highway mileage, divided by the province's area (km/km^2)
Spatial Concentration	
Population density	Provincial population divided by the province's area (persons/km^2)
Percent Urban	Provincial urban resident divided by the province population
Regulatory environment	
Vehicle Limitation	Limitation on vehicle ownership and use adopted by a province
Other	
Time trend	Year of observation

[a]All monetary values are in constant 2000 yuan. Base year for the transportation price index is 2000 and the index includes fuels and parts, intercity traffic fare, public transportation, fees for vehicles use and maintenance, and transportation facilities. The wage rate assumes working eight hours per day, 250 days of the year.

Descriptive Statistics. Table 4 provides descriptive statistics for the sample. The first line of Table 4 indicates that over the sample period there were 0.026 vehicles per 1,000 persons, ranging from a minimum of 0.001 to 0.196. On average, 45% of the population are in urban areas with an average population density of 402 persons per square kilometer. GDP per capita is 9,471 yuan and average hourly wage is equal to 10 yuan. Municipalities in 4% of the provinces have vehicle restrictions and per-capita spending on highways and bridges that is twice the spending on public transportation. Across time and across provinces, the variation in vehicle consumption is similar, whereas the standard deviations across provinces tend to be higher, reflecting greater cross-section heterogeneity than temporal heterogeneity. There is much greater variation in GDP per capita across provinces than across time (5,525 yuan versus 849 yuan). This is also true for population density. The sample mean is 402 persons per square kilometer with a standard deviation of 572.2 persons per square kilometer. This high variation reflects the large heterogeneity across provinces (575 persons/km^2) in contrast to the temporal variation (27 persons/km^2). An exception is the wage rate, which varied more over time (4.0 yuan/hour) than across provinces (3.2 yuan/hour). Average highway road density, highway investments per capita, and public transit investment per capita each varied more across provinces than over time.

Table 4: Descriptive Statistics[a]

Group	Variable	# Obs	Mean	Std Dev	Min	Max
Full Sample	Private Vehicle Consumption per 1,000 persons	403	0.026	0.03	0.001	0.196
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.02	0	0.195
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.03	0	0.254
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.21	0	1
	Percent Urban		0.450	0.15	0.139	0.893
	Road Kilometrage (km/km squared)		0.595	0.43	0.018	1.984
	Provincial Wage (Yuan/hour)		10.284	5.16	3.451	34.1
	Vehicle Use Cost Index (2000 base)		108.162	10.4	87.8	141.4
	Population Density (persons per km-squared)		402.417	572.2	2.1	3777.8
	Provincial GDP per Capita (Yuan)		9,471.70	5535.4	2743.9	30047.0
Provinces	Private Vehicle Consumption per 1,000 persons	31	0.026	0.02	0.01	0.115
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.02	0	0.087
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.02	0.005	0.087
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.18	0	1
	Percent Urban		0.450	0.12	0.268	0.817
	Road Kilometrage (km/km squared)		0.595	0.35	0.038	1.471
	Provincial Wage (Yuan/hour)		10.284	3.23	7.966	19.892
	Vehicle Use Cost Index (2000 base)		108.162	7.3	92.6	122.9
	Population Density (persons per km-squared)		402.417	575.0	2.3	3161.2
	Provincial GDP per Capita (Yuan)		9,471.70	5525.7	3622.0	27213.2
Years	Private Vehicle Consumption per 1,000 persons	13	0.026	0.02	0.006	0.067
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.01	0.002	0.016
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.01	0.002	0.044
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.03	0.032	0.129
	Percent Urban		0.450	0.06	0.375	0.534
	Road kilometrage (km/km-squared)		0.595	0.22	0.308	0.854
	Provincial Wage (Yuan/hour)		10.284	4.01	4.96	17.029
	Vehicle Use Cost Index (2000 base)		108.162	6.62	100.0	119.5
	Population Density (persons per km-squared)		402.417	27.4	366.1	445.8
	Provincial GDP per Capita (Yuan)		9,471.70	849.4	8427.3	10811.9

[a]All monetary values are in constant 2000 yuan. Base year for the transportation price index is 2000 and the index includes fuels and parts, intercity traffic fare, public transportation, fees for vehicles use and maintenance, and transportation facilities. The wage rate assumes working eight hours per day, 250 days of the year.

Urbanization Groups. To explore the characteristics of provinces by the extent of urbanization, we categorize the provinces into the highest urbanization (≥ 60% urban) and lower urbanization (< 60%) groups.

