The Effects of Changes in Prices and Income on Car and Fuel Demand in Iceland

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30 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Industrial Engineering

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Abstract

The aim of this study is to estimate the effects on gasoline demand, the demand for new cars and the development of the car fleet in Iceland from changes in income, car prices and gasoline price.

Models are defined to estimate the elasticities of these demands from the year 1982 to 2008. Results for two alternative demand specifications are examined: One in which demand is assumed to be perfectly price-and income reversible and another which allows for irreversibility.

The main results from the reversible model are that changes in income have great effects on number of cars in Iceland and the demand for new cars. Car prices also affect these demands, especially the demand for new cars. From this it can be assumed that taxes and all extra charges on cars can have great impact on consumer's choice when buying a new car.

The results from the irreversible model lend support to the notion that consumers do not necessarily respond in the same fashion to changes in gasoline price. The gasoline use decreases more when gasoline price rises than it increases when gasoline price drops.

Preface

This 30 ECTS M.Sc. project was carried out at the Faculty of Mechanical Engineering, Industrial Engineering and Computer Sciences at the University of Iceland.

First of all I would like to thank my supervisors, Research Associate Professor Birgir Hrafnkelsson and Professor Páll Jensson at the Department of Mechanical- and Industrial Engineering, for their time, co-operation and support throughout this work. Furthermore I would like to thank Ingibjörg Björnsdóttir for proof reading.

This research is a part of a co-operation project between The University of Iceland, The University of Akureyri and Orkustofnun - National Energy Authority, with the aim to explore the possible development of electric transport and the results the development could bring. The project is sponsored by Orkuveita Reykjavíkur.

Reykjavík, June 2010.

Þórkatla Hauksdóttir.

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1 Introduction

A large part of the total emission of greenhouse gases in Iceland comes from transportation, where the largest part by far comes from car use. The Icelandic government wants to resist this development. By analyzing the factors which control the demand for cars and fuel use and understanding the relationship between the variables, the government can use the knowledge to influence the effects these factors have on the demand. Moreover is it important to know the effects of income to be able to predict the future demand for fuel and cars.

Discussion in recent years, in the field of transport and in economics, has produced an accumulating concern that the equilibrium foundations of many demand models do not correspond to the realities of consumer behavior (Gately and Dargay, 1997). Particularly there is a discussion about asymmetries, which occur when the rate and path of adjustment to long-run equilibrium differs when prices or income rise or fall. Such effects are not accounted for in traditional dynamics, which assume the existence of a unique equilibrium demand for any given price or income level.

The importance of asymmetry and irreversibility in traffic and transport modeling has been recognized for some time but the literature, however, is mainly of a theoretical nature and the empirical work is still rather sparse and based largely on tests for structural change (Gately and Dargay, 1997). On a more empirical level, the motivation for the concern with irreversibility stems from the conflicting evidence regarding the price elasticities of transport demand, and particularly that elasticity estimates are often sensitive to the time period of the analysis.

In this study the elasticities of demand for fuel and cars in Iceland will be examined, both with a common classical reversible demand model and also with an irreversible model, in order to examine asymmetric effects from variables influencing the demands.

The reversible model is built up in a similar way as a previous model made in 2004 by Þórhallur Ásbjörnsson (Þórhallur Ásbjörnsson, 2004). The imperfectly reversible model developed in this study is partly based on a model by Dermot Gately and Hillard G. Huntington (Gately and Huntington, 2002). They developed an irreversible model to describe the demand for fuel use in road transport. Their analysis was based on an econometric model which utilizes price-decomposition techniques to measure separately the effects of different types of price increases and decreases.

The outline of this paper is as follows: Section 2 gives an overview of the development of car ownership and fuel use from the year 1982 to 2008. Section 3 presents a description of the demand for gasoline, new cars and the development of the car fleet. The data, methodology and models are given. Section 4 shows the econometric results. Section 5 is a discussion about the possible application of this study and in section 6 the main results are presented and explained.

2 Background issues

As mentioned earlier there are three important issues examined in this study, the demand for gasoline, the demand for new cars, and the development of the car fleet. The effects of changes in income, gasoline price and car prices on the demands are examined.

This chapter gives an overview of how car ownership and fuel use has been developing in the years 1982 to 2008. The size of the car fleet, the average age of cars and what kind of cars it consists of has a great impact on the demand for fuel. It is necessary to keep track with the cars average life time, the sale development of new cars and different types of new cars, because these factors control how old the car fleet is and how it is compounded.

2.1 The development of the car fleet in Iceland

2.1.1 Number of cars

The number of cars[1] in Iceland increased by 121% from 1982 to 2008 while the number of cars per capita increased around 63%. This can be seen in Figure 1.

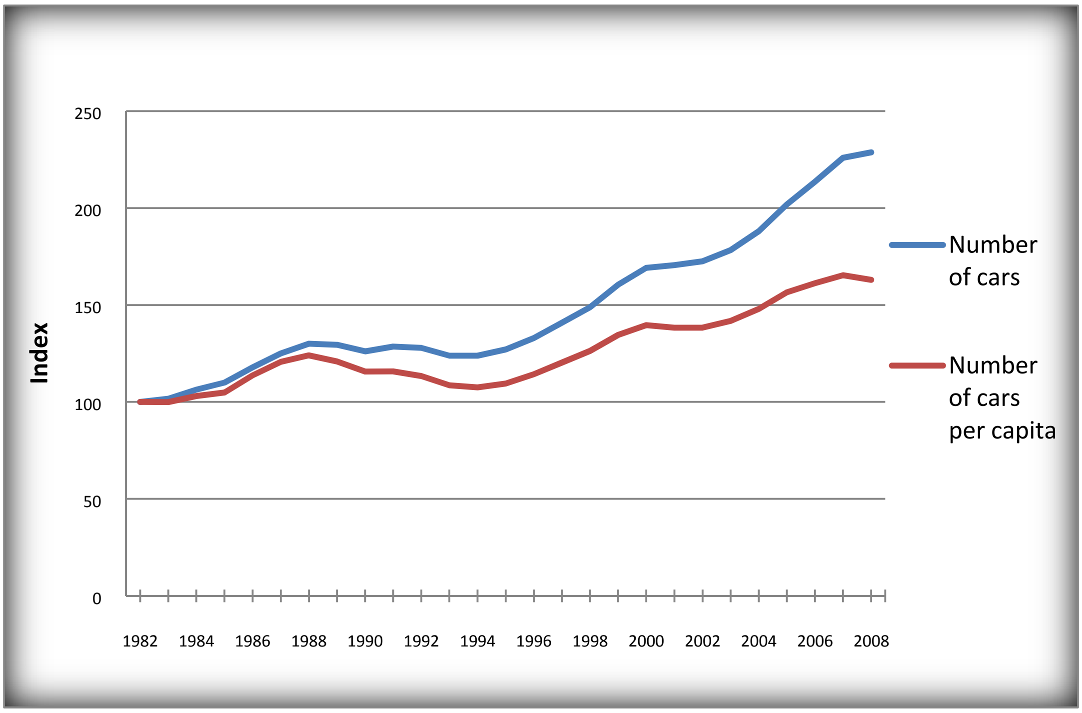


Figure 1: The car fleet in Iceland 1982-2008
Reference: Hagstofa Íslands - Statistics Iceland

[1] The number of cars for 8 passengers or less.

2.1.2 Number of cars vs. income

Real gross domestic product per capita in kronas is used as a measure for income. Real GDP has increased around 65% from the year 1982 to 2008. Figure 2 compares real GDP per capita and the number of cars per capita. From the figure it seems that there is a positive relationship between the factors.

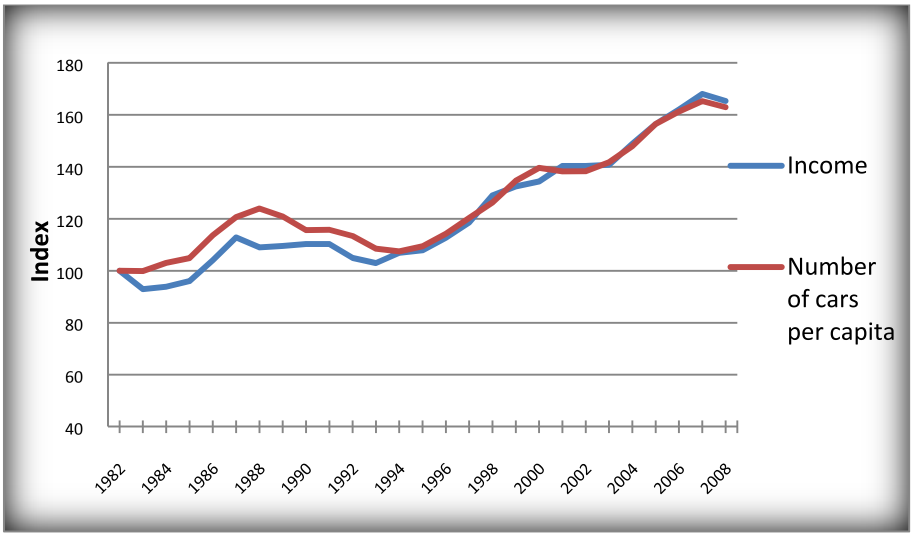


Figure 2: Number of cars and income per capita 1982-2008
Reference: Hagstofa Íslands - Statistics Iceland

The number of new cars each year fluctuates a lot more than the size of the car fleet. It is interesting to compare the number of new cars to income. Because the number of new cars varies so much between years, it is better to compare the proportional changes of both the number of new cars and income. Figure 3 shows the proportional changes between each year in the number of new cars sold and 10 times the proportional change for income. One can see some positive relation between the number of new cars and the income.

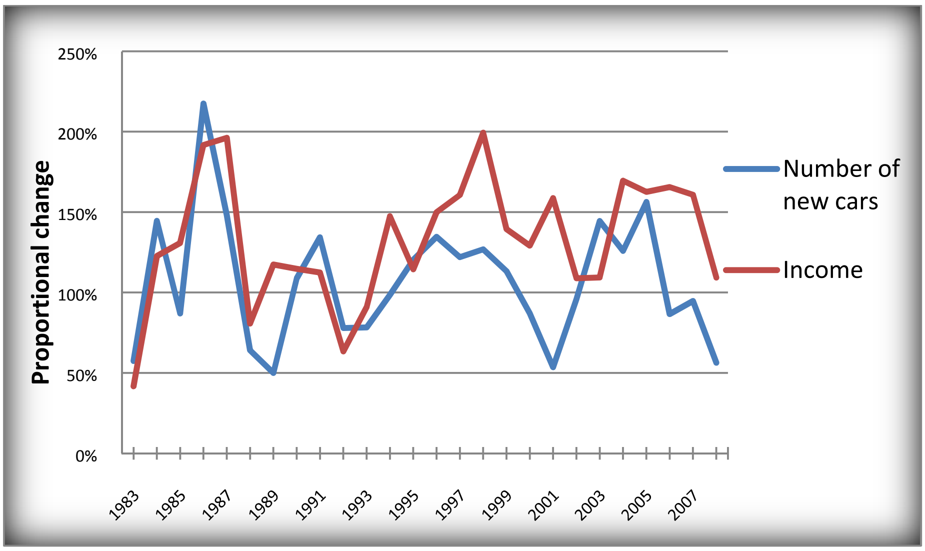


Figure 3: Number of new cars and income, proportional changes between each year, 1982-2008
Reference: Hagstofa Íslands - Statistics Iceland

2.1.3 Number of cars vs. car prices

It can be expected that the demand for new cars depends partly on car prices. Figure 4 shows the proportional changes between each year for the number of new cars and the proportional changes times 10 for car prices. From the figure it seems that there is a negative relationship between the two factors.

