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Car ownership modeling and forecasts for China

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CAR OWNERSHIP MODELING AND FORECASTS FOR CHINA

By

Xiayi Huang

A THESIS

Sumitted in partial fullfillment of the requirements for the degree of

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This thesis, “Car Ownership Modeling and Forecasts for China,” is hereby approved in partial fullfillment of the requirements for the Degree of MASTER OF SCIENCE IN APPLIED NATURAL RESOURCE ECONOMICS.

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Abstract

A great increase of private car ownership took place in China from 1980 to 2009 with the development of the economy. To explain the relationship between car ownership and economic and social changes, an ordinary least squares linear regression model is developed using car ownership per capita as the dependent variable with GDP, savings deposits and highway mileages per capita as the independent variables. The model is tested and corrected for econometric problems such as spurious correlation and cointegration. Finally, the regression model is used to project oil consumption by the Chinese transportation sector through 2015. The result shows that about 2.0 million barrels of oil will be consumed by private cars in conservative scenario, and about 2.6 million barrels of oil per day in high case scenario in 2015. Both of them are much higher than the consumption level of 2009, which is 1.9 million barrels per day. It also shows that the annual growth rate of oil demand by transportation is 2.7% - 3.1% per year in the conservative scenario, and 6.9% - 7.3% per year in the high case forecast scenario from 2010 to 2015. As a result, actions like increasing oil efficiency need to be taken to deal with challenges of the increasing demand for oil.

1. Introduction

Automobile ownership in China has greatly increased from 1.78 million vehicles in 1985 to 50.99 million in 2008. Two decades ago, private cars were only considered luxury transportation tools on the street of China, and China was called the “country of bikes” since bicycles were the most common form of transportation during that time. Most cars, SUVs and vans were purchased by work units, like government officials, rather than by individuals.

In 1994 the government began encouraging private car ownership. Recently, China’s auto sales have increased sharply and in 2009 new car sales surged past the United States, raising China’s importance to the global auto industry as the world’s biggest market. In January of 2009, sales from General Motors in China rose 97% to 219,000 vehicles from 2008, while sales from Toyota Motor Corp. rose 53% to 72,000 vehicles, and sales from Ford Motor Co. doubled from 2008. The total sales of auto vehicles in January also doubled compared with January of 2008, according to the China Association of Automobile Manufacturers on February 9th 2009. The China Association of Automobile Manufacturers (CAMAI) is the main national trade group for the auto industry in China.

According to the data from the National Bureau of Statistics of China, most of the increase in automobile sales comes from private purchases of vehicles. In 1985 among all passenger vehicles, less than 2.5 percent were private, and this proportion jumped to over 60 percent after 20 years to 2005(Deng 2007). In 2003, 70 percent of the cars bought were private purchases. Now it is not surprising to see that more than 80 percent of newly registered vehicles are privately owned vehicles (Deng 2007).

What factors fueled the growth in demand for automobile vehicles in China in recent years? It is not difficult to attribute it to the rising income level resulting from booming economic development. On the demand side, economic growth increases income for each household above subsistence levels and changes people's consumption patterns for goods and services. More and more households can afford to purchase an automobile. On the supply side, the development of the economy, development of infrastructure for public transportation, fuel supply, urbanization and other related services have also greatly improved, and these factors are expected to accompany the expansion of car ownership and the development of the automobile industry.

Purchases of private automobiles change with increases in incomes over time. For example, at low income levels, most people cannot afford to purchase a car and private cars are not commonly used. But as personal income increases, more and more people begin to buy automobiles, and car ownership increases rapidly with economic development. However, the rate of increase in car ownership will begin to decline as personal income continues to grow beyond some level that varies by country as the saturation level of car ownership is approached. The saturation levels vary from country to country depending on national characteristics (Chinese Academy of Engineering 2003).

It is said that more and more international trade practices and competition has been brought into the Chinese automobile industry since its entry to the

World Trade Organization (WTO). And the Chinese automobile market has become more related with the international automobile market. All studies since the 1960s have found that income per capita is a major determinant of the demand and sales of automobiles in both developing and industrial countries (Ingram and Liu 1999). Analysts explain that more than 90 percent of the variation of automobile consumption can be affected by income factor at the national level in developing areas, and in developed areas, the ratio is 80 percent (Chinese Academy of Engineering 2003).

Figure 1.1 summarized the relation between car ownership level and income level from 1970 to 1996 (Chinese Academy of Engineering 2003). As we can see, it shows line segments connecting a country's positions in 1970 and in 1996. These dates are chosen because they are years with comparable data across countries. Car ownership increased in all countries from 1970 to 1996, although income did not. The relation between income per capita and car ownership has been very consistent from 1970 to 1996. Thus in many car ownership forecast models, income is used as the only independent variable to explain the dependent variable - car ownership (Button 1993; Dargay and Gately 1999).

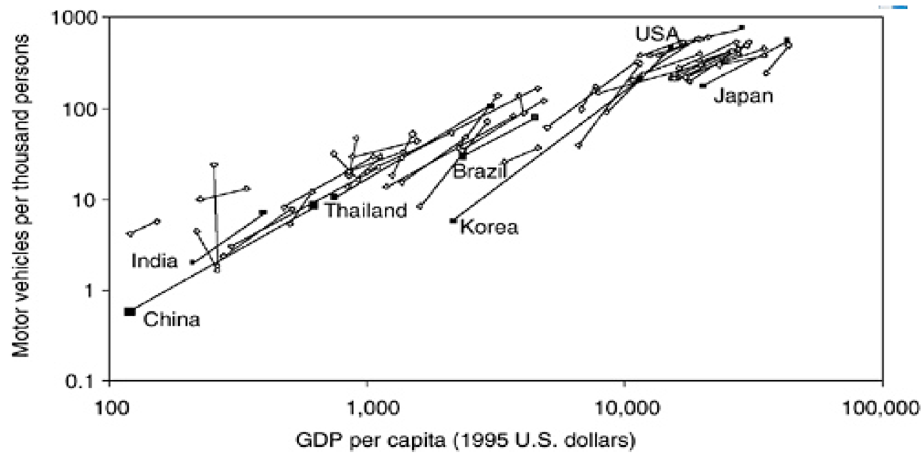

Figure 1.1 The relationship between per capita GDP (in 1995 US dollars using market exchange rates) and car ownership per thousand people for various nations, showing the changes between 1970 and 1996. Sources: motorization data for the International Road Federation, 2001 and earlier; World Bank 2001 and the Chinese Academy of Engineering 2003

Income is not the only factor that can explain car ownership. It is not surprising to see that different countries with similar income level have different car ownership patterns. There are some other factors to explain this disparity, such as demographics, GDP per capita, highway miles per capita, cost of car ownership, road infrastructure, urbanization, costs and time of alternative transportations, such as mass transit.