Table 5 reports descriptive statistics for the sample and group means. Provinces in the highest urbanization group have higher per-capita private vehicle ownership, per-capita GDP, and investments in roads, bridges, and public transit. Road density in the most urbanized provinces is nearly twice that in the remaining provinces. Population density in the highest urbanized provinces, on the other hand, is four times greater than in the 23 less urbanized provinces, 1,002 versus 227. Beijing, Shanghai, and Tianjin have the highest per-capita incomes (25,089, 27,213, and 18,126, respectively). These three provinces also have the highest average per-capita highway and public transport investments. Shanghai averages the highest population density at 3,161 persons/km^2, nearly triple that of Beijing and Tianjin due to its much smaller land area (6,341 km^2 versus 16,800 km^2 and 11,305 km^2 for Beijing and Tianjin). Tibet has the lowest average population density (2.31). On average, the highest urbanized provinces are 50% more urbanized (60% versus 40%) than the other provinces.

With the rapid development of China's economy, private vehicle ownership broke through 100 million vehicles in 2013 for the first time. Yet the variance in private vehicle ownership is large, reflecting the different rates of economic development and some unique individual characteristics of each province.

Seven cities have adopted limitation policies on purchasing and using vehicles, six of which are in the highest urbanized group. Among the lower urbanized provinces, Guiyang in Guizhou province also adopted a limitation policy.

Table 5: Descriptive Statistics for Urbanization Groups

Groups	Provinces
Highest urbanization (≥ 0.60%)	Beijing, Shanghai, Tianjin, Guangdong, Zhejiang, Jiangsu, Liaoning, Fujian
Remaining Provinces (< 0.60%)	Jilin, Shandong, Shanxi, Inner Mongolia, Chongqing, Heilongjiang, Hubei, Hainan, Shaanxi, Ningxia, Jiangxi, Qinghai, Hunan, Tibet, Xinjiang, Hebei, Anhui, Schuan, Guangxi, Henan, Yunnan, Gansu, and Guizhou

Variables	All Provinces	Highest Urbanization	Remaining Provinces
Private Vehicle Ownership per 1000 persons (vehicles)	0.026	0.045	0.021
GDP per Capita (yuan)	9471.7	17228.1	7209.4
Wage Rate (yuan/hour)	10.284	14.011	9.197
Vehicle Use Cost Index (2000 base)	108.2	103.8	109.4
Highway Investment per Capita (100 million yuan)	0.023	0.045	0.017
Public Transit Investment per Capita (100 million)	0.008	0.031	0.002
Road Density (km/km^2)	0.595	0.941	0.494
Percent Urban	0.450	0.607	0.404
Population Density (persons/km^2)	402.4	1002.7	227.3
Vehicle Restriction (1 = yes; 0 = no)	0.045	0.176	0.006

Source: National Bureau of Statistics of China (http://www.stats.gov.cn/enGliSH/NBS).eps net database (http://www.epschinadata.com/).

EMPIRICAL MODEL

Table 6 reports the results of four double-log regression models: pooled OLS [column (a)], fixed effects [column (b)] and two fixed effects models with instrumental variables [columns (c) and (d)]. Preliminary analyses found that a double-log specification provided the best model fit. In addition, including a proxy for vehicle price (see endnote 5) consistently led to inferior fits and sign reversals and was ultimately dropped from final model specifications.

Pooled Model. Column (a) reports the OLS results on pooled data that do not account for cross section or separate time effects, but the coefficient standard errors are heteroskedastic/autocorrelation consistent. The model explains 88.9% of the variation in private vehicle ownership and the variables generally have their expected signs. The positive time trend indicates that, during the sample period, provincial private vehicle ownership annually increased 14%, all else being constant. The role of the economic environment is consistent with expectations. A 1% increase in per-capita GDP increases private vehicle demand by 0.89%. And a 1% increase in the wage rate increases demand for vehicles, consistent with the value-of-time hypothesis that higher wages raise the opportunity cost of time. Although having the expected sign, vehicle use cost is not significant at any reasonable level of significance.

The infrastructure results are mixed. An increase (decrease) in road kilometers per square mile (real investments in public transportation) increases (decreases) private vehicle ownership, as expected, but the results for road density are not statistically significant. At the same time, real investments in highways decrease private vehicle ownership, contrary to expectations.