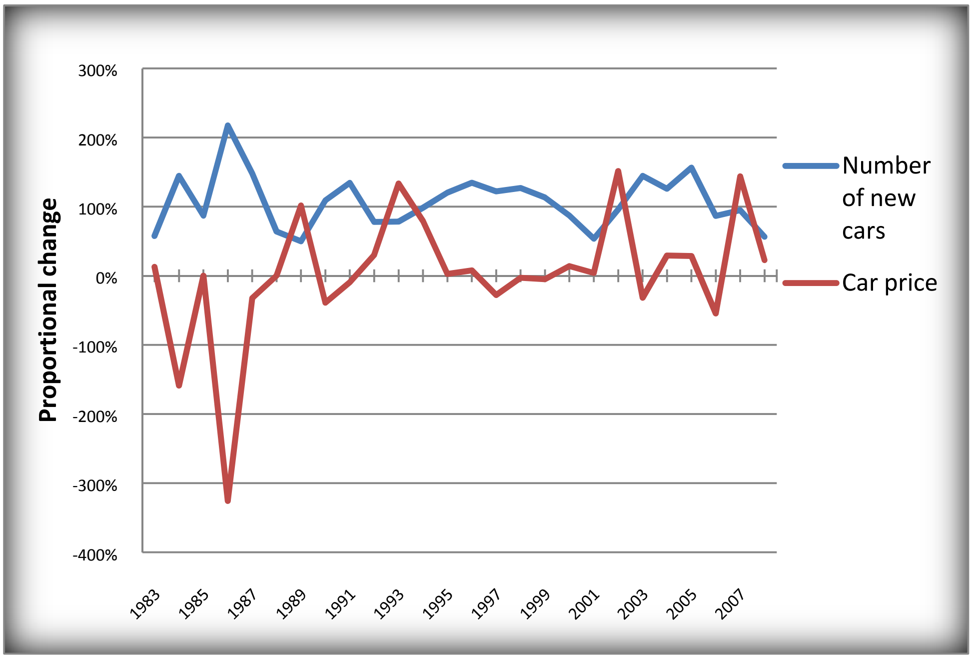


Figure 4: Number of new cars and car price, proportional changes between each year, 1982-2008
Reference: Umferðarstofa - The road traffic directorate and Hagstofa Íslands - Statistics Iceland

2.1.4 Types of cars in the car fleet

The average age of cars from the year 1986 to 2008 can be seen in Figure 5. Figure 6 shows the number of new cars sold from 1982 to 2008. When comparing these two figures one can see that it seems that the number of new cars sold affect the average age of the car fleet. When a large number of new cars is sold, like in the years 1987, 1999 and 2006, the average age of cars decreases.

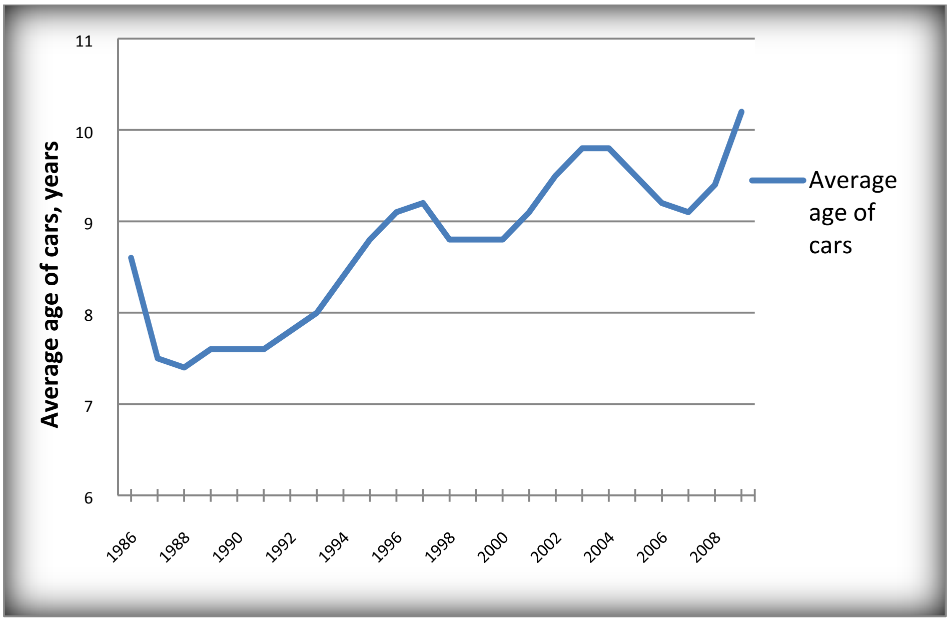


Figure 5: Average age of cars 1986-2008
Reference: Umferðarstofa - The road traffic directorate

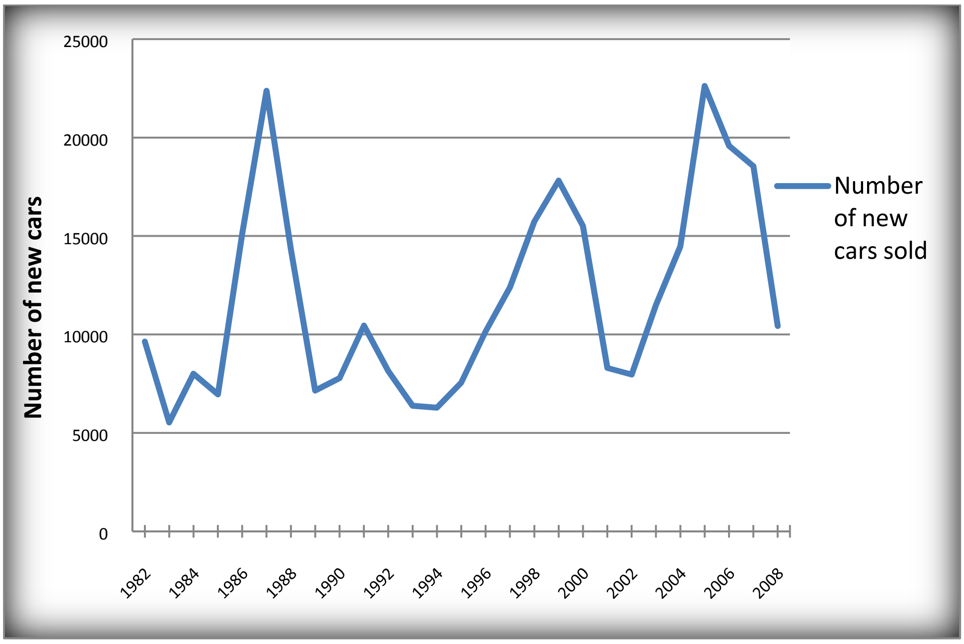


Figure 6: Number of new cars sold 1982-2008
Reference: Umferðarstofa - The road traffic directorate

Despite the fact that there is still much more of new cars sold that use gasoline than cars that use diesel fuel, the number of diesel fuel cars in Iceland increases every year. Figure 7 shows the percentage of new cars sold, which are gasoline cars and the percentage that are diesel engine cars.

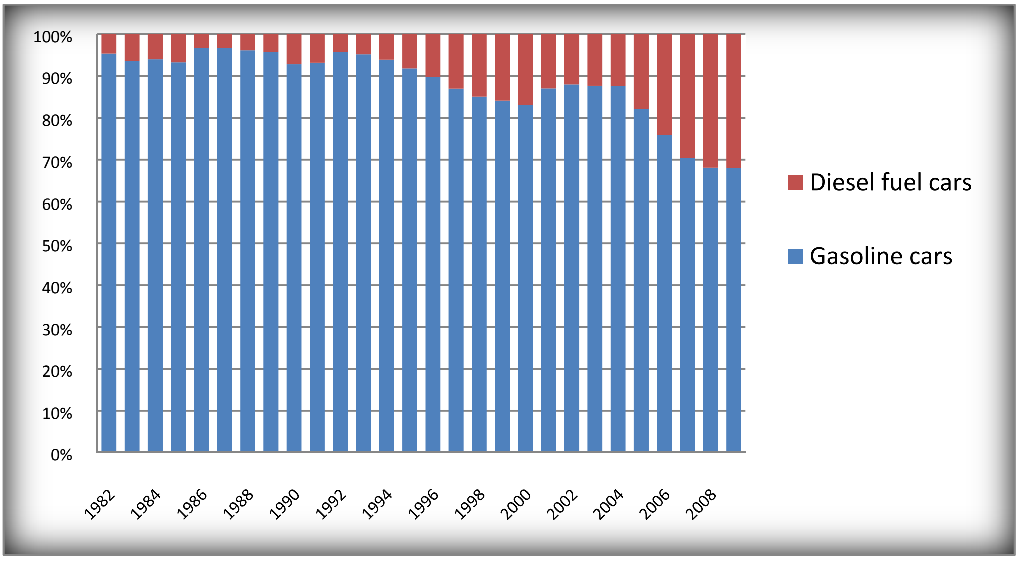


Figure 7: Different fuel source for new cars sold 1982-2009
Reference: Umferðarstofa - The road traffic directorate

From the figure it can be seen how the number of new cars with diesel engines has been increasing in the last years.

Figure 8 shows the development of different engine sizes in new cars sold. Smaller cars have the engine size of 0-1599cc, medium size cars have 1600-1999cc and larger cars have over 2000cc. From Figure 8 it can be seen that the demand for cars with larger engines has increased in the last years.

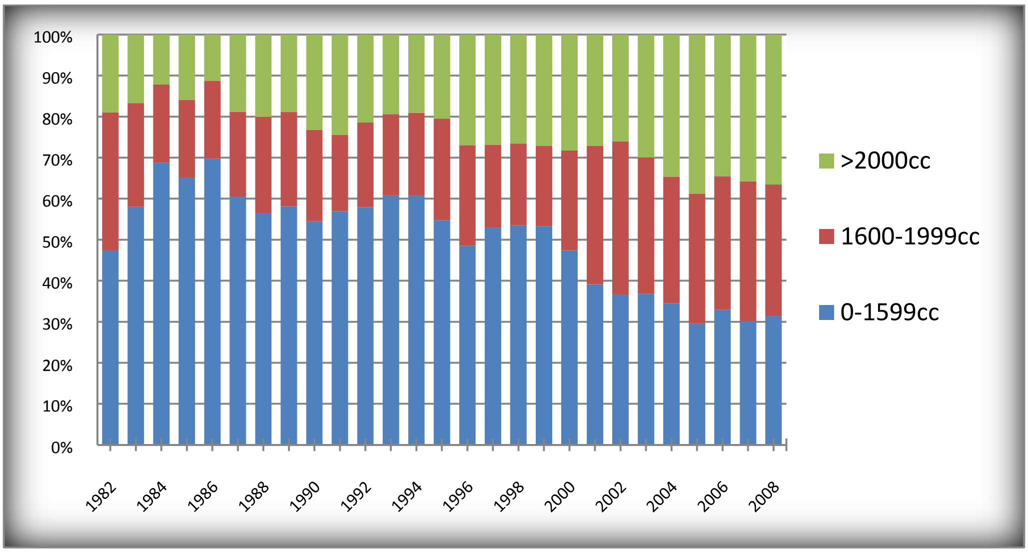


Figure 8: Different sizes of new cars sold 1982-2008
Reference: Umferðarstofa - The road traffic directorate

2.2 The development of car fuel use in Iceland

2.2.1 Car fuel use

Fuel sales have increased during the period 1982-2008. Gasoline use has increased by 62% while diesel fuel use has increased around 288%. Together the fuel use has increased around 110%. The increase can be seen in Figure 9.

