

The demand for gasoline in Japan to 2020 and new car fuel efficiency

David Bonilla†

EU Marie curie research Fellow

Cambridge Centre for Climate Change Mitigation Research

Department of Land Economy, Cambridge University

22 Trumpington street, Cambridge CB2 1QA, UK,

tel: +44 01223 335283, email: db408@cam.ac.uk

BIEE 6th Academic conference

Sept. 2006

Abstract:

Japanese private vehicle fuel efficiency has not improved significantly since 1989. The objective of the paper is to predict how (1) changes in the car stock, (2) in new car fuel efficiency, (3) in vehicle utilisation and (4) in the macro-economy impact on gasoline demand. By analysis of 12 sets of time series data (1980-02) of Japan's transport activity, its transport energy demand and its economy we calibrate the demand for gasoline to the year 2020 by private vehicles. Our study is based on several calibrated equations of which estimates feed into the main gasoline demand equations. We predict that gasoline demand increases to 22,000 (terajoules) under the high GDP scenario and declines to 20,000 (terajoules) under the BaU scenario by 2020. We find that actual fuel economy of vehicles is increasingly below test fuel economy of new vehicles. Tested Fuel efficiency is always a key assumption in predicting gasoline demand. Our results also show a weak elasticity of demand for new car fuel efficiency after increases in gasoline price. new vehicle fuel efficiency, utilisation, and the vehicle stock produce estimates of gasoline demand. By including the effect of the vehicle stock, new car fuel efficiency and demographics into a structural model of gasoline demand we improve the validity of the model's results.

1. Introduction

Personal vehicle ownership in Japan has been responsible to a large extent for Japanese economic success following the Second-World War. Higher car ownership fuelled the economy and manufacturing sector strength. Such successful expansion in car ownership has led to the ever-higher demand for gasoline and as a result for oil. In 2004 Japan is the third largest oil consumer in the world, following the USA and China, of which one fourth was accounted for the transportation sector, (BP statistical review of World Energy, 2005).

The vehicle market is of interest because of the large impact of vehicle production and use on many public policy concerns including trade flows, business cycles, energy demand and air pollution (Berkovec, 1985, pp.195). Second the rapid growth in the stock of Japanese private vehicles has increased demand for gasoline. Therefore efforts to reduce oil import dependence, by increasing vehicle fuel efficiency, ought to be a top priority of energy policy making in Japan. This article focuses on road transport activity of private vehicles; the sector accounts for 60% of total transportation energy consumption in Japan.

In this research we examine changes in:

- Car stock;
- Mobility via private vehicles;
- Gasoline (energy) demand of private vehicles;
- Survival ratios of the vehicle stock.
- Gasoline prices, and personal income
- Number of drivers

Second we extend the methodology. Our car stock approach taken incorporates capital stock characteristics and fuel efficiency of the car stock into the gasoline demand model. Failure to include the capital stock can affect the validity of the models' results since gasoline demand is highly correlated to vehicle stock. Further such an omission can prevent the analyst from predicting gasoline demand accurately. In this research rather than assuming energy efficiency improvements by introducing a deterministic trend, data on energy efficiency of vehicles is used in explaining gasoline demand and in its projection.

Aside from Sakaguchi (2000) there is limited number of studies that have considered the joint effect of supply (stock of vehicles) and demand (licensed drivers) in estimating gasoline demand for Japan. Except for Mannering and Winston (1985)¹ and Sakaguchi (2000), we go one step further by considering car utilisation and car ownership effects on gasoline demand. Further unlike many models, our model incorporates the effect of the number of drivers and population as we show in section 3 and 4. Many models of gasoline demand in the applied econometric literature and transport economics ignore the effect of annual demographic changes in the analysis of gasoline demand except for Gately (1990), and Schmalensee and Stoker (1999).

Our results bear important implications for global oil demand and the energy security of the Japanese economy.²

Our model of gasoline demand consider historical energy efficiency levels, and includes equations for the vehicle stock, population and household size. Our research contributes to clarify the historical drivers of gasoline and travel demand; we then propose a forecasting methodology to project gasoline demand. As said above our methodology includes the effects of the car stock, which few studies of gasoline demand of Japanese vehicles have done.

2. Data

2.1 The Transportation sector in the Japanese energy economy

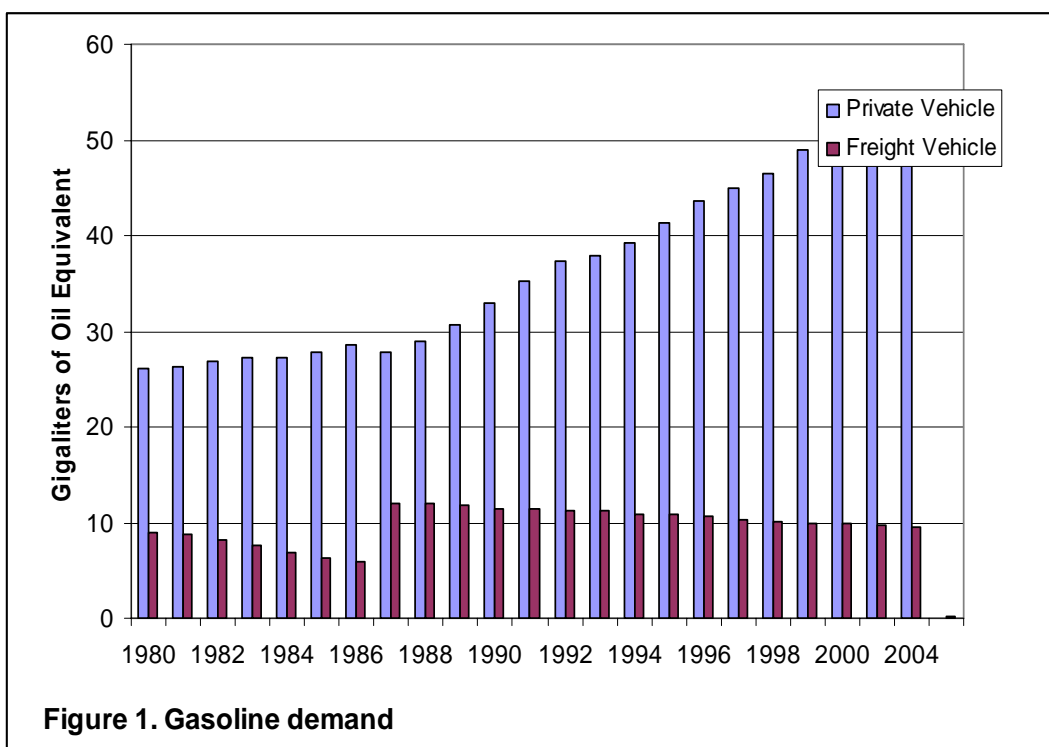
In 2003 energy demand by the transportation sector accounts for 25% of total final energy consumption against 23% in 1990 and 21% in 1980 (figures from IEEJ, 2005). A large chunk of the increase in transportation energy demand and oil demand as a whole in Japan has come from passenger vehicles which consume mainly gasoline. In recent years growth in energy consumption by the transport sector has outstripped that of industry, with rates of growth averaging 1.4% per yr. (1980-90) against 1.0% during 1990-03 (Source: IEEJ, 2005).