The spatial variables also have their expected signs but, similar to vehicle use cost, are not reliably estimated. In contrast, the regulatory policies that limit vehicle ownership or use are effective in reducing vehicle demands.

The OLS results in Table 6 provide a reasonable fit with parameter estimates whose signs generally conform to the underlying hypotheses. However, concerns with cross section heterogeneity and endogeneity, if present and not addressed, bias the OLS estimates reported in Column (a) and lead to incorrect inferences.

Fixed and Random Effects Models. Column (b) in Table 6 reports the results when re-estimating the model with cross-section fixed effects. There are two specification issues addressed in Column (b). First, the fixed effects model rejects at well below the .01 level the pooled model, that is, the null hypothesis that the fixed effects are jointly 0. Second, in controlling for cross-section heterogeneity, a common alternative specification is the random effects model. The Hausman test statistic for the random effects model rejects at the .01 level the random effects model in favor of the fixed effects specification.[7]

The results reported in Column (b) of Table 6 differ from those in Column (a) in a number of significant ways. First, the cross-section fixed effects model increases the adjusted R^2 from 0.889 to 0.983. Second, the time trend increases significantly, indicating that the annual growth in vehicle consumption per 1,000 persons was 23.0% during the sample period in comparison with 14.0% in the pooled model. In addition, real infrastructure spending on public transportation is no longer significant, although the variable maintains a negative sign.

Per-capita GDP continues to have a positive and significant effect on vehicle ownership (with a lower point estimate) and the index for vehicle use cost continues to reduce vehicle ownership, all else being constant. But the negative impact on ownership of vehicle use cost is now significant at a 0.15 level (two-tail test), which reflects a larger coefficient (in absolute value) and a more precisely estimated coefficient. Related, the vehicle ownership and use limitation policies are again negative and significant, but the magnitude of the effect has decreased (in absolute value) from -0.67 to -0.18.

Also in contrast to the OLS results, the spatial environment in Column (b) has its expected impact on vehicle ownership. A percentage point increase in the urbanization rate, all else being constant, increases vehicle demand 0.45%, whereas a 1% increase in population density, all else being constant, decreases demand 1.6%.

Omitted Variables and Endogeneity. In aggregate models, endogeneity bias and inconsistent estimates often occur by including variables that are simultaneously determined with the dependent variable or by excluding (e.g., due to data unavailability) relevant variables. When the omitted

Table 6: Panel Data Estimation Results[a]

Dependent Variable - Private Vehicle Ownership Per 1,000 Persons

	OLS		Fixed Effects (1 Way)		IV - Lagged		IV - Hausman-Taylor	
	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
Explanatory Variables	(a)		(b)		(c)		(d)	
Economic Environment								
GDP Per Capita	0.899***	0.179	0.638**	0.248	0.722***	0.278	0.996***	0.168
Wage Rate	0.681***	0.212	-0.033	0.179	0.075	0.195	0.034	0.115
Vehicle Use Cost Index	-0.404	0.652	-0.797	0.545	-1.028**	0.492	-1.041***	0.223
Infrastructure								
Highway Investments	-0.049	0.030	-0.015	0.015	0.015	0.021	0.027	0.017
Public Transit Investments	-0.055**	0.023	-0.006	0.010	-0.012	0.009	-0.007	0.007
Road Density	0.036	0.135	-0.033	0.046	0.032	0.081	0.057	0.049
Spatial Concentration								
Percent Urban	0.668	0.450	0.458***	0.167	0.384**	0.172	0.349***	0.112
Population Density	-0.076	0.092	-1.624***	0.352	-1.306***	0.391	-0.662***	0.170
Regulatory Environment								
Vehicle Limitation	-0.671**	0.275	-0.184***	0.048	-0.300**	0.126	-0.350***	0.095
Other								
Time Trend	0.138***	0.031	0.230***	0.019	–	–	–	–
Constant	-296.3***	60.0	-456.1***	34.7	3.743	3.376	-6.134***	2.238
Cross Section Fixed Effects	No		Yes		Yes		Yes	
Time Fixed Effects	No		No		Yes		Yes	
Standard error correction for								
Heteroskedasticity/	Yes		Yes		Yes		Yes[a]	
autocorrelation Clustering	No		No		Yes		Yes	
Hausman Test (p-value)	–		0.008		<0.0001		0.864	
N	403		403		372		372	
MSE	0.104		0.0175		0.0157		0.0150	
Adjusted R^2	0.889		0.983		0.985		0.976	