From the figure it is clear that a large increase in diesel fuel starts around 1996. As mentioned earlier, the explanation for this is probably that diesel engine cars have increased a lot since then.

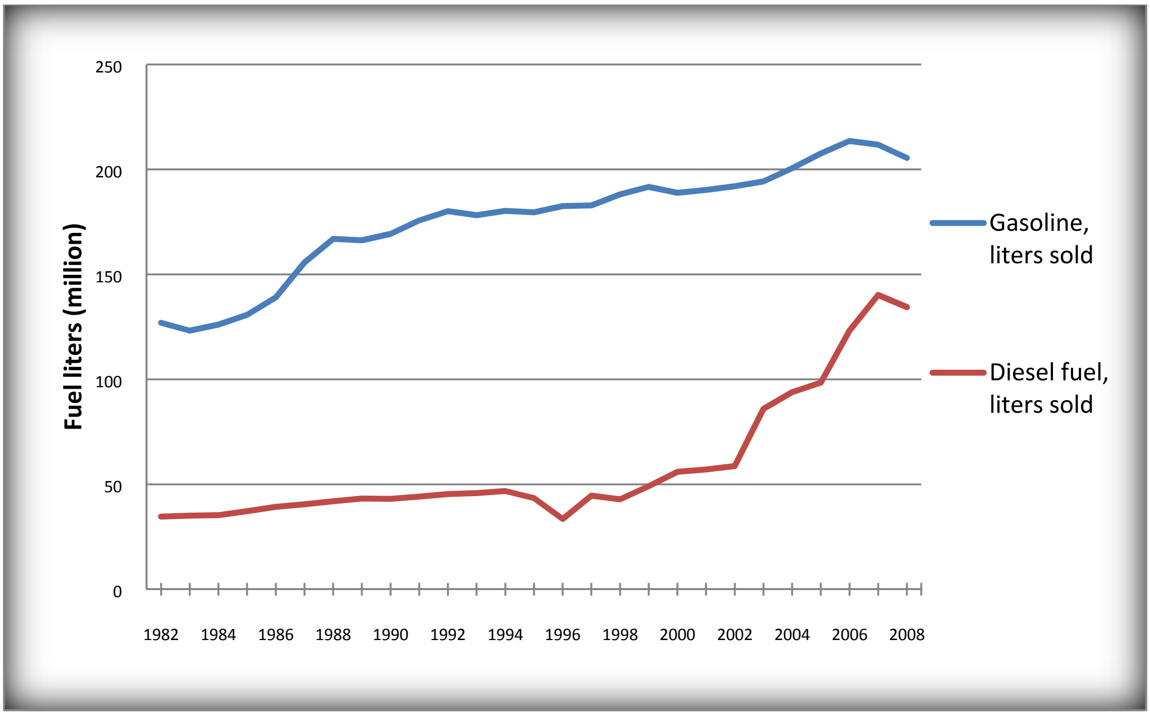


Figure 9: Gasoline and Diesel fuel, liters sold 1982-2008
Reference: Orkustofnun - The national energy authority

Figure 10 shows the development in fuel use regarding to the development of the number of cars and the number of inhabitants. The number of cars per capita has increased by 63%, that is more than fuel use per capita, which has increased by 55%. That means that fuel use per car has actually decreased between the years 1982 to 2008. When the number of cars per capita increases it is reasonable to assume that fuel use per car decreases.

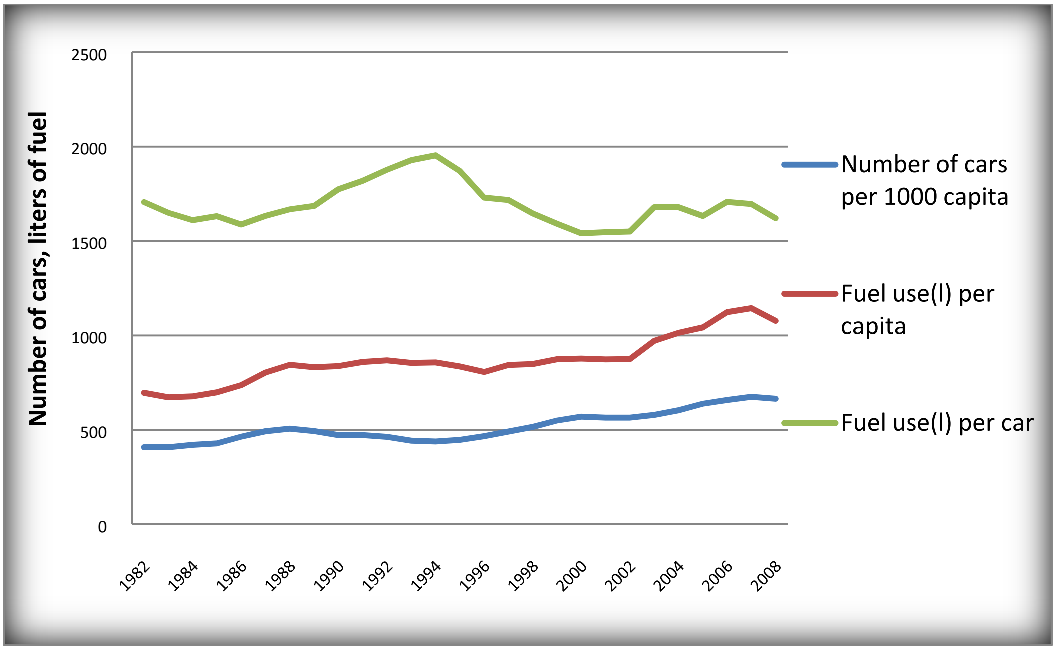


Figure 10: Liters of fuel sold and the number of cars 1982-2008
Reference: Orkustofnun - The national energy authority and Hagstofa Íslands - Statistics Iceland

2.2.2 Gasoline use vs. gasoline price

Figure 11 shows the development of gasoline use per car and the real price of gasoline from 1982 to 2008. One would expect that gasoline price could have a negative impact on the gasoline use. To better examine the relationship between these two factors, Figure 12 shows the proportional changes between each year of gasoline price and gasoline use. As expected, the figure implies that there is some negative relation between the factors.

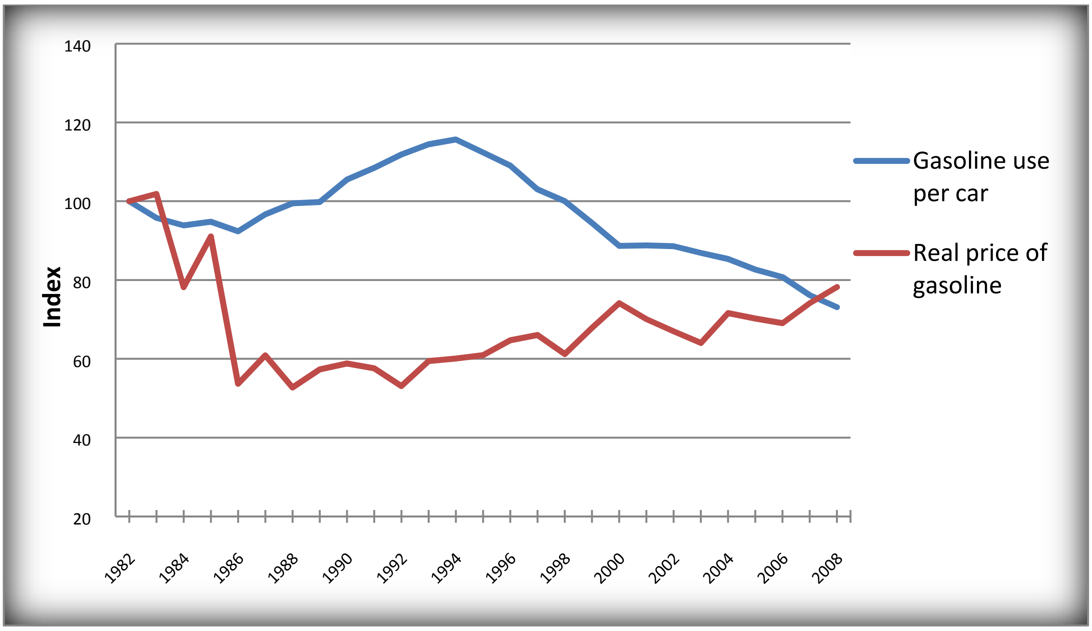


Figure 11: Gasoline use per car and the real price of gasoline 1982-2008
Reference: Orkustofnun - The national energy authority and Hagstofa Íslands - Statistics Iceland

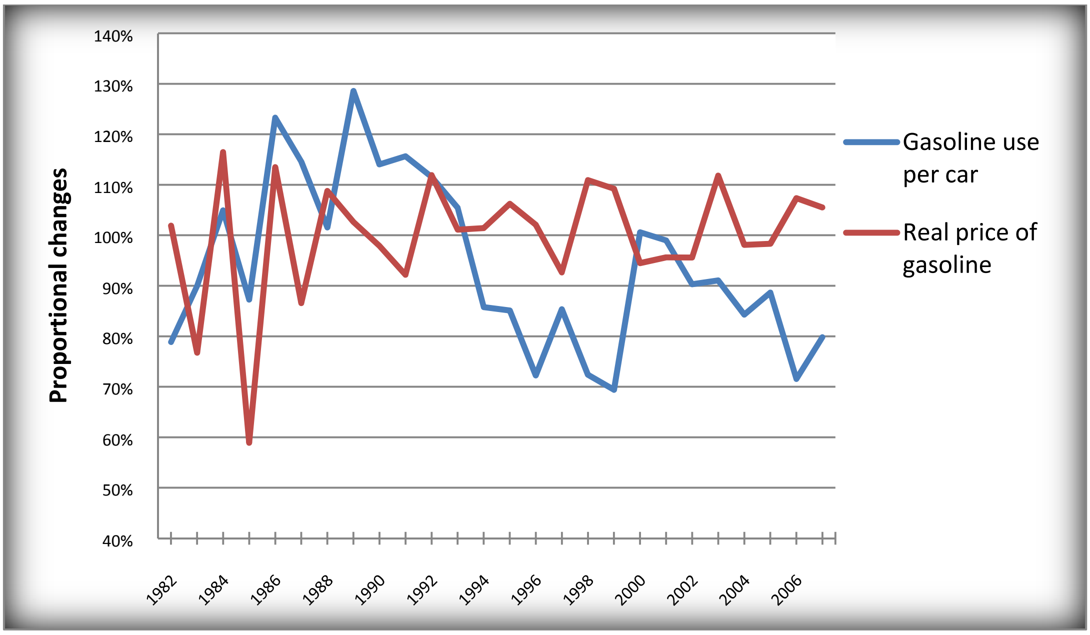


Figure 12: Gasoline use per car and gasoline price, proportional changes between each year,1982-2008
Reference: Orkustofnun - The national energy authority and Hagstofa Íslands - Statistics Iceland

The number of cars per capita increased by 63% from the year 1982 to 2008. Comparing the number of cars to the development of income, which increased around 65% that period, one can see some positive relationship between the two factors and therefore it is possible that income affects the size of the car fleet.