¹ Mannering and company adopt a conditional indirect utility function to capture vehicle choice and usage. Our approach differs from them in that we consider car utilisation explicitly and ignore vehicle choice.

² Hunt and Ninomiya (2003) can be added to important work on Japan's oil transport demand but they examine oil transport demand rather than gasoline demand using a sophisticated econometric model (structural time series technique). This paper is based on standard econometric techniques.

Gasoline demand

Japan's gasoline demand has not decreased since 1987. Fig. 1 depicts that total Japanese gasoline demand (gasoline demand including private vehicles, company cars and trucks) has grown by an average of 4% per yr. during the 1990s surpassing its own rate of growth during the 1980s (2.1% per yr., MLIT). In the 1990s gasoline demand has also grown faster than distance travelled by vehicles suggesting that there has been a rebound effect, a recovery in demand following a period of low gasoline prices, on demand and a decline in the fuel efficiency of cars. These growth rates in the demand for gasoline have also outstripped those of GDP per-capita (1.14% per yr. in 1990-02). Equivalent figures for the USA show that energy use by automobiles and light trucks rose by 1.6% (1990-01) and by 1% (1980-90)³. In Japan the recent growth in gasoline demand has been partly driven by higher sales of larger vehicles (luxury vehicles and sport utility vehicles or SUV's) as proportion of total vehicle sales (Sakaguchi, 2000). Therefore consumer preferences for less fuel-efficient cars such as these vehicles are crucial in determining the future growth of gasoline demand.

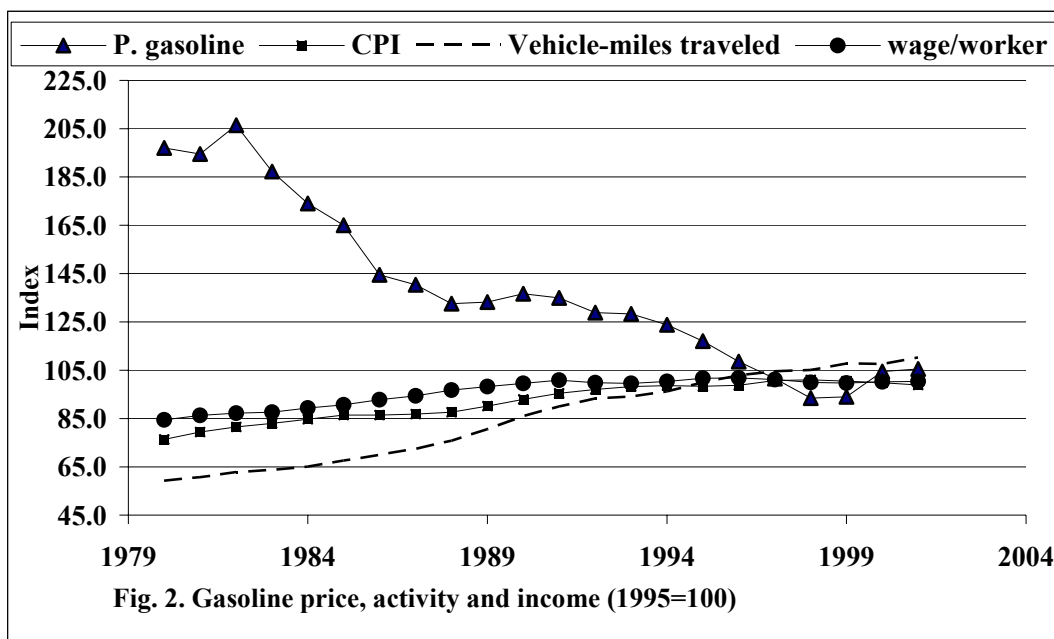


³ Transportation Energy Data Book (2004) pages 2-7. The data includes diesel consumption by light trucks.

In 2001, private passenger vehicles accounted for 80% of total gasoline consumption compared to 67% in 1990 and 68% in 1980. Therefore the use of private vehicles has gained a key role in the evolution of gasoline demand.

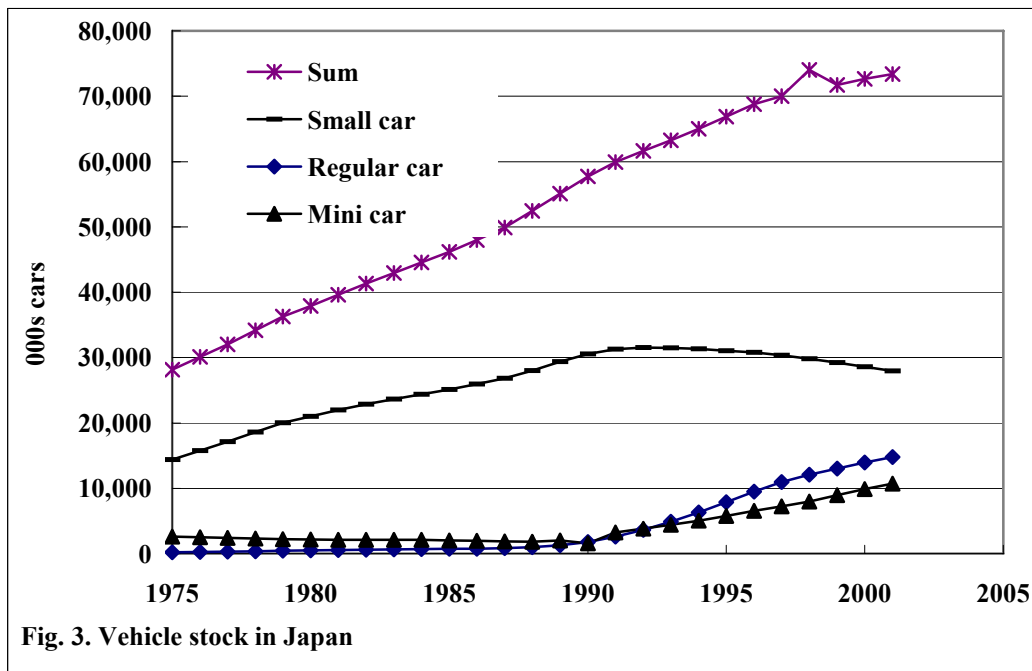
2.2. Gasoline price, travel demand and income