[a] p<0.10, **p<0.05, ***p<0.01. With the exception of Percent Urban, Vehicle Limitation, Time Trend, and Constant, all variables are in logarithmic form. For the IV models, all variables except the Constant, Wage Rate, Population Density, Urban and Vehicle Limitation are lagged one period. The instrument for Vehicle Limitation is the predicted value of Vehicle Limitation from a binary probit model on a constant term, time trend, and one-period lagged values of the logarithms of GDP Per Capita, Wage Rate, Public Transit Investment, Road Density, Percent Urban, and Population Density. The data analysis for this paper was generated using SAS/ETS software, Version 9.r of the SAS System for Windows. Copyright © 2002–2012 SAS Institute Inc., Cary, NC< USA.

* For the Hausman-Taylor (1981) estimates, a separate adjustment for heteroskedasticity is not necessary since the model estimates cross section variance components. The errors are not robust to serial correlation.

variables are correlated with included explanatory variables, the parameter estimates are not consistent, where the direction of the bias depends on the correlation between the excluded and included variables.[8]

Of particular concern in this analysis are included endogenous variables that lead to inconsistent estimates. Vehicle ownership depends on highway and bridge infrastructure, but real infrastructure spending also depends on the extent of vehicle ownership and use. Higher vehicle ownership is expected to increase real spending on highways and bridges to accommodate the greater number of vehicles. Similarly, per-capita GDP, as a proxy for income, is potentially endogenous. While economic growth and development increase GDP per capita and generate more demands for private vehicles, the growth in private vehicles facilitates higher levels of production, productivity, and GDP growth.

To address these endogeneity concerns, we estimate models using instrumental variables (IV). Traditionally, an instrumental variable is one that is correlated with independent variable(s) and uncorrelated with the error term. For this analysis, we adopted two approaches. First, we include lagged values of potentially endogenous variables as instrumental variables in the model. Logically, lagged variables are predetermined and, as such, can serve as instrumental variables. Second, we searched for potential instrumental variables outside of those in the model.[9]

Column (c) of Table 6 reports the results of a two-way fixed effects models in which the lagged values instrument for variables are of primary concern – GDP per capita, vehicle use cost, infrastructure spending on highways/bridges and public transportation, and road density. Standard errors are heteroskedastic/autocorrelation consistent and also account for clustering effects.

Notwithstanding that the IV – Lagged results reported in Column (c) of Table 6 have 31 fewer observations due to lagging one period, the results are generally consistent with the fixed effects model in Column (b). The adjusted R^2 in the IV – Lagged model is a bit higher (0.985) and the mean squared error (MSE) is lower (0.015). Rather than a time trend, this model estimates separate time effects (not reported), which imply a 20.7% average annual growth in vehicle consumption per 1,000 persons, similar to the 23.7% estimate of the annual trend in Column (b). A Hausman test again rejects a random effects in favor of a fixed effects specification.

GDP per capita in Column (c) has a similar impact on vehicle consumption as in Column (b) but the effect of vehicle use cost increases (in absolute value) by about a third, from -0.797 to -1.028. The infrastructure variables have signs that are consistent with expectations and, in this case, real spending on public transportation is significant at a 0.20 level (two-tail test). The spatial variables in IV-Lagged are robust to their values in the fixed effects model. In contrast, the coefficient for vehicle limitation has increased (in absolute value), indicating that the presence of restrictions on vehicle ownership/use reduces vehicle demands per 1,000 persons 30%.

Hausman-Taylor IV Model. Column (d) in Table 6 reports estimates from a Hausman and Taylor (1981) specification of the model. This approach has two attractive features for the current problem. First, the Hausman-Taylor model is an instrumental variables regression in which some of the model's variables are assumed to be correlated with the individual effects but uncorrelated with the observation errors. Second, the approach essentially combines elements of a fixed-effects IV regression with a one-way random effects specification. For this analysis, the assumption is that real spending on highways and bridges, real spending on public transportation, and road density are correlated with the individual effects but uncorrelated with the observation error terms. Instrumental variables are based on the model's other variables, which include GDP per capita, vehicle use cost, wage rate, percent urban, and population density.[10]

Goodness of fit statistics from the Hausman-Taylor specification in Column (d) are similar to those for the IV-Lagged model. The adjusted R^2 is slightly smaller (0.976 vs. 0.985) but the mean-squared error is smaller (0.0150 vs. 0.0157). A p-value of 0.942 for a Hausman specification test (Hausman and Taylor, 1981) accepts the null hypothesis that real spending on highways/bridges, real spending on public transportation, and road density are correlated with individual effects but not with observation errors.