One can also assume from the figures that both income and car prices affect the number of new cars. It seems that from 1982, the number of new cars with bigger engines have been increasing on the expense of the number of new cars with smaller engines.

Car fuel use per capita has increased by 55% in the period of 1982-2008. Since the number of cars per capita has increased so much, that is by 63% since 1982, the fuel use per car has decreased. From Figure 11 and 12 one could assume the gasoline price has negative effects on the demand for gasoline.

The diesel fuel use and the number of new diesel cars have been increasing fast since 1996. Unfortunately no analysis can be done on the demand for diesel fuel because there is not enough historical information available to give accurate results.

3 The demand for gasoline, new cars and the development of the car fleet

3.1 Elasticity

Models were defined to estimate the effects on gasoline demand, the demand for new cars and the development of the car fleet of changes in income, car prices and gasoline price. In other words they estimate how elastic these demands are regarding to income, car prices and gasoline price.

In economics, elasticity is the ratio of the percent change in one variable to the percent change in another variable. It is a tool for measuring the responsiveness of a function to changes in parameters in a relative way. Elasticity of demand shows in that way the responsiveness of quantity demanded of a good or a service to a change, for example in its price or the consumer's income. More precisely, it gives the percentage change in quantity demanded one might expect after one percent change in price or income.

3.2 Defining the models

An understanding of the demand for transport is essential for the analysis of serious policy and planning questions. Demand analysis has accordingly had considerable attention in transport literature. One of the most striking features of the literature is the variety of demand and forecasting models put forward. Two important sources of this variety are the choice of variables used in demand models and the choice of functional form. Differences in types of data and demand models can create significant problems for planners and policy analysts, because empirical results such as elasticities are likely to be contingent upon those choices (Oum, 1989).

A variety of models have been used to analyze the demand for gasoline and cars. The log-linear model specifies the logarithm of a demand as a linear function of the logarithms of potential determinants, such as prices and quality variables. This is the most widely used functional form for transport demand models and was therefore chosen for this research.

Five models were defined in this paper. They estimate as follows:

I. The gasoline use per capita
II. The gasoline use per car
III. The size of the car fleet
IV. The demand for new cars
V. The demand for new cars of different sizes

Each model is a function of variables that affect the dependent variable, which is the appropriate demand. The goal of this research is to estimate the effects that income, gasoline price and car prices have on these demands.

It is not necessarily so that all the three determinants affect all the five demands. The effect that each determinant has on each demand was examined carefully. The variables that seemed to have little or no effect and were not statistically significant at 10% level, were taken out of the demand model to be estimated.

One of the models is to estimate the size of the car fleet or the number of cars per capita. It can be expected that the number of cars per capita affects the other demands, thus the car fleet was also examined as a possible determinant in the other demand models.

The models take into account the fact that the effects from the independent variables do not necessarily show up immediately, but over more than one period. For all the independent variables their lagged values were also in the models for those years when the lagged values were still statistically significant at 10% level.

The time series used in the models are listed in table 1[2].

Table 1: The time series used in the models and their given symbols

Time series	*Definitions*
Income (Real GDP per capita)	Y_t
Gasoline use per capita	G_t
Gasoline use per car	E_t
Gasoline price	P_t
Car price	CP_t
Number of cars per capita	C_t
Number of new cars per capita	N_t

Below is listed which independent variables were chosen for the five models. The subscript after each variable stand for lagged values of that same variable.

I. The gasoline use per capita

$$\text{Gasoline use per capita}_t = f(\text{Income}_t, \text{Gasoline price}_{t-i}, \text{Gasoline use per capita}_{t-i})$$

It can be expected that increase in income leads to increase in the demand for gasoline per capita and that increase in gasoline price leads to decrease in gasoline use.

II. The gasoline use per car

$$\text{Gasoline use per car}_t = f(\text{Gasoline price}_{t-i}, \text{Car fleet}_t, \text{Gasoline use per car}_{t-i})$$

Gasoline price could have similar effects on gasoline use per car as for gasoline use per capita. One could also expect that the number of cars per capita has negative effects on the gasoline use per car. If a consumer buys his second car it does not mean that he will start driving twice as much as before.

[2] All data used in this study are explained more detailed in appendix A.

III. The size of the car fleet

Car fleet$_t$ *=f(Car price*$_t$*, Income*$_{t-i}$*)*

It is rational to assume that car prices have negative effects on the size of the car fleet while income should have positive influence.

IV. The demand for new cars

New cars$_t$ *= f(Car price*$_t$*, Income*$_t$*, Car fleet*$_{t-i}$*)*

It can be expected that increase in income increases the demand for new cars and that increase in car prices decrease the demand. The reason for why the car fleet is a variable in the model is that the number of cars per capita could control the need for buying a new car.

V. The demand for new cars of different sizes

New cars$_{small,t}$ *= f(Car price*$_t$*, Income*$_t$*, Car fleet*$_{t-i}$*)*

New cars$_{medium,t}$ *= f(Car price*$_t$*, Income*$_t$*, Car fleet*$_{t-i}$*)*

New cars$_{large,t}$ *= f(Car price*$_t$*, Income*$_t$*, Car fleet*$_{t-i}$*)*

3.3 The demand models

3.3.1 The reversible model

As in most demand analyses, log-linear function of the variables is used in order to find out the elasticities of demand. The time series, that is the data, are also transformed to become stationary. The problem with non-stationary series is that a strong correlation can be found between them without having no real meaning. Stationary process on the other hand is a stochastic process whose joint probability distribution does not change when shifted in time or space. As a result, parameters such as the mean and the variance also do not change over time or position. To make the series stationary they are transformed. The new transformed series describe the changes from one period to the next. That is called the first difference of a time series.

Let us take a look at the model describing the demand for gasoline per capita. The model is defined as

$$G_t = e^{c0} Y_t^{c1} P_t^{c2} P_{t-1}^{c3} G_{t-1}^{c4}$$

where c_0 is a constant, $c_1 - c_4$ describe the elasticities, G is the amount of gasoline per capita sold, Y is real GDP per capita in kronas and P is the gasoline price.

Changing the model into a log-function it becomes

$$\ln(G_t) = c_0 + c_1 \cdot \ln(Y_t) + c_2 \cdot \ln(P_t) + c_3 \cdot \ln(P_{t-1}) + c_4 \cdot \ln\,(G_{t-1})$$

where ln stands for the natural logarithm for the appropriate variable.

With taking the first difference the model becomes

$$\mathrm{ld}(G_t) = \ln(G_t) - \ln(G_{t-1})$$

$$= (c_0 - c_0) + c_1 \cdot (\ln(Y_t) - \ln(Y_{t-1})) + c_2 \cdot (\ln(P_t) - \ln(P_{t-1})) + c_3 \cdot (\ln(P_{t-1}) - \ln(P_{t-2})) + c_4 \cdot (\ln(G_{t-1}) - \ln(G_{t-2}))$$

The final model then becomes

$$\mathrm{ld}(G_t) = c_1 \cdot \mathrm{ld}(Y_t) + c_2 \cdot \mathrm{ld}(\mathrm{P_t}) + c_3 \cdot \mathrm{ld}(P_{t-1}) + c_4 \cdot \mathrm{ld}(G_{t-1})$$

where ld stands for the change of the logarithm of the appropriate variable between periods.

To be certain that the new time series are stationary, Dickey-Fuller test for stationarity was performed. The results were that all the time series used are stationary.[3] Models of this form have been used to estimate energy use all around the world. The effects that each variable has on G can be read from the constants c_1 - c_4. For example, if income changes by 1% then gasoline use change by c_1%.

This model assumes that the changes in income have as much but reversed effects on gasoline use when income increases as when income decreases.

All the other models are built up in a similar way. Below are the final versions of all the models.

The gasoline use per capita:

$$\mathrm{ld}(G_t) = c_{G,Y} \cdot \mathrm{ld}(Y_t) + c_{G,P} \cdot \mathrm{ld}(\mathrm{P_t}) + c_{G,P1} \cdot \mathrm{ld}(P_{t-1}) + c_{G,G1} \cdot \mathrm{ld}(G_{t-1})$$

The gasoline use per car:

$$\mathrm{ld}(E_t) = c_{E,P} \cdot \mathrm{ld}(P_t) + c_{E,P1} \cdot \mathrm{ld}(P_{t-1}) + c_{E,C} \cdot \mathrm{ld}(C_t) + c_{E,E1} \cdot \mathrm{ld}(E_{t-1})$$

The size of the car fleet:

$$\mathrm{ld}(C_t) = c_{C,CP} \cdot \mathrm{ld}(CP_t) + c_{C,Y} \cdot \mathrm{ld}(Y_t) + c_{C,Y1} \cdot \mathrm{ld}(Y_{t-1})$$

The demand for new cars:

$$\mathrm{ld}(N_t) = c_{N,CP} \cdot \mathrm{ld}(CP_t) + c_{N,Y} \cdot \mathrm{ld}(Y_t) + c_{N,C1} \cdot \mathrm{ld}(C_{t-1})$$

The demand for new cars of different sizes:

$$\mathrm{ld}(N_{small,t}) = c_{Ns,CP} \cdot \mathrm{ld}(CP_t) + c_{Ns,Y} \cdot \mathrm{ld}(Y_t) + c_{Ns,C1} \cdot \mathrm{ld}(C_{t-1})$$

$$\mathrm{ld}(N_{medium,t}) = c_{Nm,CP} \cdot \mathrm{ld}(CP_t) + c_{Nm,Y} \cdot \mathrm{ld}(Y_t) + c_{Nm,C1} \cdot \mathrm{ld}(C_{t-1})$$

$$\mathrm{ld}(N_{large,t}) = c_{Nl,CP} \cdot \mathrm{ld}(CP_t) + c_{Nl,Y} \cdot \mathrm{ld}(Y_t) + c_{Nl,C1} \cdot \mathrm{ld}(C_{t-1})$$

[3] The results from the Dickey-Fuller test, for all the time series, are listed in Appendix B.

3.3.2 The imperfectly reversible model

If fuel demand were perfectly price- and income reversible, demand would respond to all types of price- and income changes in similar ways. A demand reduction caused by a price increase would be exactly reversed if price were to decline to its original level: demand also would return to its original level. Moreover, if price were to recover subsequently to its previous maximum level, the demand reduction would be the same as when price increased initially.

However, if demand were not perfectly price- and income reversible, then fuel demand reduction following a price increase would not be completely reversed when price fell.