Figure 2 shows the time path of gasoline prices. While real gasoline prices have risen and decreased during the 1980-95 there has been an overall decline of 18% between 1983-2001, with large drops appearing between 1995 and 1997 (Japan Statistical Association; Japan Statistical Bureau). Figure 2 also depicts that growth of vehicle-km travelled (private vehicles) is less correlated to growth in gasoline prices (-0.93) than to income growth (-0.95). In fact income grows faster than vehicle-km travelled until 1995: from that year on income grows below vehicle-km travelled. Below we explain how key variables impacting on gasoline demand have changed during 1980-2001. We pay particular attention to changes in the volume of licensed drivers, car ownership and vehicle usage.



2.3. Vehicle stock and type

Figure 3 shows that the car stock in Japan continues to increase, despite the minimal growth in GDP per capita, since average car prices (for regular, small and mini cars) have fallen by 24% between 1980-2001. Hence the increase in the vehicle stock has led to higher gasoline demand. Although car sales turnover has declined from 12.5% in 1980 to 8.4 % in 2001, demand for vehicles continues.



From 1975-2001 the passenger car stock (regular, small and mini-cars) grew reaching 53 million cars by 2001, representing a three-fold increase since 1975⁴. In the 1980s Japan's car stock grows by 3.5% per year and by 4.3% per year in the 1990s. The minicar market in Japan has also grown rapidly (see Figure 3). In contrast the car stock in the USA grew by an average of 1.5% per year (1980-90) and by 0.4% (1990-01) (excluding vans counted as trucks but including light trucks; Transportation Energy Data Book, 2004).

Increases in the number of drivers and in car ownership have underpinned the growth of the vehicle stock in Japan. Also the percentage of households in Japan owning more than one car has grown from 15% in 1979 to 38% in 2002 (MILT, 2002). Household size decreased from 3.25 persons-household in 1980 to 2.7 in 2001 (National institute of population and Social Security Research) decreasing the number of driving adults per household.

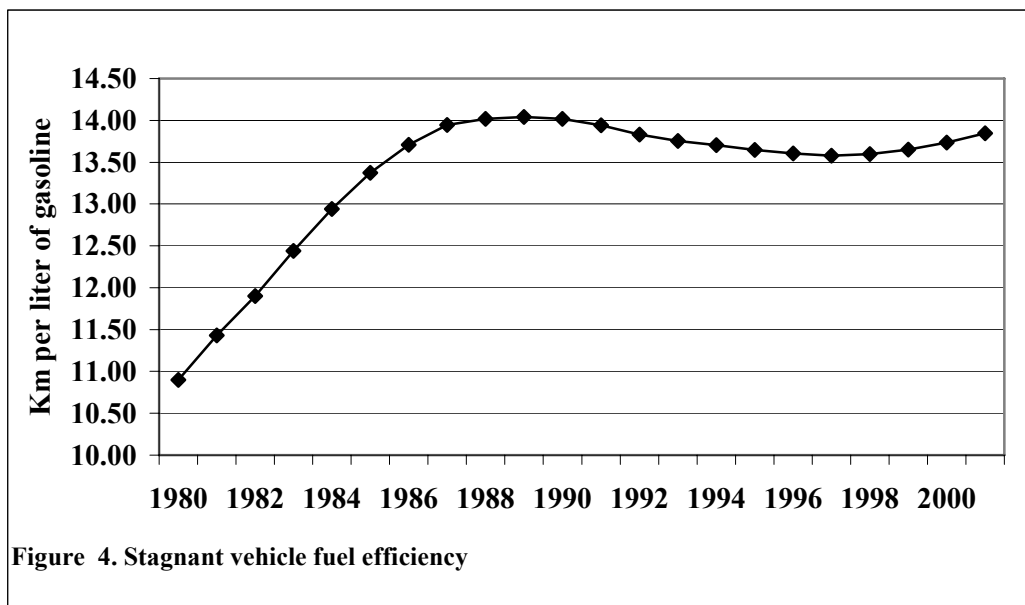
2.4. Car utilisation

Another determinant of gasoline demand is the mean annual car utilisation. Utilisation depends on both the car stock per capita and on the mean fuel intensity (Johansson and Schipper, 1997) In Japan car utilisation first declines and recovers by the late 1980s (data source: IEEJ, 2005). By the 1990s utilisation rates begin to fall to 9.5 (km/car) from a peak of more than (10.5 km/car) in 1990. Falling utilisation coincides with the decline in fuel efficiency of vehicles (the inverse of specific fuel consumption) and this decrease in fuel efficiency drove up costs of transportation per km (driven) reducing vehicle utilisation.

⁴ 1991 marks the peak in growth rates for passenger cars (9.3% y-on-y); thereafter it declines to as low as 1.9% (y-on y) in 2002 (JAMA, 2003).

2.5. Vehicle fuel efficiency

Improving efficiency is key to reducing gasoline demand. Actual Vehicle fuel efficiency (the inverse of car specific fuel consumption (litre/km)) improvements during the 1980s and 1990s are plotted in Fig. 4. Has vehicle efficiency improved faster than mobility (vehicle-m)? In 1980-90 vehicle efficiency (km/litre) rises by an average of 2.3% per yr. with vehicle (km) travelled growing by 3.3% in the same period; by the 1990s, however, demand for mobility continued to outpace improvements in car efficiency (Source: IEEJ, 2005). In fact car efficiency improvements flattened during the 1990s. Hence vehicle efficiency has not improved enough to offset the new demand for mobility in Japan; efficiency has not improved since 1989. Equivalent figures for the USA show that car fuel efficiency rose dramatically during 1980-1990 (average 2.2% per yr.) and continue to rise through the 1990s by 0.74% (ORNL, US Transportation Energy Data Book, 2004).



3. Overview of the Model Structure

In the main model gasoline demand (terajoules) is estimated over the historical (1980-2002) and forecast (2003-2020) period on the basis of economic functions. Fuel efficiency of on-road vehicles (kilometres per litre) for a given year is converted into gasoline demand turning into the basis for the estimation of energy consumption. Numerical solutions are specified in technological terms (new car fuel efficiency), and are built-in to behavioural (vehicle use, number of drivers) and regulatory responses such as fuel efficiency standards applicable to vehicles. Appendix A shows a list of variables and units used in the model.

