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An Estimation of U.S. Gasoline Demand in the Short and Long Run

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ABSTRACT

The rapid growth of gasoline consumption in the USA for the last decades brings much concern to scientists and politicians. Therefore many researchers investigated the influence of the main factors that have an impact on gasoline demand. In our study we tried to estimate gasoline demand in the USA, using national time series data for the period 1984-2010. Gasoline demand function considered in this paper includes price, income, fuel efficiency and gasoline consumption in previous year, as the main explanatory variables. The model is estimated using simultaneous equations and cointegration and error correction model (ECM). The results of both methods show a significant price and income effect on gasoline demand. The price is found inelastic and its impact on gasoline demand is very small, however when we correct for endogeneity of price variable, we obtain higher price elasticity. The results on income elasticities obtained from two methods are dubious, since the two methods gave us the different results. In whole, an income raise will lead to an increase of consumption, gasoline demand is inelastic with respect to income in the short-run, while in the long-run it is found to be elastic according to 2SLS method, while the results of cointegration method indicate that gasoline response to income changes is higher in the short-run than in the long-run. Lag of error term suggests that around 57% of adjustment between short-run and long-run occurs during the first year.

Key words: gasoline demand, price and income elasticities, short-run, long-run, cointegration, 2SLS

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Until today oil remains an integral and the most important part for energetic branch of economy for most countries. Economic growth leads to an increase in oil demand. Until the humanity switches to wide usage of alternative kinds of fuel, the world oil demand will not decrease. According to U.S. Energy Information Administration, about two thirds of oil consumption is consumed by the countries that are members of Organization of Economic Cooperation and Development, with the USA and Canada as the largest consumers, the USA consumes about 3 gallons of oil per capita per day, while the consumption of oil in other OECD countries constitutes 1,4 gallons per capita per day. Besides oil consumption in China and India with the constantly growing economy is increasing at a rapid pace. Institute for the Analysis of Global Security states that world oil consumption is expected to rise by approximately 60% till 2020. Oil demand as well as oil supply are inelastic with respect to price in the short run, therefore supply decrease will immediately cause oil prices to go up. Similarly, an increase in its demand will drive oil prices to rise and induces the suppliers to extend oil production, which normally takes time and is going with a time lag.

Among all products obtained from crude oil, the most important role belongs to gasoline. A tenth of all the produced crude oil is consumed as a motor fuel by US citizens. Low fuel taxes, high income levels, together with not properly developed public transportation system, low fuel efficiency requirements create the conditions for high gasoline consumption. Comparing to Denmark, where a car purchase is imposed with high taxes together with high parking prices refrain demand on automobiles and stimulate the Danishes to ride bicycles, America has a developed road system, lots of fill-up stations and besides, the willingness of American citizens to reside in suburbs. All this contributes to high level of gasoline consumption. An increase of gasoline consumption which is going with the fast pace brings a lot of concern to scientists, realizing that oil reserves are not infinite, and environmental protectors, as high gasoline consumption raise the emissions of carbon dioxide. So the reduction of gasoline consumption is of vital importance. An estimation of responsiveness of gasoline demand to price and income changes can be of essential help in developing the appropriate policy of gasoline consumption cutback.

Gasoline demand issue has received a large attention for the last years and U.S. gasoline market occupies the central place in its research. Many researchers tried to estimate the demand for gasoline using different econometric methods and approaches, data periods and countries, among them are Ramsey, Rasche & Allen (1975), Radchenko & Tsurumi (2004), Hughes, Knittel, Sperling (2007), Wadud, Graham, Noland (2009) for the USA, Eskelad and Feyzioglu (1994) for Mexico, Eltony & Mutairi (1995) for Kuweit, Sultan (2010) for Mauritius. In this paper the U.S. gasoline market was chosen for analysis.

In this paper we attempt to analyze gasoline demand in the USA in the short and long-run during the period 1984 to 2010 using annual national dataset. The data used in analysis does not distinguish between commercial and private gasoline consumption. As the key factors that influence gasoline demand were determined gasoline price and personal incomes. The econometric models used in this study are based on the law of demand and Engel's law and similar in the form to the previous studies. Since much investigations of this issue have been done previously, it is easier for us to define the proper model. We formulated the model in terms of simultaneous equation system, using instrumental variable method and single equation with applied cointegration method to it. The both methods found price and income variables to be significant and of correct algebraic signs according to the theory.

1.1 Objectives of the research

The main objective of this paper is to analyze the demand for gasoline, to define the main factors that have an impact on it, to estimate the significance of each factor, to analyze consumer response to gasoline price changes and personal incomes changes. In this paper we will present an econometric model of gasoline demand with the help of which we will analyze the adjustment of gasoline demand to changes in its main determinants. We will try to determine price and income elasticities in the short and long run, using two methods: 2SLS applied to simultaneous equation system and Engle-Granger cointegration technique. To distinguish the long and short-term effect, we apply Error Correction Mechanism and Partial Adjustment Model. At the end we compare the obtained results from two different estimation techniques and make a parallel with the previous researches.