Previous work on irreversibility in economic relationships has proceeded along several lines. The first work was done on the price-reversibility of agricultural supply, by Wolffram (1971) and by Traill, Colman and Young (1978). Analysis of the price- and income reversibility of fuel demand has utilized this approach.[4]

The analysis is based on an econometric model which utilizes price- and income decomposition techniques to measure separately the effect of both price- and income increases and decreases. That means the demand equations must take into account these important asymmetry phenomena:

- Imperfect price-reversibility: The demand response to price increase is not necessarily reversed completely by an equivalent price decrease.
- Imperfect income-reversibility: Analogously, the demand response to an income increase is not necessarily reversed by an equivalent income decrease.

In this approach, the following two-way decomposition of (the logarithm of) gasoline price, car prices and income are used: The accumulating series of increases in gasoline price, car prices and income, and the accumulating series of decreases in gasoline price, car prices and income.

The imperfect price-reversibility

Gasoline price is divided as

$$\ln(P_t) = \ln(P_1) + \sum_{t=0}^{t} \ln(P_{up,t}) + \sum_{t=0}^{t} \ln(P_{down,t})$$

where

$ln(P_1)$ = Log of gasoline price in starting year t=1, which is 1982;

$ln(P_{up,t})$= Increases in log of gasoline price: $P_{up,t} \geq 0$

$ln(P_{down,t})$= Decreases in log of gasoline price: $P_{down,t} \leq 0$

[4] The initial studies estimated demand elasticities with respect to price and income, and the dynamics of the long-run adjustment. But after the oil price collapse of 1986, economists began to address the question of whether the demand reductions might be reversed.

Figure 13 depicts the logarithm of gasoline price and its decomposition into two price series.

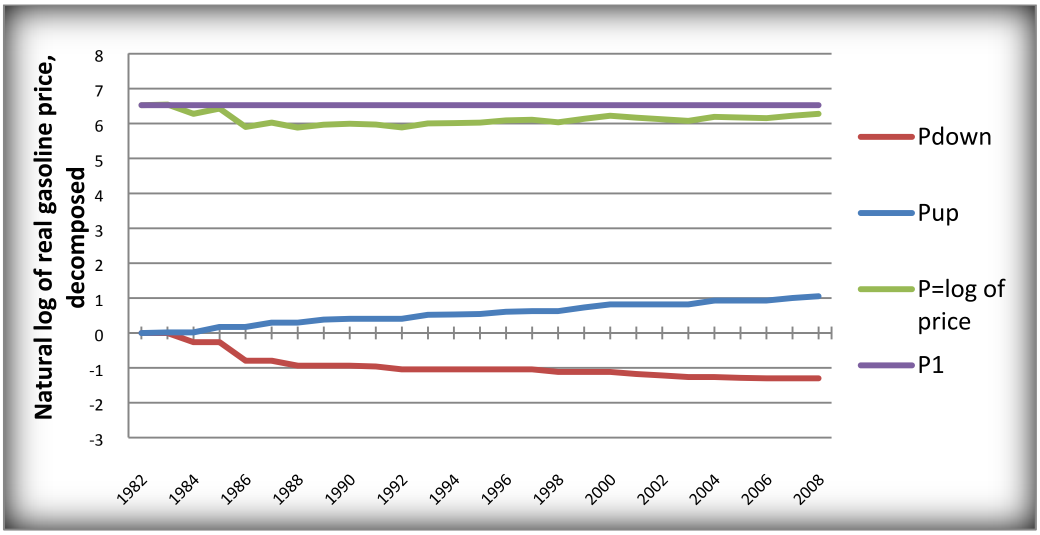


Figure 13: Decomposition of the logarithm of gasoline price

Car price is divided in the same way:

$$\ln(CP_t) = \ln(CP_1) + \sum_{t=0}^{t} \ln(CP_{up,t}) + \sum_{t=0}^{t} \ln(CP_{down,t})$$

where

ln(CP₁) = Log of car price in starting year t=1, which is 1982;

$ln(CP_{up,t})$= Increases in log of car price; $CP_{up,t} \geq 0$

$ln(CP_{down,t})$= Decreases in log of car price; $CP_{down,t} \leq 0$

Figure 14 depicts the logarithm of car price and its decomposition into two price series.

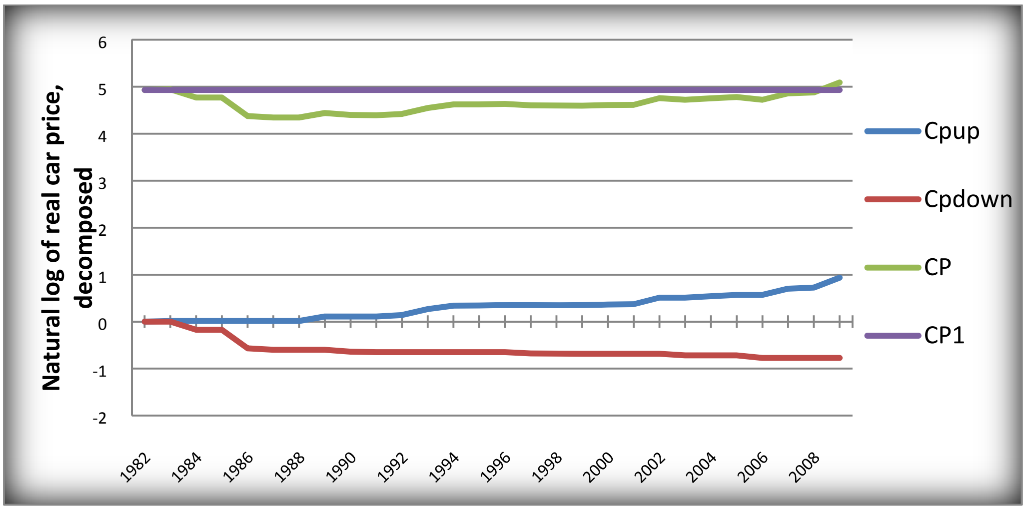


Figure 14: Decomposition of the logarithm of car price

The imperfect income-reversibility

The effects of changes in income (as well as price) are also not necessarily perfectly reversible, which most demand equation assume implicitly. The same approach is used for income decomposition as well as for price. The logarithm of income is decomposed into two series: The accumulating series of increases in income and the accumulating series in decreases in income:

$$\ln(Y_t) = \ln(Y_1) + \sum_{t=0}^{t} \ln(Y_{up,t}) + \sum_{t=0}^{t} \ln(Y_{down,t})$$

where

$ln(Y_1)$ = log of income in starting year t=1, which is 1982;

$ln(Y_{up,t})$ = Increases in log of income: $Y_{up,t} \geq 0$

$ln(Y_{down,t})$ = Decreases in log of income: $Y_{down,t} \leq 0$

Figure 15 depicts the logarithm of income and its two way decomposition.

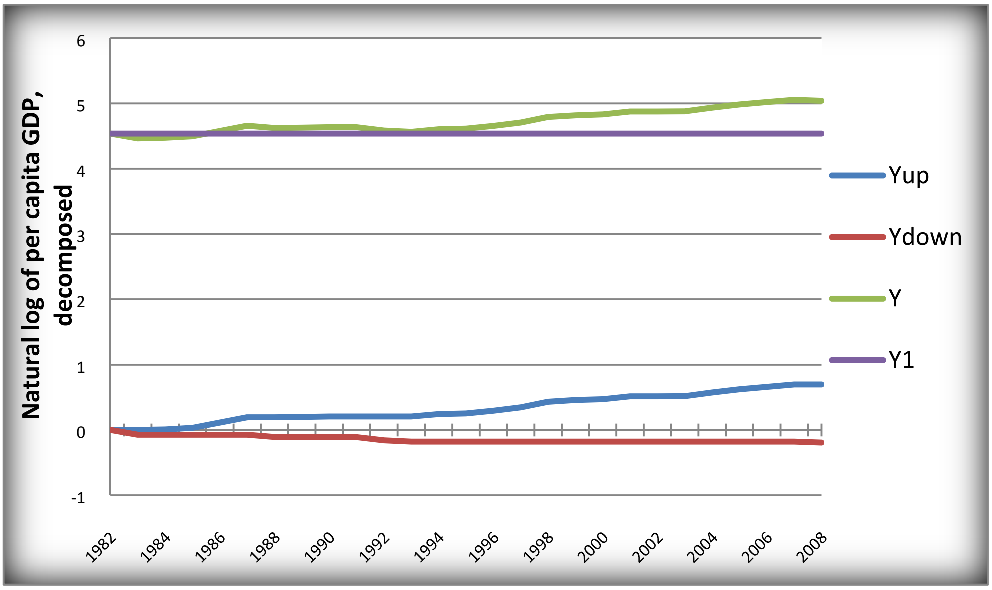


Figure 15: Decomposition of the logarithm of income

The decomposed series of gasoline price, car price and income are written in a first difference form:

$$ld(P_t) = ld(P_{up,t}) + ld(P_{down,t})$$

$$ld(CP_t) = ld(CP_{up,t}) + ld(CP_{down,t})$$

$$ld(Y_t) = ld(Y_{up,t}) + ld(Y_{down,t})$$

The imperfectly reversible models are made by combining the decomposed series of gasoline price, car price and income with the reversible demand models described earlier.

The demand model for gasoline use per car is again taken as an example.

The reversible demand model was defined:

$$\mathrm{ld}(G_t) = c_{G,Y} \cdot \mathrm{ld}(Y_t) + c_{G,P} \cdot \mathrm{ld}(P_t) + c_{G,P1} \cdot \mathrm{ld}(P_{t-1}) + c_{G,G1} \cdot \mathrm{ld}(G_{t-1})$$

The irreversible model is then defined by using the decomposed series of gasoline price, car price and income instead the ones who are not:

$$\begin{aligned}\mathrm{ld}(\mathrm{G_t}) = c_{G,Yup} \cdot \mathrm{ld}(Y_{up,t}) + c_{G,Ydown} \cdot \mathrm{ld}(Y_{down,t}) + c_{G,Pup} \cdot \mathrm{ld}(P_{up,t}) + c_{G,Pdown} \\ \cdot \mathrm{ld}(P_{down,t}) + c_{G,P1up} \cdot \mathrm{ld}(P_{up,t-1}) + c_{G,P1down} \cdot \mathrm{ld}(P_{down,t-1}) + c_{G,G1} \\ \cdot \mathrm{ld}(G_{t-1})\end{aligned}$$

All the other irreversible demand models are defined in the same manner and are as follows:

The gasoline use per car:

$$\begin{aligned}\mathrm{ld}(E_t) = c_{E,Pup} \cdot \mathrm{ld}\left(P_{up,t}\right) + c_{E,Pdown} \cdot \mathrm{ld}\left(P_{down,t}\right) + c_{E,P1up} \cdot \mathrm{ld}\left(P_{up,t-1}\right) + c_{E,P1down} \\ \cdot \mathrm{ld}\left(P_{down,t-1}\right) + c_{E,C} \cdot \mathrm{ld}(C_t) + c_{E,E1} \cdot \mathrm{ld}(E_{t-1})\end{aligned}$$

The size of the car fleet:

$$\begin{aligned}\mathrm{ld}(C_t) = c_{C,CPup} \cdot \mathrm{ld}\left(CP_{up,t}\right) + c_{C,CPdown} \cdot \mathrm{ld}\left(CP_{down,t}\right) + c_{C,Yup} \cdot \mathrm{ld}\left(Y_{up,t}\right) + c_{C,Ydown} \\ \cdot \mathrm{ld}\left(Y_{down,t}\right) + c_{C,Y1up} \cdot \mathrm{ld}\left(Y_{up,t-1}\right) + c_{C,Y1down} \cdot \mathrm{ld}\left(Y_{down,t-1}\right)\end{aligned}$$