The gasoline demand model is built to mix with the main time series model using the equations of three vehicles types: small, standard and mini. In this analysis of gasoline demand each set of vehicles are disaggregated at various levels depending on the year. These vehicle types are given in Table 1.

Table 1: Vehicle Types Employed in the Model

Vehicle class	Engine size % of market 1988	Engine size % of market 2003
Small (<2000 cc)	91	44
Mini (<660 cc)	4	28
Standard (Medium – large)	4	28
Source: IEEJ, 2003, pp. 125, table 12		

4. Estimating Japan’s vehicle stock

Gasoline demand is a derived demand since it depends on vehicle stock of gasoline fuelled vehicles. In this section we explain how the vehicle stock and vehicle sales are estimated. Economic theory suggests that the vehicle stock is a function of past investment (in vehicles), utilisation rate of older vehicles, investment in new vehicles and their current utilisation (Berndt and Botero, 1995, pp. 5). In what follows we estimate a demand function of vehicles and explain the vehicle stock that survives for the three vehicle types.

Surviving vehicle stock overtime

In this formulation vehicle sales act as inputs to estimate vehicle stock to 2020.

We estimate the surviving vehicle stock assuming vehicles are uniquely a function of vehicle sales and the age of the vehicle. The function for the vehicle sales and surviving vehicles stock is of the following form:

$$\sum_{m=1}^{18} SALES_i \times \gamma_i^m = (sales_i^1 \times \gamma_i^1) + (sales_i^2 \times \gamma_i^2) + \dots (sales_i^{18} \times \gamma_i^{18}) \quad (1)$$

Where,

- SALES = vehicle sales for i vehicle per year (000's);
 γ = survival rate of vehicle i;
m = age of vehicle: 1 to 18 years;
i = vehicle type;

Function 1 is applied to data for years 1978 to 2020. For example for vehicles surviving into 1996 sales data for 1978, through 1996 are adjusted (using Eq. 1) yielding the vehicle stock in years 1996 onwards. Eq. 1 is plugged into Eq. 1.1 into a dynamic equation of vehicle stock where vehicle stock of age m is a subset of surviving vehicle stock.

And the function for (surviving) vehicle stock is, ignoring the t subscript in the right hand side term:

and the function for vehicle stock is:

$$SURSTOCK_t = \sum_{s=1969}^{t+1980} SALES_i \times \gamma_i \quad (1.1)$$

Where,

- SALES = new car sales;
SURSTOCK = surviving car stock is the number of vehicle i of age m which have survived;
 γ = survival ratio of vehicle age m;
(t = 0, ..., 21),
s = vehicle sales in 1969, 1970, ...,
i = vehicle type.

SURSTOCK yields the vehicle stock. To project the growth to 2020 in vehicle stock as shown in Eq. 1 vehicle sales are determined by using a time series equation . Relevant data is available in MLIT (JAMA, Handbook, 2003) as well as IEEJ (2003).⁵ Vehicle sales attributed to the different vehicles is estimated on the basis of oil price level at CFI, car ownership, past car ownership, and dummy variables.⁶ The data has been obtained in time-series form for the period 1980-2003. The time-series data is derived on the basis of actual figures for only 3 vehicle types 1980-2003. Fitted data for vehicle sales are obtained through OLS and it is these figures which are then sent to the gasoline demand equation described in Section 6. The IEEJ (2003) only documents, however, disaggregated data by 3 types of vehicles which restricts the level of disaggregation in our model.

Sales weighted fuel efficiency of vehicle stock

As in other countries vehicle fleet fuel efficiency is a product of past changes in the mix of vehicles, which in turn, is determined by new vehicle fuel efficiency and car sales. Demand for new vehicle efficiency is always affected by gasoline price, the latter being the most important factor (Greene, 1990).

Econometric analysis for average fuel efficiency of new cars for Japan reveals gasoline price elasticity of such efficiency of 0.06 using data of 1980-2002. This elasticity is quite small.⁷

Figure 1 is determined by using test fuel efficiency data of (new) vehicles weighted (published by JAMA's, Automobile guidebook), by sales data of the 3 vehicle types under discussion.

The fuel efficiency of i th vehicle stock was estimated using equations 2, 2.1, 2.2 of the following form:

⁵ Survival rates are estimated over time and annually. Hence we use two equations to estimate surviving vehicle stock.

⁶ Berkovec (1985) shows that econometric estimates of vehicle demand and scrappage can be used to simulate the vehicle market.

⁷ This calculated elasticity is estimated using data of a period of mostly falling gasoline prices. Greene (1990) reports a similar elasticity for US data for falling prices (1983-89) but most elasticities reported by him lie well above 0.06. The data used in the Greene study includes data of Japanese car manufacturers on new car fuel efficiency.

$$MSH_{it} = \frac{SALES_{it}}{\sum_i TSALES_t} \quad (2)$$

and,

$$\sum_{i=Vehicles}^N TSALES_t = SALES_{MINI} + \dots + SALES_{STANDARD} \quad (2.1)$$

Where,

SALES = Sales of ith vehicles (in millions) per year;

TSALES = total sales (standard, small, mini vehicles) per year;

MSH = market share of ith vehicle (%);

i = regular, small, mini vehicles;

t = 1980, ..., 2002

In Eq. 2.1 the market share of the ith vehicle at year t is calculated. Eq 2 is applied to data from 1980 to 2003.

Eq 2.2 describes how weighted fuel efficiency is arrived at using data on fuel efficiency (sales weighted). All variables, except percentage shares, are given in kilometers per litre per vehicle.

$$WFE_t = \frac{TAEF_t}{[EFF_{it} \times MSH_{standard_t}] + [EFF_{it} \times MSH_{small_t}] + [EFF_{it} \times MSH_{mini_t}]} \quad (2.2)$$

(i = mini cars, standard, etc,)

(t = 1980, ..., 2003)

Where,

- WFE = weighted fleet fuel efficiency taking into account of vehicle sales;
TAEF = total (all new vehicles) average test efficiency in driving mode 10.15;
MSH = market share of ith car (percentage);
EFF = test fuel efficiency (new vehicle) for ith vehicle in 10.15 driving mode.⁸

The three variables are given in units of kilometers per liter per vehicle.