In general, the estimation results in Column (d) are robust. GDP per capita and vehicle use cost index have positive and negative impacts, respectively, on vehicle consumption. Interestingly, the point estimates in absolute value are essentially suggesting that a 1% increase in GDP per capita and in the use cost index will have offsetting effects on provincial vehicle consumption per 1,000 persons. Wage rate has an expected positive sign but is not significant at any reasonable level of significance.

Infrastructure spending and road density variables again have their expected signs and are not significant at a 0.10 (or smaller) level. However, relative to IV-Lagged model, spending on public transit is less significant (0.30 level on a two tail test), whereas highway infrastructure investment is significant at a 0.11 level (two-tail test). Percent urban has a similar impact on vehicle consumption and the effect of population density is much lower in absolute value (-1.306 vs. -0.662). Also robust is the impact of vehicle limitation in the Hausman-Taylor specification, indicating that the effect of these policies reduces provincial vehicle consumption per 1,000 by 35%.[11]

Highest Urbanization Provinces

In order to gain more insight on the variation in private vehicle ownership among the provinces, Table 7 reports separate Hausman-Taylor estimates for the highest (≥ 60%) and less urbanized (< 60%) provinces, as identified in Table 7.[12] Overall, each model fits the data well. Importantly, the estimation results identify the oftentimes large differential impacts that determining factors have on provincial vehicle private vehicle consumption.

Whereas private vehicle ownership grows a bit more than proportionately than GDP per capita in all of China's provinces, there is a strong disproportionate relationship in the highest urbanized provinces. In particular, a 1% increase in provincial GDP per capita more than doubles private vehicle ownership, 1.67% in the highest urbanized provinces compared with a 0.69% for the less urbanized provinces. Although not as dramatic as GDP per capita, the other economic variables also have larger coefficients (in absolute value) in the highest urbanized provinces. The one possible exception is the wage rate. The hypothesis was that an increase in the wage rate would increase private vehicle ownership, holding GDP per capita constant, since higher wages reflect higher values of time. The results for each group of provinces produced a positive sign, as expected, but are statistically insignificant in each case. The largest cities in China (e.g., Shanghai and Beijing) have significant congestion delays, more uniform spatial development in contrast to the hub and spoke networks in the West, and a large public transportation infrastructure. The net effect of these factors may be that the travel time advantage of privately owned vehicles relative to alternative means of travel is not significant.

The infrastructure variables for the highest urbanized provinces are uniformly stronger in their effects, carry their expected signs, and are statistically significant. Real investment in highway infrastructure and in road density increase, as expected, private vehicle ownership. Further, real investments in public transportation have their expected impacts, decreasing private vehicle ownership.

Characteristics in the spatial environment between the two groups also affect private vehicle demands differently, all else being constant. The extent of urbanization has nearly twice the impact on vehicle consumption in the highest urbanized provinces. At the same time, a 1% increase in population density reduces per-capita private vehicle ownership by 0.67% in the most urbanized areas. This compares with a much weaker 0.13% (0.13 p-value, not reported) impact in the less urbanized areas.

Increases in vehicle use cost significantly decrease private vehicle consumption in less urbanized areas but have a much weaker (and statistically insignificant effect in a two-tail test) in the most urbanized areas. Vehicle ownership and use restrictions have little statistical effect, in contrast to the much stronger results in Table 6. This may reflect separate explanations for each group. In the less urbanized areas, the absence of a significant effect likely reflects the lack of variation since only one province implemented a vehicle restriction during the sample period. For the highest urbanized areas, the sign on the vehicle limitation is consistent with expectations, but the p-value is much lower 0.19. This group comprises only 84 observations, and the loss in degrees of freedom reduces the precision of the estimate.