The demand for new cars:

$$\begin{aligned}\mathrm{ld}(N_t) = c_{N,CPup} \cdot \mathrm{ld}\left(CP_{up,t}\right) + c_{N,CPdown} \cdot \mathrm{ld}\left(CP_{down,t}\right) + c_{N,Yup} \cdot \mathrm{ld}\left(Y_{up,t}\right) + c_{N,Ydown} \\ \cdot \mathrm{ld}\left(Y_{down,t}\right) + c_{N,C1} \cdot \mathrm{ld}(C_{t-1})\end{aligned}$$

The demand for new cars of different sizes:

$$\begin{aligned}\mathrm{ld}\left(N_{small,t}\right) = c_{Ns,CPup} \cdot \mathrm{ld}\left(CP_{up,t}\right) + c_{Ns,CPdown} \cdot \mathrm{ld}\left(CP_{down,t}\right) + c_{Ns,Yup} \cdot \mathrm{ld}\left(Y_{up,t}\right) \\ + c_{Ns,Ydown} \cdot \mathrm{ld}\left(Y_{down,t}\right) + c_{Ns,C1} \cdot \mathrm{ld}(C_{t-1})\end{aligned}$$

$$\begin{aligned}\mathrm{ld}\left(N_{medium,t}\right) = c_{Nm,CPup} \cdot \mathrm{ld}\left(CP_{up,t}\right) + c_{Nm,CPdown} \cdot \mathrm{ld}\left(CP_{down,t}\right) + c_{Nm,Yup} \cdot \mathrm{ld}\left(Y_{up,t}\right) \\ + c_{Nm,Ydown} \cdot \mathrm{ld}\left(Y_{down,t}\right) + c_{Nm,C1} \cdot \mathrm{ld}(C_{t-1})\end{aligned}$$

$$\begin{aligned}\mathrm{ld}\left(N_{large,t}\right) = c_{Nl,CPup} \cdot \mathrm{ld}\left(CP_{up,t}\right) + c_{Nl,CPdown} \cdot \mathrm{ld}\left(CP_{down,t}\right) + c_{Nl,Yup} \cdot \mathrm{ld}\left(Y_{up,t}\right) \\ + c_{Nl,Ydown} \cdot \mathrm{ld}\left(Y_{down,t}\right) + c_{Nl,C1} \cdot \mathrm{ld}(C_{t-1})\end{aligned}$$

Given the way in which the gasoline price, car price and income have been decomposed, the perfectly reversible model is a special case of the imperfectly reversible model, that is when the coefficients corresponding to increases and decreases are the same, both for price and income. Thus the hypothesis of perfect price or income reversibility can be tested using a Wald test of imposing these equality restrictions on the coefficients of an imperfectly reversible model.

Other studies of imperfect price-and income reversibility for road transport have even decomposed prices and income more thoroughly. That is done with the aim to measure separately the effects of different types of price increases and decreases (Gately and Huntington, 2002).

The data, from the period that is examined in this paper, does not include great fluctuation and too decomposed model does not improve the results. Furthermore the observations used in this study are not as many as needed for such a complex model.

3.4 The methodology

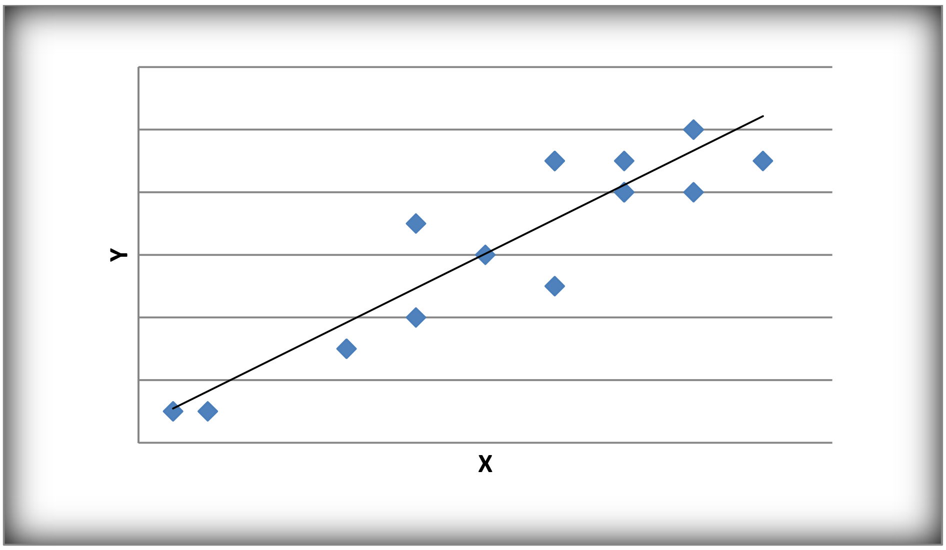
Regression analysis is a technique for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or many independent variables. Regression analysis helps to understand how the typical value of the dependent variable changes when anyone of the independent variables becomes varied.

The simplest linear regression model is when changes in the dependent variable *Y* is explained as a linear function of one independent variable.

A line is found in the form:

$$Y_t = \alpha + \beta x_t + \mu_t$$

μt is the error on time t, t=1..T where T is the number of observations. The coefficients α and β are chosen so that the distances from the values to the line are as small as possible. β measures how change in X appears in the change in Y and α is a constant that shows the value of Y if β was zero.



The most common method to minimize this distance is called OLS (e. ordinary least squares). The method minimizes the sum of squared distances between the observed responses in the dataset and the responses predicted by the linear approximation.

The formulas for the estimated coefficients α and β are:

$$\hat{\beta} = \frac{\sum x_t y_t - T\overline{xy}}{\sum x_t^2 - T\overline{x}^2}$$

$$\hat{\alpha} = \overline{y} - \hat{\beta}\overline{x}$$

All the models are estimated with OLS. Sometimes models require more complicated techniques because OLS can neglect the fact that some variables can be endogenous and not give accurate results. The residuals for all the models were examined and the assumptions of no autocorrelation and no heteroskedasticity were not rejected. Thus, OLS can be used and should give as accurate results as other methods. [5]

[5] Detailed residual analysis is to be found in Appendix C.

4 Econometric results

In this chapter the econometric results are summarized for the demand equations for gasoline use, new cars, and the developing of the car fleet in Iceland. The elasticities are presented in tables 2-12 showing the percentage change in the appropriate demand to 1% change in the independent variables. Each coefficient will though be interpreted as the effect of 10% change in the corresponding explanatory variable on the dependent variable.

4.1 The demand for gasoline per capita

Table 2 shows the results of the coefficients in the reversible model, estimating the demand for gasoline per capita in the years 1982-2008.

Table 2: Demand for gasoline per capita (G_t)

	Coefficients						
	Income	Gasoline price		Lagged adj.	Long-run elasticity		
	Y_t	P_t	P_{t-1}	G_{t-1}	*Income*	*Gasoline price*	R^2
G_t	0.226	-0.107	-0.11	0.377	0.362	-0.348	0.621

When estimating the demand for gasoline per capita the results were that gasoline price and income are the main factors that control the demand. The relationship between the size of the car fleet and the demand for gasoline was also examined. It is reasonable to assume that an increase in the number of cars per capita would increase the gasoline use but surprisingly the results showed that number of cars per capita has almost no influence on the demand for gasoline.

The main results are that when gasoline price goes up, the effects on gasoline use show up mostly the same year and the year after the price change. 10% increase in gasoline price decreases the demand for gasoline per capita by 3.48% in the long run.[6] When income increases by 10% the gasoline use per capita increases by 2.26% within one year and by 3.62% in the long run.

These results from the reversible model describe the effects of increase in income and gasoline price and assume that the effects on the demand are as much but reversed when income and gasoline price decrease.

Table 3 displays the results from the imperfectly reversible model showing the asymmetric effects of the independent variables.

---

[6] Long-run gasoline price elasticity is calculated as $(p_0 + p_1)/(1-g_1)$ were p_0 and p_1 are the coefficients to P_t and P_{t-1}, g_1 is the lagged adjustment coefficient for the dependent variable, G_{t-1}. Long-run income elasticity and car price elasticity are calculated the same way.
The lagged adjustment coefficient g_1 is expected to have a value between 0 and 1. The implied speed of adjustment to changes in the independent variables (in this case gasoline price and income) is measured by $1- g_1$. The adjustment speed could range from instantaneous (when g_1=0) to very slow (when g_1 approaches 1).

Table 3: Demand for gasoline per capita showing asymmetric effects (G_t)

	Coefficients							
	Income		Gasoline price				Lagged adj.	
	$Y_{up,t}$	$Y_{down,t}$	$P_{up,t}$	$P_{down,t}$	$P_{up,t-1}$	$P_{down,t-1}$	G_{t-1}	R^2
G_t	0.245	***<u>0.114</u>***	-0.275	-0.06	-0.182	***<u>-0.003</u>***	0.312	0.684
	Cannot reject equality		Reject equality		Cannot reject equality			

A coefficient that was not statistically significant at 10% level is boldfaced, italicized and underlined.

For the decomposed gasoline price and income, a Wald test was performed of the null hypothesis that the two coefficients for increases and decreases are equal, using a 5% cutoff for the F-statistic probability. For income it was not possible to reject the equality. For gasoline price on the other hand the null hypothesis was rejected for the first lag, thus the difference between the coefficients is significant. When gasoline price rises by 10% the demand for gasoline decreases by 2.75% but when the gasoline price decreases by 10% the gasoline use increases only by 0.6% within the first year after the changes.

From the results of both models, the reversible and the irreversible model, one can draw the conclusion that a model which could best describe the demand for gasoline per capita is a model that assumes for no asymmetric effects of changes in income but assumes for asymmetric effects of gasoline price changes.

The final model can then be written as follow:

$$\mathrm{ld}(\mathrm{G_t}) = c_{G,Y} \cdot \mathrm{ld}(Y_t) + c_{G,Pup} \cdot \mathrm{ld}(P_{up,t}) + c_{G,Pdown} \cdot \mathrm{ld}(P_{down,t}) + c_{G,P1} \cdot \mathrm{ld}(P_{t-1}) + c_{G,G1} \cdot \mathrm{ld}(G_{t-1})$$

The results are shown in table 4 and 5.

Table 4: Demand for gasoline per capita showing asymmetric effects of gasoline price (G_t)

	Coefficients					
	Income	Gasoline price			Lagged adj.	
	Y_t	$P_{up,t}$	$P_{down,t}$	P_{t-1}	G_{t-1}	R^2
G_t	0.297	-0.194	-0.087	-0.121	0.421	0.642
		Reject equality				

Table 5: Long-run elasticities of demand for increase and decrease in income and gasoline price

	Long-run effects of 1% increase		Long-run effects of 1% decrease	
	Income	*Gasoline price*	*Income*	*Gasoline price*
G_t	0.513	-0.544	0.513	-0.359

All the coefficients are statistically significant and the null hypothesis in the Wald test, which states that the two coefficients for increases and decreases in gasoline price are equal, was rejected.