Energy is playing a more and more important role in the rapid economic development of China, especially the transportation sector. Since China is experiencing the most rapid motorization growth in the world, there are increased concerns over energy consumption. Data from Chinese Academy of Engineering shows that China's oil demand by transportation sector has been increasing with the rapid growth of private car ownership. For example, the consumption of oil was 3.0 million barrels per day (mbd) in 1995, and in

2000, it grows to 4.5 mbd. In 2008, the number is 8 mbd. To meet this rapid increased demand of oil by transportation sector, China needs to import more oil from the other countries, which will result it as a net import country of petroleum.

The basic purpose of this paper is to develop a simple OLS linear regression model to forecast the total car ownership in China. This is used to estimate the transportation energy demand and will help forecast energy needs and provides projections for oil consumption by private cars through 2015.

The rest of this paper is organized as follows: chapter 2 presents a review of the literature concerning different forecasting models; chapter 3 summarizes historical pattern of total car ownership in China from 1949 to 2008; chapter 4 illustrates the forecast model and methodology employed in this paper; chapter 5 tests the regression model for classical assumptions; chapter 6 provides an evaluation of the model and forecasts; chapter 7 projects the oil demand by private cars through 2015; the final chapter concludes with a brief discussion of policy and future work.

2. Literature Review

Traditional modeling of automobile demand is classified into two methods: one is single equation aggregate models; the other is single or multi-equation disaggregated choice models (Prevedouros and An 1998). The aggregate models are primarily sensitive to macroeconomic or social influences, while the discrete choice models deal with the effects of changes in both price and non-price vehicle characteristics and other effects.

Button uses a quasi-logistic function to forecast car ownership in less developed countries. He observed that the slow growth rate of car ownership in the less developed countries in the beginning will be replaced by rapid growth with the improvement of per capita income which will result in approaching a much higher level of car ownership at a saturation level (Button 1993).

The saturation level is a statistical parameter. Button explains that there are two other ways to understand the saturation level: one is as a firm, long-term probable maximum level of cars owned per capita; the other is as a short-term maximum level of car ownership given existing constraints and conditions (Button 1993). He also noted that different countries or regions will ultimately result in different levels of saturation with the growth of the economy. It has been found that the UK and other developed countries tend to have saturation per capita from 0.4 to 0.7, which means four to seven vehicles per ten people. In 2009, the number of cars per capita in China is about 0.05, which is about 0.5 vehicle per ten people and is far fewer than the saturation point of the UK and other developed countries.

Studies by Ingram and Liu (Ingram and Liu 1999) explain that urban car ownership increases as the same rate as income. Private car ownership becomes prominent as income grows while the share of commercial vehicles in the motor fleet decreases. Saturation is defined as a level of vehicle ownership at which the rate of growth in vehicle ownership per capita becomes zero. For developed countries, like US, the growth rate car ownership will eventually decrease to zero. The final stable level of car ownership is called a saturation level. For US, the saturation level is 8 car ownership among 10 people.

Several studies and the data of 50 countries and regions from high income to low income nations show evidence of different saturation levels, which will change as each economy develops over time (Ingram and Liu 1999). It is estimated that the saturation level is affected by car ownership per capita, GDP per capita, population, oil prices and technology.

3. Historical Pattern

Figure 3.1 summarizes the data of total car ownership in China from 1949 to 2008. When the new China was founded in 1949, there were only 0.509 million cars and a population of 541 million. This means that there was only 1 car among 1063 people. After 59 years, in 2008 total car ownership increased to 50.996 million, or increased by 1000 times, compared with 1949. The thus, total car ownership of China has increased steadily at an average compound annual growth rate of about 12.65% during the past 59 years. At the same time, annual average growth rate of population and car ownership per capita is respectively 1.52% and 11.98%. And the car ownership per capita has grown from 0.018 in 1980 to 0.628 in 2009(about 35 times). If keeps increasing at this rate, the car ownership will reach 239 million in 2020, and will overtake US as the world's largest automobile market (assuming the growth rate of US vehicle ownership stays at current levels).

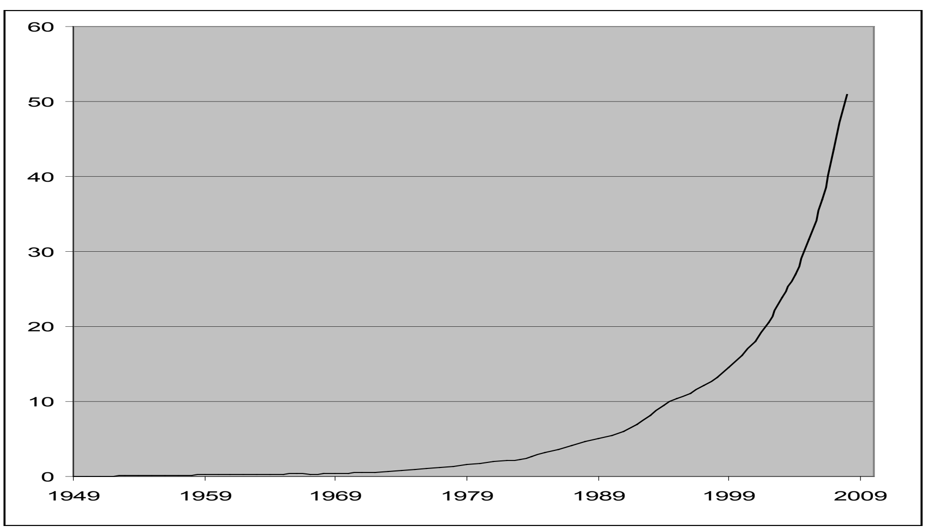

Figure 3.1 Total car ownership of China from 1949 to 2008 (millions of vehicles). Source: Statistics Database of National Knowledge Infrastructure

The relationship between motor car ownership and GDP is complicated as can be seen from figure 3.2. But the average annual growth rate for them is close. For car ownership, the average annual growth rate is 12.79%, and for GDP is 12.39%. The growth of car ownership is relatively steadier than that of GDP. We can't say from this figure that car ownership grows at a similar growth rate of GDP. In 1987, the growth rate of GDP is negative while car ownership is positive, which suggests that there are some other factors that influence the development of car ownership in China.