And for vehicle i ,

$$AFE_{it} = [EFF_{it}] \times [WFE_t] \tag{2.3}$$

Where,

- WFE = sales weighted fuel efficiency (as defined in Equation 2.2 (km/l);
AFE = Adjusted new car fuel efficiency of ith vehicles (km/l);
EFF = Test fuel efficiency (new vehicle) at (km/l).⁹
 i = regular, small, mini vehicles;
 t = 1980, ..., 2002

AFE (Eq. 2.3) is the product of test fuel efficiency of new cars and fuel efficiency (sales weighted). In Eq. 2.3 the adjusted new car fuel efficiency (AFE) is calibrated using data on test fuel efficiency (EFF). AFE is formulated as a function of weighted fuel efficiency and test (new car) fuel efficiency for each of the three vehicle types. This calculation (Eq. 2.3) is made for vehicle sales of all vehicles types to determine their real fuel efficiency for years 1980-2003, as shown in Figure 5.

⁸ Data from IEEJ, 2003, p. 125 and Japan Automobile Manufacturers Association (JAMA), Jidousha Guidebok. Data for TAEFF is found in IEEJ (2003, pp. 125); for EFF in JAMA guidebook (2003); and for MSH based on sales data of JAMA Handbook (2003). 10.15 driving mode refers to the driving cycle of Japanese drivers in which urban and highways environments are considered to reflect a typical driving pattern. This pattern is then used by Japanese Government to determine the fuel efficiency of vehicles.

⁹ This fuel efficiency data (IEEJ, 2003, p. 125) is revised every two years by IEEJ/EDMC.

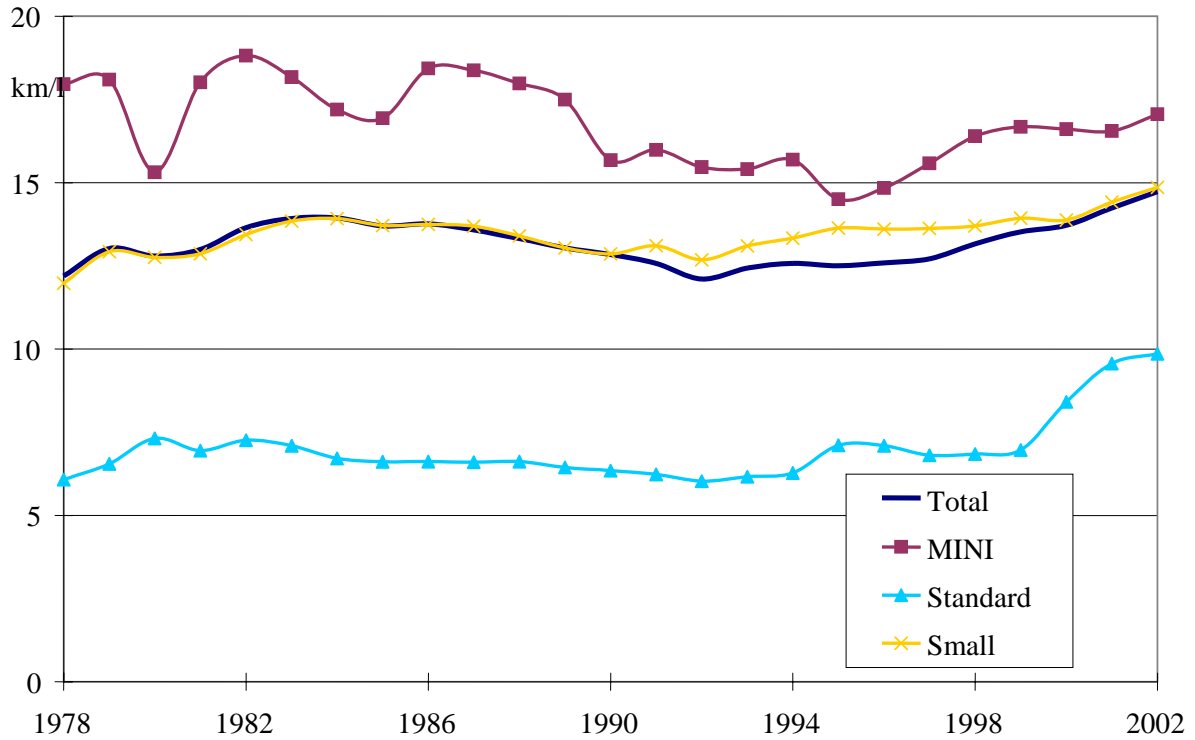


Figure 5. Efficiency of vehicle stock

After adjusting our fuel efficiency data for sales of each of the three types of vehicles we find that the differential between tested fuel efficiency of the stock and sales weighted fuel efficiency (fig. 5) diverges from 17% for 1978 to 35% for 2003. Hence sales weighted fuel efficiency of the vehicle fleet is lower than tested fuel efficiency. The adjustment made removes the bias for higher fuel efficiency of the original data based on fuel efficiency of new vehicles that includes the effect of fuel efficiency standards.

Standard and small cars fuel efficiency

The estimation of small (new) cars fuel efficiency and that of mini (new) vehicles is conducted similarly.

5. Estimating gasoline Consumption

The estimation of energy consumption by vehicle is determined on the basis of co-dependent economic and technological relationships.

Energy Consumption in Road Transport

The energy efficiency of vehicles changes over time in response to changing consumer preferences for larger or smaller vehicles, gasoline prices and R& D expenditure policies designed to reduce the fuel intensity of the vehicle stock. A set of these policies including promotion of low emission vehicles, fuel efficiency of new vehicles, and improved traffic flow and mandatory agreements between the Japanese government and vehicle manufacturers is estimated to reduce fuel use by road vehicles by 54.9 (Mt-CO₂) or by 18% by 2010 of emissions of that sector (Minato, 2005). Mandatory fuel efficiency standards alone are expected to reduce carbon dioxide emissions by 21 Mt-CO₂ by 2010. The effect of decreasing fuel intensity of the vehicle fleet is accelerated by driving behaviour since larger and newer cars are driven substantially more kilometres per year than older or smaller cars. Hence, the on-road impact of new, more (or less) energy intensive, vehicles is greater than their numbers show.

Gasoline demand is obtained by an equation that includes the ratio of the product (vehicle stock times vehicle use), to fuel efficiency of the stock defined in Eq. 2.3 for the three vehicles. Gasoline demand for the *i*th vehicle is obtained by applying the following form:

$$\sum_{m=1}^{18} GDAP \&_i^m \times uti_i = \left[\frac{(stock_i^1 \times uti_i^1)}{AFE_i} \right] + \left[\frac{(stock_i^2 \times uti_i^2)}{AFE_i^2} \right] + \dots + \left[\frac{(stock_i^{18} \times uti_i^{18})}{AFE_i^{18}} \right] \quad (2.4)$$

Equation 2.4 is applied to data for every year from 1996 to 2020 for vehicle *i*.