The results are that if gasoline price increases by 10%, the demand for gasoline decreases by 1.94% but if price decreases by 10% the demand increases by 0.87% within the first year after the price change. From this one can assume that people react differently to gasoline price increase than to decrease. If income increases by 10% the demand for gasoline per capita increases by 2.97% within the year and by 5.13% in the long run. The final model assumes that a decrease in income has as much but reversed effects on gasoline use.

If gasoline price increases by 10% the gasoline use decreases by 5.44% in the long run but increases by only 3.59% if the price falls by 10%.

4.2 The demand for gasoline per car

Table 6 shows the results of the coefficients in the reversible model, estimating the demand for gasoline per car in the years 1982-2008.

Table 6: Demand for gasoline per car (E_t)

	Coefficients				Long-run elasticity	
	Gasoline price		Car fleet	Lagged adj.		
	P_t	P_{t-1}	C_t	E_{t-1}	Gasoline price	R^2
E_t	-0.080	-0.124	-0.520	0.347	-0.312	0.660

When estimating the demand for gasoline per car the results were that the size of the car fleet and gasoline price are the main factors that control the demand.

Income was also examined as a factor that could affect gasoline use per car. The results were that income has some positive influences on the demand, when income increases the gasoline use per car increases as well. Even so, the coefficient estimating the effect was not statistically significant and therefore not in the demand equation.

10% increase of the size of the car fleet decreases the demand for gasoline per car by 5.2%. It is not surprising that the number of cars has negative impact on gasoline use per car. When a household buys a second car, the car usages does normally not double, the usage per car reduces.

10% increase in gasoline price decreases the demand for gasoline per car in the long run by 3.12%. The effects show mostly up the same year and the year after the increase.

Table 7 displays the results from the imperfectly reversible model showing the asymmetric effects of the independent variables.

Table 7: Demand for gasoline per car (E_t) showing asymmetric effects

<table>
<tr><td></td><td colspan="6">Coefficients</td><td></td></tr>
<tr><td></td><td colspan="4">Gasoline price</td><td>Car fleet</td><td>Lagged adj.</td><td></td></tr>
<tr><td></td><td>$P_{up,t}$</td><td>$P_{down,t}$</td><td>$P_{up,t-1}$</td><td>$P_{down,t-1}$</td><td>C_t</td><td>E_{t-1}</td><td>R^2</td></tr>
<tr><td>E_t</td><td>-0.106</td><td><u>-0.074</u></td><td>-0.156</td><td>-0.002</td><td>-0.559</td><td>0.334</td><td>0.773</td></tr>
<tr><td></td><td colspan="2">Cannot reject equality</td><td colspan="2">Reject equality</td><td></td><td></td><td></td></tr>
</table>

A coefficient that was not statistically significant at 10% level is boldfaced, italicized and underlined.

For the decomposed gasoline price a Wald test was performed of the null hypothesis that the two coefficients for increases and decreases are equal, using a 5% cutoff for the F-statistic probability. The null hypothesis could not be rejected for the first year after price changes but it was rejected for the second year after price changes.

As for the demand for gasoline per capita a final model is made, which is a combination of the reversible and the irreversible model. The model does not assume any asymmetric effects from income but does expect asymmetric effects from gasoline price the year after price change.

The final model is written as follows:

$$\begin{aligned}\mathrm{ld}(E_t) = c_{E,P} \cdot \mathrm{ld}(P_t) + c_{E,P1up} \cdot \mathrm{ld}\left(P_{up,t-1}\right) + c_{E,P1down} \cdot \mathrm{ld}\left(P_{down,t-1}\right) + c_{E,C} \cdot \mathrm{ld}(C_t) \\ + c_{E,E1} \cdot \mathrm{ld}(E_{t-1})\end{aligned}$$

The results are shown in table 8.

Table 8: Demand for gasoline per capita (E_t) showing asymmetric effects of gasoline price

<table>
<tr><td></td><td colspan="5">Coefficients</td><td colspan="2">Long-run elasticity</td><td></td></tr>
<tr><td></td><td colspan="3">Gasoline price</td><td>Car fleet</td><td>Lagged adj.</td><td>1% increase</td><td>1% decrease</td><td></td></tr>
<tr><td></td><td>P_t</td><td>$P_{up,t-1}$</td><td>$P_{down,t-1}$</td><td>C_t</td><td>E_{t-1}</td><td>Gas price</td><td>Gas price</td><td>R^2</td></tr>
<tr><td>E_t</td><td>-0.072</td><td>-0.155</td><td>-0.004</td><td>-0.625</td><td>0.357</td><td>-0.353</td><td>-0.118</td><td>0.716</td></tr>
<tr><td></td><td></td><td colspan="2">Reject equality</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

If gasoline price increases by 10% the demand for gasoline per car increases the year after the increase by 1.5% but if the gasoline price decreases the demand increases only by 0.04%. From these results one can assume that gasoline price has asymmetric effects on the demand for gasoline per car.

When gasoline price increases by 10% the gasoline use per car decreases by 3.5% in the long run but if gasoline price declines by 10% the gasoline use per car increases by 1.18% in the long run.

4.3 The size of the car fleet

Table 9 shows the results of the coefficients in the reversible model, estimating the size of the car fleet in the years 1982-2008. Income and car prices were found to have the most effects on the size of the car fleet.

Table 9: The elasticities for the car fleet in Iceland (C_t)

	Car price coefficient	Income coefficients		
	CP_t	Y_t	Y_{t-1}	R^2
C_t	-0.111	0.445	0.369	0.677

Income has more influence on the size of the car fleet than car prices do. The effects from the income do not show up immediately but mostly over the period of two years. 10% increase in income increases the car fleet by 8.14% in the long run, while 10% increase in car prices decrease the car fleet by 1.11% within the first year after the increase.

Changes in car prices have much more impact on the purchase of new cars than on the size of the car fleet as is shown in the next chapter. 10% increase in car prices reduces the purchase of new cars around 15% and that probably explains why the inflow to the car fleet decreases and the number of cars per capita diminish by 1.11%

Surprisingly it seems that gasoline price does not affect the numbers of cars. One can assume that changes in gasoline price affect how people drive, and what kind of cars they buy, but not the size of the car fleet.

Table 10 shows the asymmetric results of the coefficients, estimating the size of the car fleet in the years 1982-2008.

Table 10: Asymmetric elasticities for the car fleet in Iceland (C_t)

	Coefficients						
	Car price		Income				
	$CP_{up,t}$	$CP_{down,t}$	$Y_{up,t}$	$Y_{down,t}$	$Y_{up,t-1}$	$Y_{down,t-1}$	R^2
C_t	-0.164	<u>***-0.095***</u>	0.432	<u>***0.184***</u>	0.434	<u>***0.090***</u>	0.691
	Cannot reject equality		Cannot reject equality		Cannot reject equality		

A coefficient that was not statistically significant at 10% level is boldfaced, italicized and underlined.

For the decomposed car price and income a Wald test was performed of the null hypothesis that the two coefficients for increases and decreases are equal, using a 5% cutoff for the F-statistic probability. It was not possible to reject the equality for neither car price nor income. It seems therefore that the irreversible model does not add much to the reversible model and the results from table 9 are considered to be the best results.

4.4 The demand for new cars and cars of different sizes

Table 11 shows the results of the coefficients in the reversible model, estimating the demand for new cars of different sizes in the years 1982-2008. Car prices, income and the size of the car fleet were found to have the most effects on the demand for new cars.

Table 11: Demand for new cars (N_t)

	Coefficients			
	Car price	Income	Car fleet	
	CP_t	Y_t	C_{t-1}	R^2
N_t	-1.458	5.272	-4.176	0.544
$N_{small,t}$	-1.948	4.594	-4.678	0.581
$N_{medium,t}$	-1.269	4.862	-2.83	0.502
$N_{large,t}$	-0.783	6.483	***-3.273***	0.457

A coefficient that was not statistically significant at 10% level is boldfaced, italicized and underlined.

Income has great effects on the demand for new cars. 10% increase in income increases the purchase of new cars by 52.3%. Increase in income has much more effect on the purchase of new cars than the size of the car fleet. This means that more new cars come into the fleet and more old ones go out when income increases. The result is that the car fleet changes with increasing income and consists more of newer and better cars that use less energy and are better for the environment. On the other hand it looks like the purchase of large cars increase more with income rather than the purchase of smaller cars which use less energy and thus are better for the environment.

Changes in car prices have also more effects on the demand for new cars then the size of the car fleet. 10% increase in car prices decreases the purchase of new cars by 14.58%. It seems though that the elasticity is the largest for small cars and the smallest for large cars, but that is in contrast of what most research in other countries show. The result that car prices do indeed have this much effect on the demand for new cars points out that taxes and all extra charges on cars can make much difference when taking the decision to buy a new car.

The relationship between the demand for new cars and gasoline price was also examined but the results did not give any accurate results and it was therefore difficult to assume anything about the relation between those variables.

Table 12 shows the results for the irreversible model for the demand for new cars.

Table 12: Demand for new cars showing asymmetric effects (N_t)

	Coefficients					
	Car price		Income		Car fleet	
	$Cp_{up,t}$	$Cp_{down,t}$	$Y_{up,t}$	$Y_{down,t}$	C_{t-1}	R^2
N_t	-2.181	-1.101	5.824	***<u>5.863</u>***	-4.326	0.561
$N_{small,t}$	-2.299	-1.777	4.727	***<u>5.419</u>***	-4.631	0.586
$N_{medium,t}$	-1.99	***<u>-0.911</u>***	5.628	***<u>4.582</u>***	-3.172	0.518
$N_{large,t}$	-2.764	***<u>0.199</u>***	8.351	***<u>6.664</u>***	***<u>-4.002</u>***	0.452

A coefficient that was not statistically significant at 10% level is boldfaced, italicized and underlined.

For the decomposed car price and income a Wald test was performed of the null hypothesis that the two coefficients for increases and decreases are equal, using a 5% cutoff for the F-statistic probability. For all four equations it was not possible to reject the null hypothesis, which means it is not possible to assume that the effects from car prices and income on the demand for new cars are asymmetric.

It is therefore assumed that the effects of car prices and income on the demand for new cars are reversible and the results shown in table 11 from the reversible model are the best results.

5 The application of the study

This study is a part of a co-operation project between The University of Iceland, The University of Akureyri and Orkustofnun - National Energy Authority. The aim of the project is to explore the possible development of electric transport and it is sponsored by Orkuveita Reykjavíkur.

The co-operation project is an interdisciplinary research with the involvement of many specialists in the field of energy and transportation as well as in other related branches. Many factors must be considered when possible development for electric transport is examined. The main idea is to develop a model which includes factors that influence electric transport. The model is supposed to be a support for those who need to make decisions, such as politicians and other directors.

The goal of this model is to examine different developments of the influence factors for the next decades. That is done by examining different scenarios, such as different types of electric cars and what consequences they have on the environment. The methodology of system dynamics is used to construct the model.

One part of the model is to examine the demand for electric cars and predict the development. Many factors control the demand, such as the number of types of cars offered, the number of fueling stations, information spread and advertisement. Very important factors are fuel price, purchase price and income.

The aim of this project has been to examine the consumer behavior regarding gasoline engine cars. The results of the project can predict future fuel and car use. It is not unlikely that consumer behavior is similar to the one regarding electric cars, which could be added to the model.