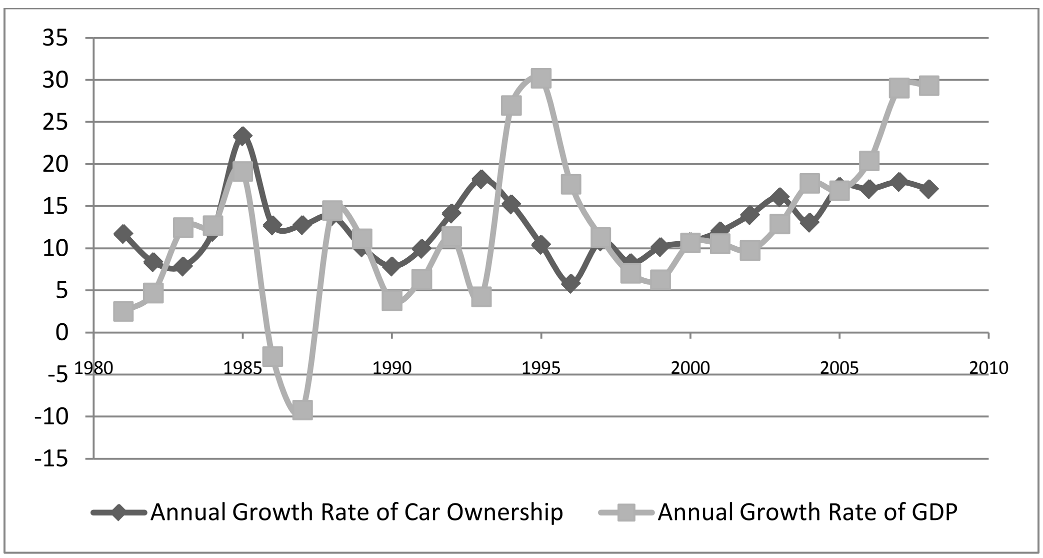

Figure 3.2 Comparison of historical annual growth rate between car ownership and GDP from 1981 to 2008. Source: Statistics Database of National Knowledge Infrastructure

4. The Forecast Model

Analysts find that there are three primary demographic and economic factors that influence the growth of car ownership and sales in developing countries. They are population growth, increased urbanization and economic development (Tanner 1966; Ma and Zhao 2009; Holweg et al. 2009). In order to explain private car ownership in China, the independent variables chosen in this study should be a significant measure of all these three primary demographic and economic factors.

Table 4.1 summarizes the changes of population, urbanization, income, highway mileage and GDP that took place in China from 1980 to 2009.

The table shows that the average population growth rate of 1.05% is far less than the average car ownership growth rate of 13.15% per year. But it doesn't mean that the growth rate of vehicles is not sensitive to population change. Much of the slow growth rate of population since 1980 is due to the successful family planning programs, like the one child per family policy.

As a country with the largest population in the world, China's rapid automobile sales growth and auto industry development is initially attributed to the huge gain in consumption demand. And it surpassed the United States to become the largest automobile market in the world in 2009. Thus all the variables in the forecast model are based on per capita.

Table 4.1
Historical data of car ownership, GDP, savings deposits and highway mileage

Year	Population(thousands)	Urban Population(thousands)	GDP(millions current dollar in PPP)	Car Ownership(millions of vehicles)	Car Ownership per capita	GDP per capita (Yuan)	The balance of savings deposits per capita (yuan)	Highway mileage per capita (km)
1980	987,050	192,322	189,400	1.7829	0.001806291	460	40.47	0.0008949
1981	1,001,342	201,560	194,111	1.9914	0.001989967	489	52.33	0.0008969
1982	1,015,634	211,409	203,183	2.1575	0.002122396	525	66.44	0.0008922
1983	1,029,926	221,444	228,456	2.3263	0.002258368	580	86.64	0.0008884
1984	1,044,218	231,419	257,432	2.6041	0.002495376	692	116.4	0.000888
1985	1,058,510	241,739	306,667	3.2112	0.003033698	853	153.29	0.0008903
1986	1,075,070	254,749	297,832	3.6195	0.003366758	956	208.22	0.0008956
1987	1,093,000	268,407	270,372	4.0807	0.003733486	1104	281.92	0.0008986
1988	1,110,260	282,458	309,523	4.6439	0.004182714	1355	344.26	0.0009003
1989	1,127,040	296,666	343,974	5.1132	0.00453684	1512	461.07	0.0009
1990	1,143,330	311,041	356,937	5.5136	0.004822405	1634	622.72	0.0008994
1991	1,158,230	324,520	379,469	6.0611	0.005233071	1879	797.91	0.0008989
1992	1,171,710	337,841	422,661	6.9174	0.005903679	2287	1003.61	0.0009018
1993	1,185,170	351,175	440,501	8.1758	0.00689842	2939	1282.81	0.0009142
1994	1,198,500	364,702	559,225	9.4195	0.007859408	3923	1795.48	0.0009327
1995	1,211,210	378,324	728,007	10.4	0.008586455	4854	2448.98	0.0009552
1996	1,223,890	393,025	856,085	11.0008	0.008988389	5576	3147.41	0.0009689
1997	1,236,260	407,893	952,653	12.1909	0.009861113	6054	3743.53	0.000992
1998	1,248,100	422,755	1,019,460	13.193	0.010574619	6308	4280.78	0.0010248
1999	1,259,090	437,455	1,083,280	14.5294	0.011550888	6551	4739.94	0.0010746
2000	1,267,430	452,027	1,198,480	16.0891	0.012694271	7086	5075.81	0.0011067
2001	1,276,270	467,023	1,324,800	18.0204	0.014119583	7651	5779.53	0.0013304
2002	1,284,530	481,943	1,453,830	20.5317	0.015983823	8214	6765.95	0.0013742
2003	1,292,270	496,807	1,640,970	23.8293	0.018439877	9101	8018.27	0.0014005
2004	1,299,880	511,690	1,931,640	26.9371	0.021094255	10502	9708.28	0.0014391
2005	1,307,560	526,703	2,257,070	31.5966	0.024164551	14185	10787	0.0014764
2006	1,314,480	541,451	2,716,870	36.9735	0.028127853	16500	12293	0.0026299
2007	1,321,290	556,147	3,505,530	43.5836	0.032985643	20169	13058	0.0027123
2008	1,328,020	570,926	4,532,790	50.9961	0.038400099	23708	16407	0.0028088
2009	1,334,740	585,842	4,984,730	62.8061	0.047054932	25575	19537	0.0028926
Growth Rate	1.05%	3.97%	12.39%	13.15%	11.98%	15.15%	24.11%	4.83%

China's labor force is transferring from farms in rural areas to factories in urban areas and more and more farmers are seeking their fortunes in cities. Data on the number of highway miles per capita shows the boost of highways and freeways with the development of urbanization and public transportation in China. A variable highway mile per capita is an important measure of urbanization in China. Economic development and the resulting increases in income explain the changing patterns of spending on goods and services.