And gasoline demand for the whole period is calibrated as:

$$GDAP \&_{it} = \frac{PbstockH_{it} \times Uti_{it}}{AFE_{it}} \quad (2.5)$$

In Eq. 2.5 the gasoline demand of vehicle i at year year t is determined.

Where,

GDAP& = calibrated gasoline demand by private vehicles (TERAJOULES);
Pbstockh = stock per household (VEHICLE STOCK/ HOUSEHOLD) of ith vehicle;
Uti = utilization of ith vehicle (KM/VEHICLE);
AFE = estimated fuel efficiency of ith vehicle (KM/LITRE per vehicle); estimated in eq. 2.3.

(t=1980,...,2003);

(i= vehicles types).

Eq. 2.5 includes the vehicle stock and household effects and behaviour of drivers. We predict each of the variables of Eq. 2.5 to the year 2020.

Small cars gasoline Demand

The estimation of small cars gasoline demand is conducted similarly.

6. Forecasting gasoline demand by vehicle type

Using numerical results from Eqs. 1 through 2.5 together with estimates of several regressions projections are generated for gasoline demand of each of the three vehicles types

for 2003-2020 period.¹⁰ Projections of gasoline demand contained in Figure 6 for a BaU scenario.

The projections require a number of assumptions on:

1. Household income (using published forecasts by IEEJ (2006));
2. vehicle stock and use;
3. vehicle efficiency;
4. vehicle ownership;
5. Number of drivers per household.

We generate 2 cases in the projection: a fuel efficiency improvement (FEI) case and frozen fuel efficiency (2002 level) (FFE) case. The FFE case is an assumption on policy failure, or an assumption that new car fuel efficiency (subject to Government regulation, manufacturer behaviour) is not going to improve in the projection period. Tables 4 and 5 show the assumptions and outcomes.

In the FEI case the model shows that the effect of including fuel efficiency improvements shifts (BaU GDP and High GDP) the demand for gasoline downwards with visible effects on gasoline demand compared to frozen fuel efficiency case (Table 5). For example, in a BaU case which assumes an improvement in fuel efficiency of 1% per year for the three vehicles, the exercise concludes that gasoline demand of standard vehicles increases by only 0.04% from 2002 to 2020 ; by 1.08% p/year for small vehicles and by a 2.6% for mini vehicles. Under high oil price scenario gasoline demand of standard vehicles decreases by 0.4% from 2004. In contrast to the FEI case, in the FFE case with car fuel efficiency fixed at 2002 level, gasoline demand grows by 0.83 %/pa by (2004-2020 for total gasoline demand for the three vehicles. In this scenario high GDP growth leads to a growth of 1.5 % pa. in gasoline demand (Table 5). Further, the model can explain the effects of raising the average fuel efficiency of three types of vehicles (in the FEI case, BaU GDP) in 0.16 km/litre increments up to 16.7 km/l by 2020,. In all scenarios no rebound effect is assumed since vehicle utilization is flat. *The rebound effect is the increase in kilometres driven given a decrease in the cost per kilometer, in turn, led by declines in gasoline prices (Greening, 2000, pp.394).* In the scenarios the rebound in gasoline demand is neglected because it is believed that utilization will not increase following an increase in gasoline prices.

¹⁰ The coefficients are available from the author.

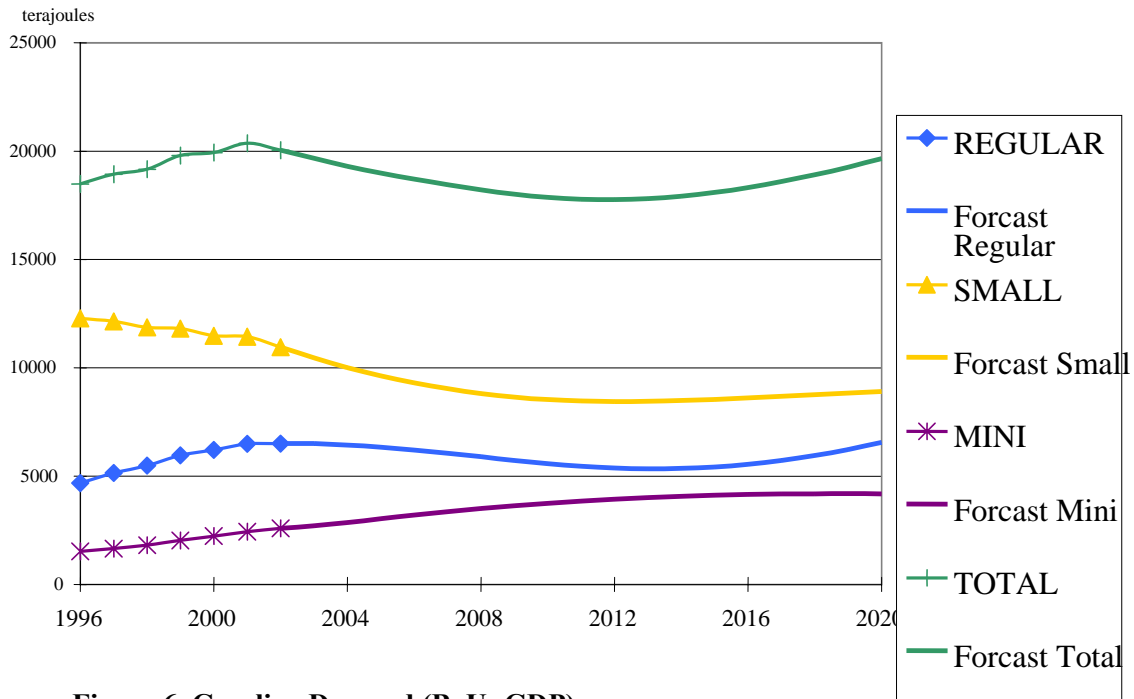


Figure 6. Gasoline Demand (BaU: GDP)

In most scenarios the bulk of gasoline demand savings is led by small vehicles rather than by standard vehicles, since the former account for the largest share of gasoline consumption.

How does our forecast compare to projections shown in Table 6? Our forecasts differ from the (IEEJ, 2006) mainly on:

- Vehicle stock assumptions.
- *Vehicle sales and GDP*
- *Household effects on vehicle sales*

Table 4. Scenario assumptions for gasoline demand to the year 2004-2020

	BaU (% pa)	High growth (% pa)
GDP growth	1.3	2.5
No. Drivers	0.6	0.6

Source: for GDP IEEJ (2006).