Table 7: Hausman-Taylor Estimates by Level of Urbanization

Dependent Variable	Private Vehicle Ownership Per 1,000 Persons			
	< 60% Urbanized		**≥ 60% Urbanization**	
	Estimate	**s.e.**	**Estimate**	**s.e.**
Explanatory Variables	*Economic Environment*			
GDP Per Capita	0.696***	0.192	1.670***	0.278
Wage Rate	0.140	0.123	0.216	0.251
Vehicle Use Cost Index	-1.102***	0.484	-0.458***	0.478
	Infrastructure			
Highway Investments	0.012	0.019	0.053*	0.029
Public Transit Investments	-0.0002	0.008	-0.043***	0.014
Road Density	0.028	0.049	0.631***	0.153
	Spatial Environment			
Percent Urban	0.302*	0.162	0.529***	0.155
Population Density	-0.136	0.089	-0.676***	0.195
	Regulation			
Vehicle Limitation	0.226	0.184	-0.156	0.118
	Other			
Constant	-7.378***	2.257	-16.566***	3.596
Adjusted R^2	0.9794		0.9858	
Cross Section Fixed Effects	Yes		Yes	
Time Fixed Effects	Yes		Yes	
N	268		84	
MSE	0.0139		0.0096	
Adjusted R^2	0.9794		0.9858	

Note: Standard errors in parentheses. * p<0.15, ** p<0.1, *** p<0.05

DISCUSSION AND CONCLUDING REMARKS

The objective of this paper was to identify those factors that underlie China's significant growth in private vehicle ownership since 2000. Private vehicle consumption per 1,000 vehicles increased over 20% per year, with higher growth rates in the less urbanized areas and, more recently, with the annual growth rate falling (rising) in the more (less) urbanized areas.

The analysis developed and tested hypotheses on the impact that economic, infrastructure, spatial, and regulatory environments have upon private vehicle ownership across China's provinces during the period 2000–2012. The Hausman-Taylor (HT) specification provides the best overall fit of the model, and the results are relatively robust to one-way fixed effects and lagged instrumental variable models.

The HT estimates for the overall sample lead to the following conclusions. One, the model strongly rejects the null hypotheses that economic, spatial, and regulatory environments have no effect on private vehicle ownership. Among the specific factors, the model did not provide reliable estimates for the wage rate – included as a proxy for the value of time. Also, the estimated results give a private vehicle demand elasticity (-1.041) for vehicle use costs that equal the income (GDP per capita) elasticity of demand (-0.996). This suggests that (e.g., tax) policies intended to increase a private vehicle's operating cost could be an effective tool to offset increases in GDP per capita. However, separate model estimates by level of urbanization argue against this, as discussed below.

Two, and contrary to expectations, the sample results accept the null hypothesis that infrastructure investments and road density have no impact on private vehicle provincial demands. Although these variables have the expected signs, at standard levels of significance the results do not reject the null hypothesis. When disaggregated by level of urbanization and separately estimated, model results shed additional light on the differential role of infrastructure spending.

Third, non-economic factors that drive private vehicle ownership in high urbanization provinces are not drivers of private vehicle ownership in less urbanized provinces. The general result is that for the most urbanized provinces, economic, infrastructure, spatial, and regulatory environments all drive private vehicle ownership decisions. But there are important differences from the results for the total sample. Per-capita GDP has a much stronger positive impact on vehicle ownership with a much larger 1.67 elasticity estimate. By comparison, the GDP per-capita elasticity for less urbanized areas is 0.70. Also, the results indicate that for high urbanized areas, increases in use cost have negative but unreliably estimated effects on private vehicle demands; increases in vehicle use cost have larger effects on demands than increases in GDP per capita. This accords with inferences that one could draw from the descriptive statistics in Table 5, where highly urbanized provinces have much higher GDP per capita, vehicle ownership rates, wages, and infrastructure investments.

The most important difference from the results for the full sample relates to infrastructure spending where highway and public transit investments have the expected positive and negative impacts, respectively, on provincial vehicle demands in the most urbanized provinces. Also consistent with expectations is a strong positive impact on private vehicle demands with increases in road density. Although on a two-tail test, the impact of vehicle limitation policies for the most urbanized areas is statistically insignificant, the model rejects the null hypothesis of no impact at a .10 level using a one-tail test.

Fourth, the disaggregated results for the lower urbanized provinces, although based on a sample three times as large, are much weaker. For these provinces, the model rejects the null hypothesis that economic factors have no effect on private vehicle demands where consumer demands are more sensitive to the use cost than to increases in GDP per capita. The spatial environment continues to be important but with weaker impacts on demands.[13]

A broad implication from these results relates to the set of factors that affect private vehicle demands as provinces become more urbanized. In less urbanized provinces, economic factors and, specifically, income and vehicle-related costs are primary drivers of private vehicle demands. As less urbanized provinces transition into areas with higher rates of urbanization, the findings in this study indicate that in addition to economic factors, infrastructure, spatial, and regulatory factors are important in shaping a province's private vehicle demands.