Furthermore, owning a car is becoming a practical and affordable option for more and more families because of the diversified and expanded economic activities, thus leading to a booming market for private vehicles. Among all the relevant variables that influence car ownership, economic development appears to be the most significant factor. It also can be seen from table 4.1 that the growth rate of both population and urban population were moderate during the time period compared with the growth rate of GDP which was, on the other hand, substantial. As an important indicator of economic development, Gross Domestic Product (GDP) based on purchasing power parity (PPP) per capita in China has been increasing dramatically from \$250.831 (2% of US) in 1980 to \$6778.091 (15% of US) in 2009 in 2010 US dollars (International Monetary Fund). This is an estimate of national living standards and macro-economic development. People living in a country with a higher GDP per capita tend to have a better well-being as indicated by the overall measures of social, economic and environmental factors.

Car ownership is strongly associated with per capita income (Schipper 1995). The amount of savings per capita is a more direct indicator to describe the overall income status and potential purchasing power in China since people intend to deposit most of their income in the bank.

Given the number of factors that influence car ownership, GDP per capita, saving deposit per capita and highway miles per capita are key factors. Since GDP per capita is a key measure of economic development, savings deposit per capita is a direct indicator of purchasing power changes in China, and highway miles per capita represents the urbanization changes, all the variables are necessary as the independent variable to explain private car ownership since population growth, increased urbanization and economic development are the three main factors that influence the growth of car ownership in developing countries. In order to build an ordinary least square linear regression model to predict short term car ownership, a function including these variables as independent variables is developed.

The plots of the variables show the nature of these variables: nonlinear. To make a linear regression model, we need to convert the nonlinear equation into a linear one by taking the logarithm of all the variables.

Therefore, the model is:

$$LN(C_t) = \alpha + \beta_1 LN(G_t) + \beta_2 LN(S_t) + \beta_3 LN(H_t) + \mu_t$$

C_t = Private car ownership per capita;

G_t = GDP per capita (yuan in nominal terms);

H_t = Highway miles per capita (km);

S_t = Saving deposits per capita (yuan);

μ_t is random error which contains the unexpected variations on car ownership per capita that cannot be explained by GDP per capita, savings deposits per capita and highway miles per capita. The predicted value of car ownership per capita will not be exactly equal to the actual value in the real world. The difference between can be explained as random error which is μ_t.

Highly increasing household income has led to greater savings and has transformed the demand for consumption goods as more and more people can afford to buy a car which provides a large market for automobiles. Therefore, savings deposits per capita (S_t) are positively related with car ownership (C_t). So the expected sign of the coefficient of S_t should be positive.

As a developing country, China's automotive industry is still in its growing stage. In order to manufacture vehicles, the automotive industry needs to purchase lots of products and services from many other industries, like various metals and electronics. When GDP per capita (G_t) increases, it indicates that the downstream industry for automotive industry also increases. The growth of GDP provides a powerful economic force for both the automobile manufacturing and service industry. The expected sigh of the coefficient of G_t is positive.

As an infrastructure industry, highway construction plays an important role in the development of the automobile industry. In China, the highway construction industry is mostly managed by the government. The total road length open to traffic has increased from 50,000 miles in 1949 to 751,894 miles in 2011. Fast increasing private vehicle use needs more highways. Total highway mileage (H_t) makes an important contribution to car ownership (C_t), so the expected sigh of the coefficient of H_t is positive.

All data are available from the statistics database of China National Knowledge Infrastructure (CNKI) from 1980 to 2009. μ_t is the residual that cannot be explained by this equation, β_1, β_2 and β_3 are the coefficients which are estimated by least squares regression. As explained, the expected signs of β_1, β_2 and β_3 are all positive.

The regression results

$$LN(C_t) = -3.917 + 0.168\, LN(G_t) + 0.278\, LN(S_t) + 0.634\, LN(H_t) + \mu_t$$

	(0.132)	(0.076)	(0.083)
t =	1.269	3.663	7.62

N = 30, R^2 = 0.996, adjusted R^2 = 0.996, F = 2207.5, d = 1.23

The overall fit of the model is plausible. The signs of the coefficients are all positive as expected. The R squared and adjusted R squared are both 0.996, and the F-statistic indicates that the overall model is statistically significant to explain the relationship between car ownership per capita and GDP per capita, highway miles and savings deposits from 1980 to 2009.

5. Tests of Classical Assumptions

5.1 Multicollinearity

All the t-scores in the regression result are significant except G_t. It is possible that there might be multicollinearity in the model. Multicollinearity can affect the regression result with decreased t-scores in the coefficients. Variance inflation factors (VIF) need to be calculated to detect multicollinearity. A common rule is that if VIF is bigger than 5, then the multicollinearity is severe. For VIF_G, a regression that G_t is a function of H_t and S_t is run, and $VIF_G = 76.46$; For VIF_H, a regression that H_t is a function of G_t and S_t is run, and $VIF_H = 12.07$; For VIF_S, a regression that S_t is a function of G_t and H_t is run, and $VIF_S = 55.34$. All the VIFs for the original result are well above 5 which indicate severe multicollinearity in the regression result.

However, since multicollinearity does not cause bias to the coefficients in the regression model and theory justifies that all the independent variables should be included; we will do nothing and keep the regression specification in its original form. However, the multicollinearity explains the low t-score on G.

5.2 Omitted Variables

The regression result shows that the coefficient of G_t is not significant as the other variables. In order to decide whether G_t should be included in the model or not, we need to run a four part test for G_t.

Before run a four part test for G_t, a regression with only savings deposit per capita (S_t) and highway miles per capita (H_t) as the independent variables produces these results:

$$LN(C_t) = -2.64 + 0.374LN(S_t) + 0.723LN(H_t) + \mu_t$$
$$(0.009) \qquad (0.045)$$
$$t = 41.4 \qquad 16.1$$

N = 30, $R^2 = 0.9958$, adjusted $R^2 = 0.9955$, F = 3236

Comparing the two equations, the overall fit, for example, R^2 fell from 0.996 to 0.9958, and adjusted R^2 fell from 0.996 to 0.9955. Although the t score of both S_t and H_t is 41.4 and 16.1 respectively, more significantly, the coefficients change significantly, from 0.278 to 0.374 for S_t, and from 0.634 to 0.723 for H_t, indicating bias in the second result.

Now we can summarize the four part test by comparing the omitted regression result with the original regression result:

1. Theory: G_t is an important variable which represent the overall significance of the economic development of China during the past thirty years and it is the main cause of changes in private car ownership.
2. T- test: the estimated coefficient of G_t is not significant as the other variables in the expected sign.
3. Adjusted R^2: adjusted R^2 barely changes when G_t is omitted, indicating that G_t might be irrelevant.

4. Bias: the coefficients of S_t and H_t change significantly when G_t is dropped, meaning that the omitted regression might be biased.