Table 5. Scenario comparisons for gasoline demand to the year 2004-2020 (this Study)

	Fuel efficiency (km/l) by 2020*	Gasoline demand 2004-2020 (% pa)
No Fuel efficiency Improvement (BaU GDP)	2002 level	0.83
Fuel efficiency Improvement 1% pa (BaU GDP)	16.65	0.11
No Fuel efficiency change (high GDP growth)	13.92	1.51
Fuel efficiency change (high GDP growth)	16.65	0.77

Notes: Base year for GDP: 2004 (IEEJ, 2006). The projections for GDP are given in Table 4. *Fuel efficiency of the entire vehicle stock is sales weighted (See equation 2.3); the METI has not yet set standards beyond 2010. In some scenarios fuel efficiency levels are kept constant to 2020. The fuel efficiency level is not directly comparable to official policy targets since numbers are weighted by sales.

Table 6. Scenario comparisons for gasoline demand to the year 2004-2020

	IEEJ Study* (% pa)	This study (% pa)
Reference	-0.60%	0.11%
High growth	-0.36%	0.77%
High prices	-0.57%	-0.40%

f*Base year : 2004 (IEEJ, 2006). In high price scenario oil prices reach 50 US\$/barrel (real term)

Conclusion

The rapid growth in the stock of Japanese private vehicles has increased the demand for gasoline, which has not decreased since 1987. Therefore predicting gasoline demand is essential to foresee future oil requirements of the Japanese economy. We have identified key historical relationships impacting on gasoline demand thus allowing an approach involving changes in vehicle stock and fuel efficiency rather than building a single equation model using a deterministic trend in modelling gasoline demand as others do.

The three key empirical models developed here rely on economic conditions before and after an economic boom and an energy crisis. From a methodological view our car stock approach incorporates capital stock characteristics into the gasoline demand model with the inclusion of supply curve to capture the surviving car stock. By including the car stock variable and demographic changes we improved the validity of the model's results, as well as the accuracy of gasoline demand projections.

In order to accurately project gasoline demand the real level of vehicle fuel efficiency is estimated to explain this demand. New car fuel efficiency was adjusted with car market trends and found to be well (17% in 1978 to 35% in 2002) above weighted fuel efficiency. Gasoline demand is modeled under several scenarios. Under fuel efficiency improvements gasoline demand could grow by 0.11% pa. in 2004-2020. In the absence of improving efficiency demand could increase to 0.83% pa. in that period.

This research should be extended to examining how the diffusion of luxury, SUV's and mini cars affect the overall fleet fuel efficiency and growth in gasoline demand. The research should also examine consumer choice of vehicles since such choices will impact on the future level of vehicle fuel efficiency shaping the evolution of gasoline demand in the next decades.