Areas for future research are numerous, many of which are additional robustness checks. Examples include: 1) updating the panel data while searching for better testing alternative instrumental variables; 2) analyzing private vehicle demands for smaller geographical units (e.g., city level) or from household survey data; 3) estimating the impacts of specific vehicle restrictions; 4) applying alternative estimation methodologies (e.g., dynamic models); 5) developing a better understanding of the roles that highway investments and alternative forms of public transit investments have on vehicle ownership; and 6) determining the consequences of these results for congestion, air quality and health, and highway safety.

Endnotes

1. A Gompertz function is a sigmoid function and a special case of the generalized logistic function that has a different position for the inflection point.

2. Since the model controls for per-capita GDP, average wage is expected to capture value of time more than income. Since the income effect and the value of time effect of average wage is expected to increase private vehicle consumption, there is an upward bias on the effect of average wage. The magnitude of the bias depends on the extent to which average wage is a good proxy for value of time.

3. Increases in population density also affect other highway modes (e.g., bus travel) and the relative effect could be a net shift from private vehicle to public transit. This analysis focuses on the demand for private vehicles rather than the share of private vehicles in the modal mix.

4. National Bureau of Statistics, China (http://www.stats.gov.cn/enGliSH/) and EPS China Data (http://edp.epsnet.com.cn/database_en.html). China's administrative structure includes three levels: provincial, autonomous regions, and municipalities. Provinces and autonomous regions are sub-divided into prefectures, counties, and cities. And counties are sub-divided into townships. Municipalities are city-provinces (Beijing, Chongqing, Shanghai, Tianjin) that the Central Government directly controls. This analysis includes the China's 22 provinces, five autonomous regions, and four municipalities.(http://www.china.org.cn/english/kuaixun/64784.htm).

5. Because there is no consumer price index (CPI) for transportation for Tibet, we use Xinjiang's CPI for transportation as a proxy since Tibet and Xinjiang provinces have similar economic environments. Also, in preliminary models, we created a proxy for vehicle price based on tax revenues from vehicle purchases, the vehicle tax rate, and changes in private vehicles from one year to the next. Except for some new energy vehicles, almost all vehicles are taxed. Because the variable consistently led to poorer results and perverse signs, we excluded the variable from the final versions. Part of the reason this was a poor proxy is that data on vehicle purchase taxes include public transit in addition to private vehicles.

6. Wang (2016, p. 31-36) reports the details of these policies, particularly for Shanghai and Beijing.

7. Rejecting the random effects model rejects the null that the error term and the explanatory variables are uncorrelated. Standard errors in these models are heteroskedastic/autocorrelation consistent.

8. For instance, there may be higher vehicle consumption than expected, given the urbanization rate. Excluding from the equation vehicle purchase credit policies will bias upward the coefficient of the urbanization variable if more lenient credit policies are expected to have a larger effect on urban relative to rural populations. Systematic measurement errors also produce inconsistent estimates.

9. We explored a number of instruments outside those included in the model. The most promising was road lamps. When governments invest money on roads and bridges, they also build road lamps on the roadsides. So the number of road lamps is expected to be highly correlated with investments on roads and bridges but uncorrelated with the error term. Preliminary analyses

found that the model fits with this instrument were inferior to those reported in Columns (c) and (d) in Table 6.

10. Consistent with IV-Lagged specification, GDP per capita and vehicle use cost are lagged one period. Wage rate, percent urban, and population density are unlagged.

11. Hausman and Taylor (1981) assume that the means of the regressors are uncorrelated with the individual effects. If the regressors rather than their means are uncorrelated with the individual effects, Amemiya-MaCurdy (1986) demonstrate that this leads to more efficient instruments. For this analysis, the Amemiya-MaCurdy (1986) estimates differ very little from the reported estimates in Column (d) of Table 6. SAS/ETS 14.1 User's Guide, Panel Procedure Details. Copyright © 2002-2012 SAS Institute Inc., Cary, NC, USA.

12. There was not sufficient variation in the vehicle limitation policies to estimate separate models for provinces whose urbanization was less than or equal to 50%, between 50% to 60%, and 60% or more.

13. On a one-tail test, population density is significant at a 0.10 level of significance.

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