The four part test shows that 2 of them indicates that G_t should be included in the regression, while another 2 of them indicates that G_t should not be included in the regression. But From a theoretical point of view, G_t is a relevant variable because it measures economic development from 1980 to 2009, thus it cannot be excluded from the original equation.

However, we still cannot conclude that there are no omitted variables. Besides the variables in this model, it is likely that there are other factors that can affect car ownership, for example, costs of alternative transportation, costs of ownership and driving, price of cars and price of gasoline and various policies that could affect car ownership. But with a high R^2 of 0.996, since the data of price is not available and policies are not quantifiable, the original specification of the model is chosen as the final regression model.

5.3 Serial Correlation

Serial correlation in a dynamic model will cause OLS to no longer be the minimum variance unbiased estimator. The Durbin-Watson d statistic is used to see if there is first-order serial correlation in the residuals of an OLS regression equation. The calculated Durbin-Watson d statistic is d = 1.23. Given the sample size of 30 and 3 explanatory variable, the upper critical d value d_U is 1.65; d_L is 1.21 using a 5% level of significance. Given the null hypothesis of no serial correlation and a two-sided alternative hypothesis:

Ho: $\rho <= 0$ (no positive serial correlation)

Ha: $\rho > 0$ (positive serial correlation)

The appropriate decision rule is:

If $d < d_L$ reject Ho

If $d > d_U$ do not reject Ho

If $d_L <= d <= d_u$ inconclusive

Since, $d = 1.23$, $d_L = 1.21$, $d_L = 1.65$, $d_L < d < d_u$, thus the test for first order autocorrelation is inconclusive.

5.4 Spurious Correlation

To test for spurious correlation, it is first necessary to plot all the dependent and independent variables against time in figure 5.1:

It can be seen from these curves that there is an upward growth trend for all of them. The mean values of these variables are increasing over time. Thus, this indicates that these variables are likely nonstationary.

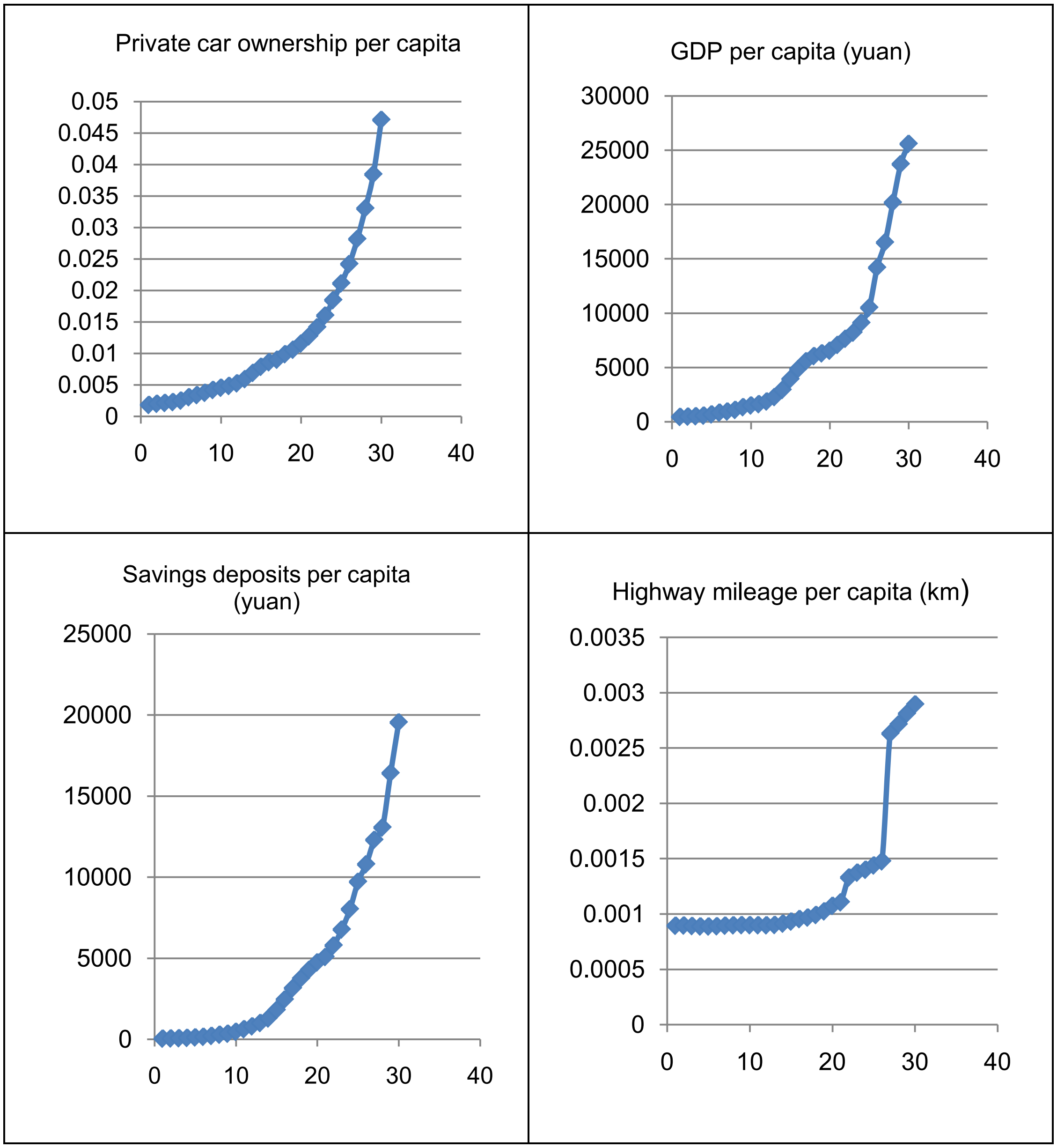

Figure 5.1 Plots of independent and dependent variables against time

Spurious correlation is a strong relationship between two or more variables that is not caused by a real underlying causal relationship but by the same underlying trend (Studenmund 2005). It will cause inflated values of t-scores and adjusted R squares, resulting in incorrect specifications.

Spurious correlation can be caused by nonstationary time series. A time series variable is stationary only if the mean and the variance are constant over time and the simple correlation coefficient between observations of the variable depends on the length of the lag and no other variable. Otherwise, it's nonstationary. In fact, in a time series regression, not only the dependent and independent variables can be nonstationary, the error term can also be nonstationary.

The Dickey – Fuller Test can be used to examine if a variable is nonstationary or stationary by building the hypothesis that the variable has a unit root based on the estimate of a_1 in three forms: no constant, no trend, or with a trend. In this paper, the third form with a constant and a trend is more useful because from the plot, these data clearly have trends.