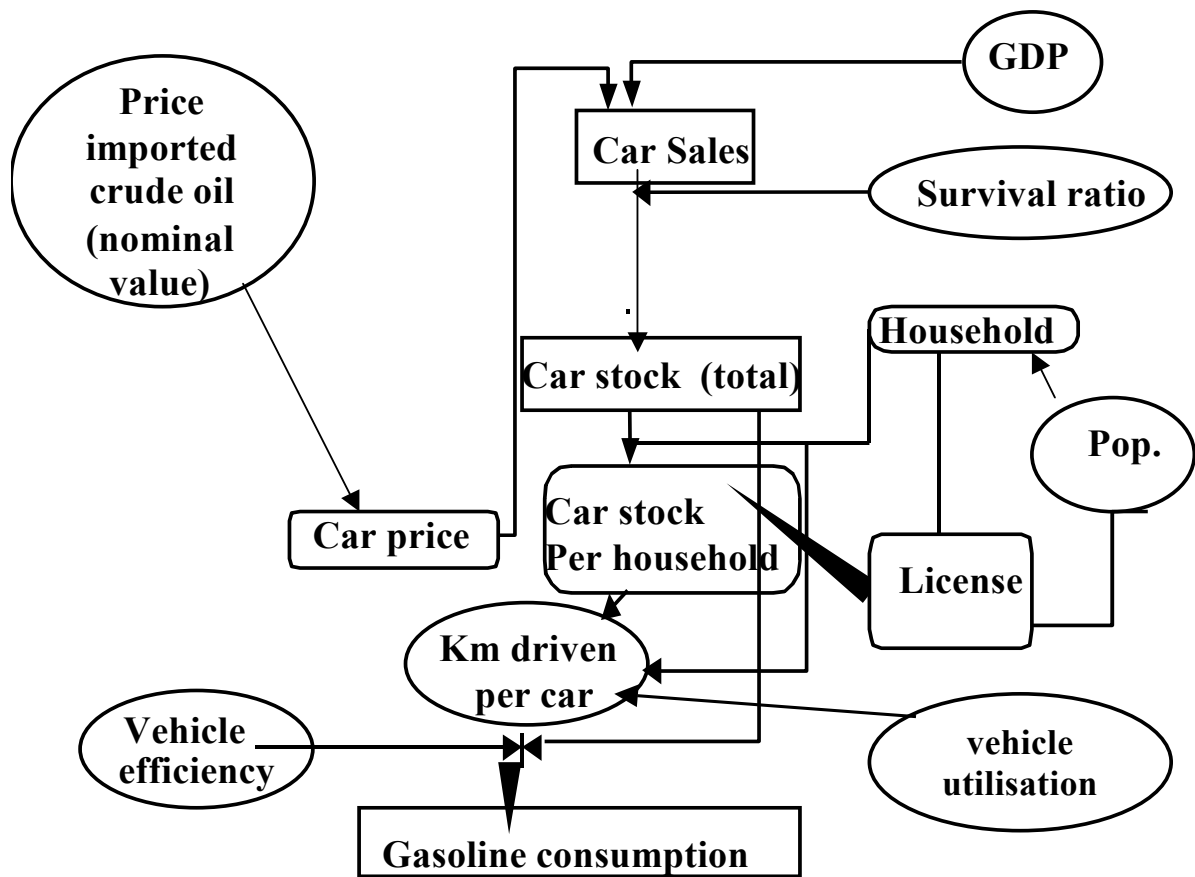


Fig. 6. Model for forecasting gasoline demand of Japan

APPENDIX 1

Table 1. List of variables

	<i>Variable</i>	<i>Unit</i>
HI	Household income	proportion
H	Household	millions
LICH	Licence per household	proportion
CFIOP	Oil price	US\$/barrel
CR	Yen to dollar exchange rate	ratio
ANR	Sales standard vehicle	1000
ANS	Sales small vehicle	1000
ANM	Sales mini car vehicles	1000
AST	Total car holdings	1000
ASTH	Vehicle per household	ratio
MSR	Actual Mileage regular and small vehicles	KM
MM	Mileage of mini vehicles	KM
RE	Fuel Efficiency new regular vehicle	Km/l
RS	Fuel Efficiency new small vehicle	Km/l
RM	Fuel Efficiency new mini vehicle	Km/l
D1	Dummy variable for new tax year	
GDAP& RED	Estimated gasoline demand for vehicle i Regular	TERA JOULES 1000/HOME
PBSTOCKH	Vehicle stock/ household	
ASTOCK	Transport Vehicle. Stock	MILLIONS
	Actual Vehicle stock	MILLIONS
SURSTOCK	Surviving vehicle stock	000 vehicle
γ	Survival rate of Vehicles (by Age of vehicle)	Rate
EFF	New Vehicle Fuel Efficiency (vehicle type)	KM/L
TAEFF	New Vehicle Fuel Efficiency (all vehicles, vehicle type)	KM/L
	Vehicle Fuel Efficiency (actual)	KM/L
WFE	Fuel Efficiency weight factor (vehicle type)	KM/L
AFE	Fuel Efficiency (adjusted) by vehicle type	KM/L
Uti	Kilometers per vehicle	1000 km/ L
m	Index for vehicle age	1-18 years
i	Index of vehicle types: standard, small and mini	1-3
t-1	Previous year	

Acknowledgements

Supported by the European Commission: EU-Marie Curie Fellowships 2005-2007 6th Framework Programme. The opinions expressed in the article pertain to the author. The author is solely responsible for the information communicated, published or disseminated and it does not represent the opinion of the Community and the Community is not responsible for any use of the data that appears therein.

References

- Arima J. (2000) The top runner program. Workshop on Best Practices and Measures, 11-13 April 2000, Copenhagen.
- Berkovec, J. 1985. New car sales and used car stocks: A model of the automobile market. *Rand Journal of Economics*, 2 (16), 195-294
- BP Statistical Review of World Energy (2005) available at: www.bp.com/statisticalreview
- ECCJ (2005) "What is the top runner programme?" available at: www.enecho.meti.go.jp, Agency of Natural Resources and Energy, (Japan).
- Gately, D. 1990. The US demand for highway travel and motor fuel. *The Energy Journal*, 3 (11), 59-72
- Greene, D.L. (1990). "CAFE OR PRICE? An Analysis of the Effects of Federal Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-89," *The Energy Journal*, vol. 11, no. 3, September.
- Greening L., Greene D., and Difiglio C. Energy efficiency-the rebound effect- a survey. *Energy policy* 28, pp.-389-401.
- Hunt, I., Ninomiya, Y. 2003. Unravelling trends and seasonality: a structural time series analysis of transport oil demand in the UK and Japan. *The Energy Journal* 63-92, 3 (24)
- Johnstone, N. 1995. Modelling passenger demand, energy consumption and pollution emissions in the transport sector. Department of Applied Economics, WP amalgamated series No. 9527, University of Cambridge
- Johansson, O., Schipper L., 1997. Separate estimations of vehicle stock mean fuel intensity and mean annual driving distance. *Journal of Transport Economics and Policy* 3 (31), 277-292

Minato K. (2005) Fuel economy and clean vehicles promotion policies in Japan. Japan Automobile Research Institute. Presentation November, 10.

Oak Ridge National Laboratory. Transportation Energy Data Book Edition 24. Report prepared by Davis C. and Diegel S.W. Center for transportation analysis and Engineering science and technology division. Dec. 2004 . US DOE AC05-00OR22725.

Mannering, F., Winston C. 1985. A dynamic empirical analysis of vehicle ownership and utilisation. *Rand Journal of Economics*, 2 (16), 215-236,

Sakaguchi, T. 2000. Influence for fuel efficient motor vehicles on gasoline demand for individual user owned passenger cars. *Energy Policy* 895-903 (Communication)

Schmalensee, R., Stoker, T.M 1999. Household gasoline demand in the United States. *Econometrica*, 3 (67), 645-662,

The basic framework: the data on transportation energy consumption, economic data:

References [Data sources]

- A. Institute of Energy Economics, Japan (2003, 2005) *Handbook of Energy Economics and Statistics, EDMC*.
 - B. Japan Automobile Manufacturers Association (JAMA), *Jidousha Guidebok*.
 - C. Japan Statistical Association, *Kouri Bukka Toukei Chousa Nennpou (Annual Report on the Retail Price Survey)*, <http://www.jstat.or.jp/index.html>.
 - D. Japan Statistical Bureau, *Bukka Shisuu Nennppou (Consumer Price Index (CPI))*, <http://www.stat.go.jp/data/cpi/>
 - E. Japan Automobile Manufacturers Association (JAMA), *Sekai Judousha Toukei, World Automobile Statistics*.
 - F. Automobile Business Association of Japan and Nikkan Jidousha Shinbun Sha (eds), *Jidousha Nennkann Handbook*.
 - G. MLIT, Ministry of Land, Infrastructure and Transport (2002) *Waga Kuni no Jidousha Hoyuu Doukou (Japanese Car Ownership Trends)*.
 - H. Land, Infrastructure and Transport, *Jidousha Yusou Toukei Nennpou (Annual Automobile Transportation Statistics)*, <http://www.mlit.go.jp/english/index.html>
- National Institute of Population and Social Security Research. Population projections available at: <http://www.ipss.go.jp/index-e.html>

Jidousha Nennkann Handbook (2002-2003 Edition), Nikkan Jidousha Shinbun-sha, Nippon Jidousha Kaigisho, ISBN:4901830082.

Kaya, Y. (1981) “Jyouyousha to sono Nennryou juyou doukou ni kannsuru kenkyuu”, (Reassert on Trends for Passenger Vehicles and their Fuel Consumption), available at: <http://www.nira.go.jp/icj/tt-sric/dat/1982/234079-290.html>

Statistics Bureau, Director- General for Policy Planning (Statistical Standards) & Statistical Research and Training Institute (1999), Soukei Chousa Sourann: Kok-henn. (Statistical Survey Country Edition), Ministry of Internal Affairs and Communications.

Statistics Bureau, Director- General for Policy Planning (Statistical Standards) & Statistical Research and Training Institute (1999), Soukei Chousa Sourann: Chihou Jichitai-henn. (Statistical Survey Local Government Edition), Ministry of Internal Affairs and Communications.

National Federation of Statistical Associations (1997), Minkann Toukei Guide (Private Sector Statistical Guide), NFSA.

Japan Management Association (JMA) Research Institute (2003), Business Data Kensaku Jitenn (Business Data Encyclopaedia), JMA Research Institute Inc. ISBN:4990150813