6 Summary

The aim of this study has been to examine how changes in income, gasoline price and car prices affect the demand for gasoline, the demand for new cars and the development of the car fleet.

Models were defined to estimate the elasticities of these demands. Results for two alternative demand specifications were examined: One in which demand is assumed to be perfectly price- and income reversible and another which allows for irreversibility

The perfectly reversible models are a special case of the imperfectly reversible models, that is when the coefficients corresponding to increases and decreases are the same, both for price and income coefficients. Thus the hypothesis of perfect price reversibility was tested by using a Wald test of imposing these equality restrictions on the coefficients of an imperfectly reversible model.

That means that if the results from a Wald test were such that it was not possible to reject equality of coefficients to increases and decreases the outcome became that the model is reversible.

Only two models rejected Wald's test and seem to be irreversible. That is the demand for gasoline per capita and the demand for gasoline per car. In both cases it is gasoline price that has asymmetric effects on the demands.

The effects from the other two determinants, income and car prices, did not seem to be asymmetric.

Table 13 shows the long-run elasticities of the demand for gasoline per capita and gasoline per car when income and gasoline price increase and decrease by 10%.

Table 13: Long-run effects of 10% increase and 10% decrease in income and gasoline price

	Long-run elasticities of demand			
	10% increase		10% decrease	
The Final demand models	*Income*	*Gasoline price*	*Income*	*Gasoline price*
The gasoline use per capita	5.13%	-5.44%	5.13%	-3.59%
The gasoline use per car		-3.53%		-1.18%

Table 14 displays the results of long-run effects from 10% increase in income, car prices and gasoline prices on the other final demand models. The results are assumed to be as much but reversed when the independent variables decrease by 10%.

Table 14: Long-run effects of 10% increase in income, car prices and gasoline price

Long-run elasticities when income and car prices increase by 10%		
The Final demand models	*Income*	*Car prices*
The size of the car fleet	8.14%	-11.10%
The demand of new cars	52.72%	-14.58%
The demand of small new cars	45.94%	-19.48%
The demand of medium sized new cars	48.62%	-12.69%
The demand of large new cars	64.83%	-7.83%

The results for the demand of new cars of different sizes are interesting. When income increases by 10% the demand for large cars increases by 64.83% while the demand for small cars increases by 45.94%. The effects of car prices on the demand for new cars of different sizes were not expected. The results are that when car prices increase by 10% the demand for small and medium sized cars decrease more than for large cars. One would expect the opposite, because larger cars are more expensive than smaller cars.

Results from other studies, where the asymmetric effects of price and income on the demand for fuel and cars are estimated, showed much more asymmetric effects than in the study presented. (Gately and Hungtington, 2002). The reason for that is probably that most of the variables used in this paper have been increasing much more than decreasing in the period of 1982-2008. For example has income been increasing the whole period and thus difficult or not possible to examine asymmetric effects from income. The little asymmetric results in this paper are therefore not surprising.

Even though the equality of the two coefficients for increases and decreases could not be rejected both for income and car prices the values, that the coefficients were given, might indicate some asymmetric effects. For car prices the coefficients were always higher for increases than coefficients for decreases. The result were similar for income, the coefficients to increases in income were most of the time higher than the coefficients to decreases.

It will be interesting to continue to examine asymmetric effects in road transport in Iceland and examine longer periods with more fluctuating variables. It would then be possible to make the model more detailed and get more accurate results for the asymmetric effects of the variables.

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Appendix A: Data

All data used in this study are listed in table 15.

Table 15: : Data series (n= number of observations)*

Data	*Period*	*Where from*	*n**
Real GDP in kronas calculated from consumer price index	1982-2008	Hagstofa Íslands – Statistics Iceland	27
Gasoline sold, in 100 liters	1982-2008	Orkustofnun - National Energy Authority	27
Diesel fuel sold, in 100 liters	1982-2008	Orkustofnun - National Energy Authority	27
Population of Iceland	1982-2008	Hagstofa Íslands – Statistics Iceland	27
Real price of gasoline in kronas per 100 liters calculated from consumer price index	1982-2008	Hagstofa Íslands – Statistics Iceland	27
Real price of cars in kronas calculated from consumer price index	1982-1996	Report from Þórhallur Ásbjörnsson	27
	1997-2008	Hagstofa Íslands – Statistics Iceland	
Number of cars in Iceland	1982-2008	Hagstofa Íslands – Statistics Iceland	27
Number of new cars in Iceland	1982-2008	Umferðarstofa - The road traffic directorate	27
Number of new cars in Iceland, 0-1599cc	1982-2008	Umferðarstofa - The road traffic directorate	27
Number of new cars in Iceland, 1600-1999cc	1982-2008	Umferðarstofa - The road traffic directorate	27
Number of new cars in Iceland, over2000cc	1982-2008	Umferðarstofa - The road traffic directorate	27
Number of new cars with gasoline engine	1982-2008	Umferðarstofa - The road traffic directorate	27
Number of new cars with diesel engine	1982-2008	Umferðarstofa - The road traffic directorate	27
Average age of cars in years	1982-2008	Umferðarstofa - The road traffic directorate	27

Appendix B: Test for stationarity

Dickey-Fuller test for stationarity was carried out to check if the time series used in the models were stationary. The null hypothesis is that the series are not stationary. The null hypothesis was rejected for all the time series which means they are all stationary.

The results are listed in table 16. If the test statistic is larger than the critical values the null hypothesis is rejected.

Table 16: Dickey-Fuller test for stationarity

			Test critical values		
Time series	*Definitions*	*t-statistic*	*1% level*	*5% level*	*10% level*
Income (Real GDP per capita)	Y_t	-2.834	-2.661	-1.955	-1.609
Gasoline use per capita	G_t	-2.697	-2.661	-1.955	-1.609
Gasoline use per car	E_t	-2.651	-2.661	-1.955	-1.609
Gasoline price	P_t	-3.212	-2.665	-1.956	-1.609
Car price	CP_t	-4.701	-2.661	-1.955	-1.609
Number of cars per capita	C_t	-2.753	-2.665	-1.956	-1.609
Number of new cars per capita	N_t	-3.335	-2.661	-1.955	-1.609
Number of new small cars per capita	$N_{small,t}$	-3.331	-2.665	-1.956	-1.609
Number of new medium sized cars per capita	$N_{medium,t}$	-2.936	-2.661	-1.955	-1.609
Number of new large cars per capita	$N_{large,t}$	-3.179	-2.661	-1.955	-1.609

Appendix C: Residual analysis

It is important to do a residual analysis. In this research the program Eviews 6 was used. With Eviews it is easy to carry out all kinds of tests to analyze the residuals. In this analysis it was examined for each model if autocorrelation and heteroskedasticity could be found in the residuals and finally it was also examined if the residuals were normally distributed.

Testing for autocorrelation

The Breusch-Godfrey serial correlation LM test or simply a LM-test was carried out to estimate if there were autocorrelation in the residuals. The null hypothesis is that there is no serial correlation. For all the models the null hypothesis was not rejected using a 10% cutoff for the F-statistic probability. In other words, autocorrelation was not found in the residuals for all the models.

Results are listed in table 17. If the p-value is smaller than 0.10 the null hypothesis is rejected.

Table 17: LM-test for autocorrelation in residuals

The reversible demand models	*Symbol*	*F-statistic*	*P-value*
The gasoline use per capita	G_t	0.563	0.753
The gasoline use per car	E_t	0.461	0.827
The size of the car fleet	C_t	1.074	0.418
The demand of new cars	N_t	0.903	0.517
The demand of small new cars	$N_{small,t}$	0.926	0.503
The demand of medium sized new cars	$N_{medium,t}$	1.031	0.441
The demand of large new cars	$N_{large,t}$	2.105	0.110

The irreversible demand models	*Symbol*	*F-statistic*	*P-value*
The gasoline use per capita	G_t	0.604	0.723
The gasoline use per car	E_t	0.640	0.697
The size of the car fleet	C_t	1.038	0.442
The demand of new cars	N_t	1.193	0.359
The demand of small new cars	$N_{small,t}$	1.352	0.297
The demand of medium sized new cars	$N_{medium,t}$	1.391	0.285
The demand of large new cars	$N_{large,t}$	1.660	0.204

Testing for heteroskedasticity

The residuals are called heteroscedastic if the residual variables have different variances and homoscedastic if constant. White test is a statistical test that establishes whether the residual variance of a variable in a regression model is constant. The null hypothesis in White test is that the residuals are homoscedastic. For all the models the null hypothesis was not rejected using a 10% cutoff for the F-statistic probability. In other words, there is no heteroskedasticity in the residuals.

Results are listed in table 18. If the p-value is smaller than 0.10 the null hypothesis is rejected.

Table 18: White test for heteroskedasticity in residuals

The reversible demand models	*Symbol*	*F-statistic*	*P-value*
The gasoline use per capita	G_t	2.331	0.111
The gasoline use per car	E_t	0.731	0.686
The size of the car fleet	C_t	0.497	0.803
The demand of new cars	N_t	0.117	0.993
The demand of small new cars	$N_{small,t}$	0.102	0.995
The demand of medium sized new cars	$N_{medium,t}$	0.454	0.833
The demand of large new cars	$N_{large,t}$	0.454	0.833

The irreversible demand models	*Symbol*	*F-statistic*	*P-value*
The gasoline use per capita	G_t	1.277	0.355
The gasoline use per car	E_t	0.879	0.599
The size of the car fleet	C_t	0.100	1.000
The demand of new cars	N_t	0.064	1.000
The demand of small new cars	$N_{small,t}$	0.065	1.000
The demand of medium sized new cars	$N_{medium,t}$	0.297	0.979
The demand of large new cars	$N_{large,t}$	0.126	1.000

Testing for normality

To examine if the residuals were normally distributed a simple test called Bera-Jarque was carried out for all the models. The null hypothesis in a Bera- Jarque test is that the residuals are normally distributed. For 12 models of 14 the null hypothesis was not rejected using a 5% cutoff for the Bera-Jarque probability. In other words, for 12 models the residuals are normally distributed. The two models that do not have normally distributed residuals were the reversible model for the demand for small new cars and the irreversible model for the demand for small new cars.

Results are listed in table 19. If the p-value is smaller than 0.05 the null hypothesis is rejected.

Table 19: Bera-Jarque test for normally distributed residuals

The reversible demand models	*Symbol*	*Jarque-Bera*	*P-value*
The gasoline use per capita	G_t	0.842	0.656
The gasoline use per car	E_t	0.603	0.740
The size of the car fleet	C_t	4.916	0.086
The demand of new cars	N_t	4.610	0.100
The demand of small new cars	$N_{small,t}$	**16.700**	**0.000**
The demand of medium sized new cars	$N_{medium,t}$	0.838	0.658
The demand of large new cars	$N_{large,t}$	0.517	0.772

The irreversible demand models	*Symbol*	*Jarque-Bera*	*P-value*
The gasoline use per capita	G_t	0.922	0.631
The gasoline use per car	E_t	0.760	0.684
The size of the car fleet	C_t	4.193	0.123
The demand of new cars	N_t	6.143	0.097
The demand of small new cars	$N_{small,t}$	**21.390**	**0.000**
The demand of medium sized new cars	$N_{medium,t}$	0.926	0.629
The demand of large new cars	$N_{large,t}$	4.115	0.128