$\Delta Y_t = a_1 Y_{t-1} + u_t$

$\Delta Y_t = a_0 + a_1 Y_{t-1} + u_t$

$\Delta Y_t = a_0 + a_1 Y_{t-1} + a_2 t + u_t$

And the hypothesis is constructed as:

H_o: $a_1 = 0$ (nonstationary)

H_A: $a_1 < 0$ (stationary)

If the estimate of a_1 is significantly less than 0, then we can reject the null hypothesis of nonstationarity. If the estimate of a_1 is not significantly less than 0, then we cannot reject null hypothesis of nonstationarity. And since the variables in this study are in logarithm form, it is necessary to test the logarithm form for nonstationarity.

If a variable, either the dependent variable or an independent variable, is stationary, then it is useful to keep it in its original form; if the variable is nonstationary, the first-difference form may be more useful, or the residuals should be tested for cointegration.

Critical values for Dickey Fuller test for unit roots with finite sample sizes in linear regression can be calculated from table 5.1(Mackinnon 1991). For any sample size N, the estimated critical value is $t_c = \beta_\infty + \beta_1/N + \beta_2/N^2$. Here, when time series T = 1(linear regression), and N= 29, the 5% critical value for the with trend and a constant Dickey Fuller test is: t_c = -3.4126 - 4.039/29 - 17.83/ (29^2) = -3.573; the critical value for the no trend Dickey Fuller test is t_c = -2.8621 – 2.738/29 – 8.36/29^2 = -2.966. Since the automotive industry in China is still in the developing stage, and all the variables in the model are increasing with time from 1980 to 2009, we need to use the third form with a constant and trend to run the Dickey Fuller test.

For LN (C_t), the result of Dickey Fuller test is:

$$\Delta LN(C_t) = 0.718 + \underset{\substack{(0.104)\\ t = 0.945}}{0.099}\, LN(C_{t-1}) + -0.008\, t + u_t$$

N = 29, R^2 = 0.25, adjusted R squared = 0.19, F = 4.32

Since, t = 0.945 > t_c = -3.573, we cannot reject the null hypothesis of nonstationary, and cannot conclude that LN (C_t) is stationary.

For LN (G_t), the result of Dickey Fuller test is:

$$\Delta LN (G_t) = 1.02 – 0.15 LN (G_{t-1}) + 0.02 t + u_t$$

(0.101)

t = - 1.47

N = 29, R^2 = 0.08, adjusted R squared = 0.007, F = 1.10

Since, $t > t_c$, the coefficient of LN (G_{t-1}) is not significantly less than zero, thus we cannot reject the null hypothesis of nonstationary.

For LN (S_t), the result of Dickey Fuller test is:

$$\Delta LN (S_t) = 0.34 – 0.007 LN (S_{t-1}) - 0.005 t + u_t$$

(0.039)

t = - 0.189

N = 29, R^2 = 0.48, adjusted R squared = 0.44, F = 11.8

The coefficient is not significantly less than zero, thus we cannot reject the null hypothesis of nonstationary.

For LN (H_t), the result of Dickey Fuller test is:

$$\Delta LN (H_t) = -0.599 – 0.078 LN (H_{t-1}) + 0.007 t + u_t$$

(0.094)

t = - 0.822

N = 29, R^2 = 0.169, adjusted R squared = 0.106, F = 2.66

There coefficient of LN (H_{t-1}) is not significantly less than zero, thus we cannot reject the null hypothesis of nonstationary.

At this point, all the Dickey Fuller tests shows that there is no evidence to reject the hypothesis that these variables are nonstationary, but we still cannot conclude that these variables are stationary, thus it is possible that the regression result is spurious. To resolve this issue, we need to run a test for cointegration.

5.5 Cointegration

In the previous section, the Dickey Fuller tests on all the variables show that nonstationarity is likely. However, it is possible that the linear combinations of them are stationary, that is to say, they could be cointegrated. Cointegration consists of matching the degree of nonstationarity of the variables in an equation that makes the error term of the equation stationary and rids the equation of any spurious regression results (Studenmund 2005). If the variables are cointegrated, then spurious regressions are avoided and the variables should stay their original form.

The Dickey Fuller test on the residuals can be performed to test if the variables are cointegrated. And critical values can also be obtained from Table 5.1, when N = 1, T= 29, the 5% critical value for no trend Dickey Fuller test is $t_c = -2.8621 - 2.738/29 - 8.36/29^2 = -2.966$.

To calculate the residuals,

$$e_t = LN(C_t) - \alpha - \beta_1 LN(G_t) - \beta_2 LN(S_t) - \beta_3 LN(H_t),$$

$$\Delta e_t = a_0 - a_1 e_{t-1} + \lambda_t$$

H_o: $a_1 = 0$ (unit root exists)

H_A: $a_1 < 0$ (unit root doesn't exist)

If a_1 is significantly less than zero, then reject the null hypothesis of a unit root in the residuals, if a_1 is not significantly less than zero; do not reject the null hypothesis.

The result of the Dickey Fuller test is:

$$\Delta e_t = 0.0015 - 0.693\ e_{t-1} + \lambda_t$$

(0.198)

t = -3.51

N = 30, R squared = 0.31, adjusted R squared = 0.29, F = 12.286

Since $t < t_c$, reject the null hypothesis of unit root in the residuals, thus conclude that the variables are cointegrated, and the equation can be estimated in its original specification.

Table 5.1

Response surface estimates of critical values. (MacKinnon 1990) (T is time series)

T	Variant	Level	β∞	(s.e)	β1	β2
1	no constant	1%	-2.5658	0.0023	-1.96	-10.04
		5%	-1.9393	0.0008	-0.398	
		10%	-1.6156	0.0007	-0.181	
1	no trend	1%	-3.4336	0.0024	-5.999	-29.25
		5%	-2.8621	0.0011	-2.738	-8.36
		10%	-2.5671	0.0009	-1.438	-4.48
1	with trend	1%	-3.9638	0.0019	-8.353	-47.44
		5%	-3.4126	0.0012	-4.039	-17.83
		10%	-3.1279	0.0009	-2.418	-7.58

6. Evaluation of the Model and Forecast

The estimation result:

$LN(C_t) = -3.917 + 0.168\, LN(G_t) + 0.278\, LN(S_t) + 0.634 LN(H_t) + \mu_t$

shows that 99.6% of the actual car ownership per capita from 1980 to 2009 can be explained by GDP per capita, savings deposits per capita and highway mileage, as shown in the figure bellow. The results show that the overall performance of the regression equation is acceptable, and it is appropriate to use as the final estimation model to illustrate the relationship between car ownership per capita and GDP per capita, savings deposits and highway miles. Thus it can be used to forecast short term car ownership in China given actual values or appropriate quantitative assumptions of GDP per capita, savings deposits per capita and highway miles per capita.

In figure 6.1, actual and predicted car ownership is illustrated graphically against time from 1980 to 2009. The predicted data shows strong ability to reproduce the actual data.

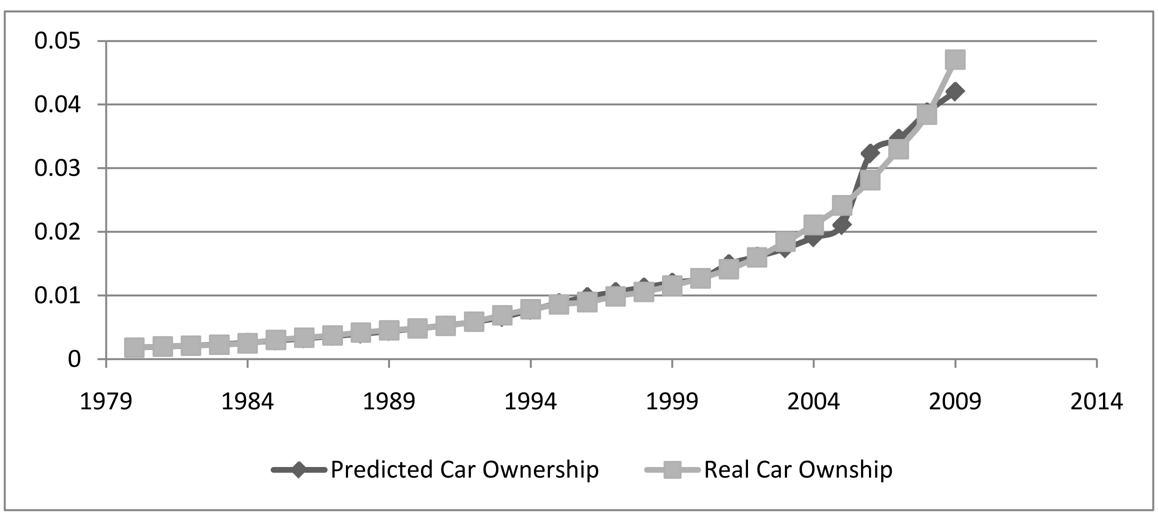

Figure 6.1 Comparison of predicted and actual car ownership. Source: Statistics Database of National Knowledge Infrastructure

For example, if in 2010 GDP per capita increases by 8%, per capita savings deposit increases by 15% and miles of highway per capita increase by 4%, assuming all else is held constant, the predicted value of car ownership per capita will be 0.045. The result is less than the actual amount in 2009 due to the standard error. If the values of GDP increases 1%, assuming all the other variables stay constant, the calculated predicted value of car ownership will increase 0.17%; if the values of savings deposits per capita increase 1%, assuming that all the other variables stay constant, the predicted value of car ownership per capita will increase 0.28%. If the highway miles per capita increases 1%, assuming all the other variables stay constant, the predicted value of car ownership will increase 0.63%. Highway miles per capita have the most significant impact of all the independent variables on the dependent variable.

7. Implication for Gasoline Demand to 2015

Transportation is the fastest growing oil-consuming sector in China. The growth of car ownership in China directly relates to the increasing demand for petroleum. The rapidly growing economy, large population and increasing car ownership contributes to the growth of oil consumption.

As a net oil importing country since the early 1990s, China became the second largest oil importer in the world in 2009 behind United States. Petroleum consumption has increased from 1.765 million barrels per day in 1980 to 8.324 million barrels per day in 2009. Oil accounts for 19% of total Chinese energy consumption in 2008 (EIA).

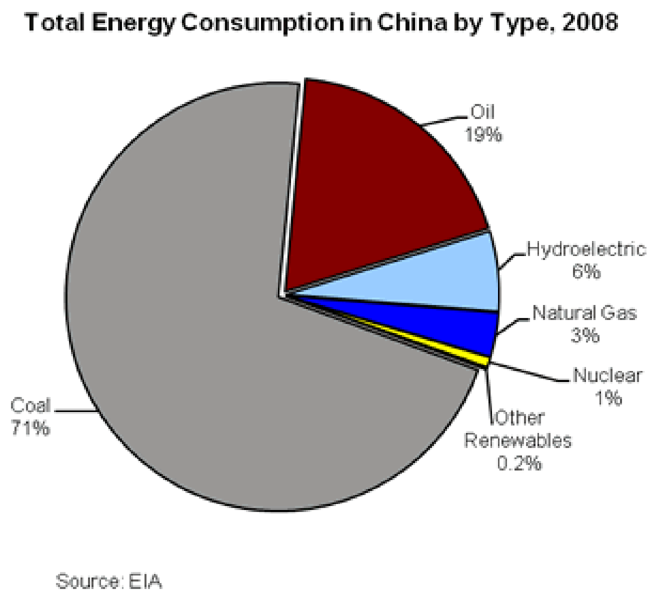

Figure 7.1 Total energy consumption by type of China in 2008. Source: EIA

Based on the forecast model of car ownership developed here, we can see that car ownership in China will continue to grow in the future. If GDP per capita keeps increasing at the rate of 8%, savings deposits continue increasing at the rate of 15% and highway miles keeps growing at the rate of 2% per year, and then car ownership will reach 0.06186 per capita in 2015. And the population of China is estimated to be about 1,369,743,000 in 2015 by United Nations, thus there may be some 84.7 million vehicles in China.

According to the Annual Report of Urban Road Transport Development, the annual vehicle miles traveled by private cars in China have been about 15,000 – 16,875 miles in 2005. Compared with other developed countries, the vehicle miles traveled (VMT) is much higher. For example, the VMT of private cars in Japan, France and Germany was about 6,250-8,750 miles per year between 1970 and 1990 (Schipper 1995).

In 2004, China issued a two-phase, weight-based national fuel consumption standard for passenger vehicles called the Passenger Vehicle Fuel Consumption Limits (GB19578-2004) for the purpose of facilitating the development and application of automotive energy saving technologies, improving the fuel economy of motor vehicles and providing a solution to the energy and environmental issues resulting from increasing transportation fuel consumption (He 2005). According to the Standard, if both of the two phase standards are implemented, the fuel consumption rates of private cars will be reduced by about 15% (He 2005). And the estimated MPG for private cars will be around 32 on road (Wang 2006).

Gasoline consumption by private cars is calculated as:

Gas = Car Ownership per capita * Population * Vehicle Miles Traveled / MPG

For example, given car ownership per capita = 0.061857943, population = 1,369,743,000, vehicle miles traveled = 15,000 and MPG = 32, the total gasoline consumption by private cars in China by 2015 will be 3.97×10^{10} gallons (or 946 million barrels). That is to say, by 2015, the oil consumption by private cars will be increased to 2.6 million barrels per day, which is much higher than the 1.9 million barrels per day used in 2009.

To make continuous projections of oil consumption by private cars from 1980 to 2015 based on optimistic assumptions about China's economic development, assume the growth rate of GDP per capita is 8%, the growth rate of savings deposits per capita is 15% and the growth rate of highway miles per capita is 2%. This results in the positive forecast shown in Figure 7.2. An alternative scenario based on conservative economic development trend is results from: the growth rate of GDP per capita is 3%, the growth rate of income savings deposit per capita is 5% and the growth rate of highway mileage per capita is 1%. The results of these two different scenarios are as follows:

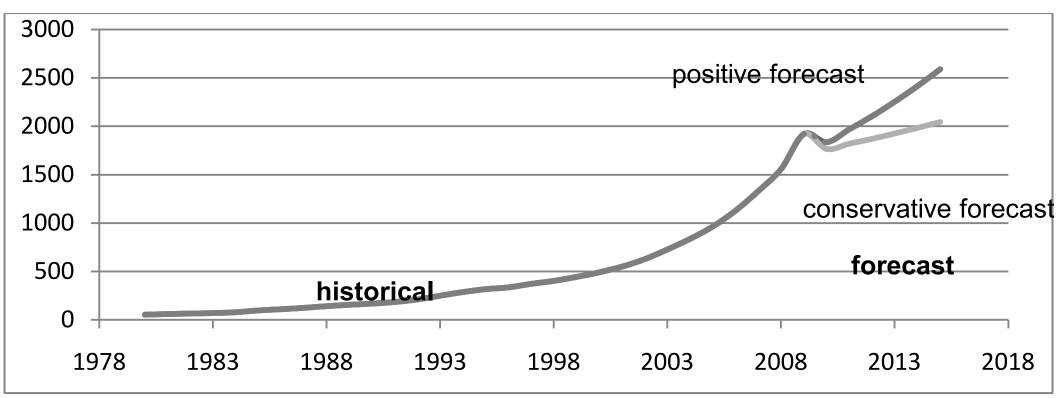

Figure 7.2 Oil consumption by private cars in two scenarios (thousand barrels per day). Source: Statistics Database of National Knowledge Infrastructure

As can be seen in the figure, in the conservative scenario car ownership in total will reach 66.84 million in 2015 with 2.0 million barrels of oil consumption per day. The oil demand by transportation sector will rise rapidly, with an annual growth rate of 2.7% - 3.1% in this conservative forecast, but 6.9% - 7.3% in the high case forecast from 2010 to 2015. Both of the two scenarios show potential growth in oil consumption which will put a great pressure on the balance of oil demand and supply.

This result shows that oil consumption by private cars in China is enormous and will continue to grow. To achieve sustainability of the automotive industry, the government is making efforts to promote technology improvement and improved energy economy.

In 1994, the first policy affecting the automobile industry was to encourage the development of the industry and automobiles were promoted as consumption goods. In order to protect the new Chinese local automobile manufacturers from fierce competition from international manufacturers with advanced technology, this policy established import quotas and stiff tariffs on imported vehicles and auto parts (Gallagher 2002). And it is required for joint ventures to share their technology with their partners and establish joint technical centers. Since then, more and more joint ventures have been promoted by the government to help encourage improvement of automotive technology leading to the development of China's own automobile industry.

As a result, more and more advanced technologies have been adopted by local manufacturers. For example, Shanghai GM is a joint venture of Shanghai Automotive Industry Corporation (SAIC) and GM. Its first vehicle, a Buick Xin Shi Ji (New Century), is one of the most popular sedans in China and represented a great improvement in technology at that time (Gallagher 2002).

In 1999, The “Emission Standard for Exhaust Pollutants from Light-Duty Vehicles” was implemented (He 2005). In 2004, the Automotive Industrial Policy was aimed at encouraging the purchase and use of small vehicles. In the same year, policy was revised by the government to encourage research and innovation to produce more of China’s own intellectual brand vehicles. Now the current Automotive Industrial Policy promotes the use of alternative fuels, such as compressed natural gas, methanol, and liquid petroleum gas (He 2005).

8. Conclusion

China has experienced rapid growth of car ownership since 1980 with the growth of GDP per capita, savings deposits per capita and highway miles per capita. The growth rate of car ownership per capita will keep rising until it reaches the saturation point. As a country with the highest car ownership level per capita, the United States reached a saturation level when its GDP per capita is at 20,000 U.S. dollars based on 1985 price (Wang 2006). And its saturation level is as high as 800 car ownership per 1000 people (Wang 2006). It will take years for China to match the car ownership level in the United States which is about 20 times of the level in China, since the car ownership per capita of China is only 47 per 1,000 people in 2009. If the saturation level of 800 per 1,000 people occurs in China, the total car ownership will reach 1068 million vehicles based on the population in 2009, which will result in 32.7 million barrels of oil consumption per day in the conservative economic forecast. This would be all of OPEC's current oil production, and it is not likely that the world petroleum industry could satisfy this demand.

During this study, an ordinary linear regression model was developed to evaluate car ownership per capita using GDP per capita, savings deposit per capita and highway miles per capita as independent variables. This is used to forecast Chinese car ownership through 2015. Tests of the classical assumptions show that the overall regression result is significant in explaining the relationship between car ownership per capita and GDP per capita, savings deposit per capita and highway miles per capita. And the combinations of these variables are stationary. Thus the model can be used to forecast the short term car ownership in the near future given appropriate projection of GDP per capita, savings deposit per capita and highway miles per capita. For long term forecast, this model may not be accurate enough because the trend of these variables may change due to unexpected economic changes or the saturation point may be reached. The forecast of car ownership from 1980 to 2015 will be different based on different economic scenarios.

On the other hand, as private car ownership is still a relative new phenomenon in China, statistical data related to it is very limited. The price of private vehicles is not available, thus it cannot be used as a variable. And as another important component to consider, the costs of car ownership is also far more complicated and greater in China than other countries, which includes the purchasing price of the car, maintenance costs, costs of parts, tolls as well as parking fees. In order to explain car ownership more accurately and include the uncertainties of price and costs as independent variables in the forecasting model, a quantitative way of defining these variables needs to be developed.

Oil consumption by private cars is projected by using the model developed in this study. The estimates of oil consumption reflect an important part of energy consumption. And it indicates that if China follows the trend as projected, the oil consumption by private cars will be increased to 2.6 million barrels per day by 2015. A serious question is raised: how will China meet this demand?

China faces great challenges in dealing with the increasing consumption of energy. Actions such as, improving private car energy efficiency, encouraging public transportation and technology development in the automobile industry have to be taken. It is the responsibility of all of us to achieve sustainability of automotive industry.

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