1.2 Outline

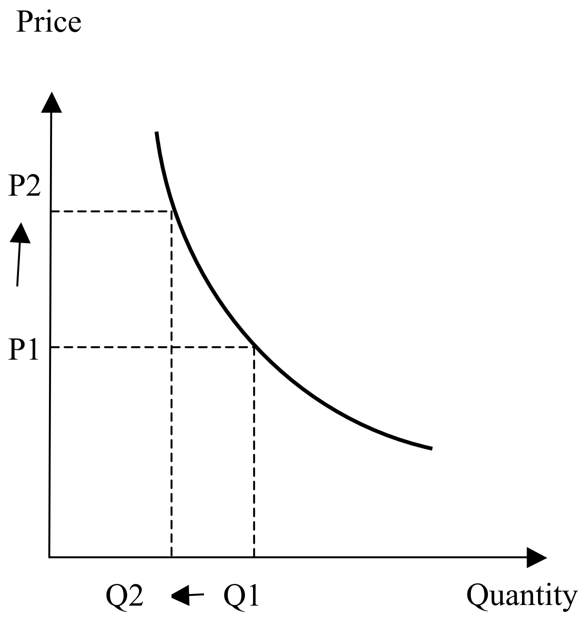
The paper structure is as follows:

Chapter 1 is the introduction, where the purpose of the study is stated, the importance of researched issue and obtained results are discussed. Chapter 2 provides the overview of the main theories involved into the given research. Chapter 3 presents the literature review where the study papers of previous researchers are considered. Chapter 4 is the analysis of U.S. gasoline market, where its main tendencies are discussed. Chapter 5 discusses the models that are employed in the study, data selected for models and methodology chosen for research fulfillment. Chapter 6 is an overview of econometric procedures needed to be performed before obtaining the final results. Chapter 7 provides the empirical testing results and the final estimates of the regressions. In Chapter 8 we lead a comparison of our obtained results with the results of previous studies of the considered issue. Chapter 9 contains conclusion and discussion of the empirical findings.

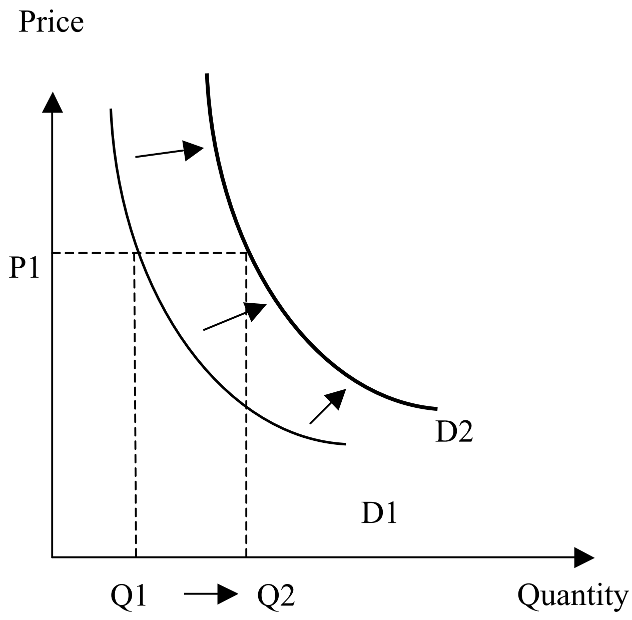
2. THEORIES

2.1 The law of demand

The law of demand is probably the most important in the theory of demand, which does not arise any doubts about its validity between economists. First, formulated by the British scientist Alfred Marshal, it states if the price of a good increases, the demand for this good will shrink and vice versa, if the price falls, the demand will rise. Consequently, people will try to decrease their consumption of a given good in case if its price goes up and replace, if possible, the consumption of this good by its substitute. Demand curve is represented in the form of downward sloping curve with the price on the ordinate axis and the quantity demanded on the absciss axis. On the graph 2.1 is depicted a demand curve, which shows the inverse relationship between price and demand, every price corresponds to a definite quantity demanded. It should be noted that price doesn't change demand, it changes quantity demanded, that is why a change in price causes movements along the demand curve to find the appropriate quantity.



Graph 2.1 Demand curve



Graph 2.2 A change in demand

If the demand relationship changes due to changes of non-price factors, while the price remains constant, it causes shifts in the demand curve, which is depicted on the graph 2.2. We can observe that given the same price the demand increased, shifting the curve D1 towards D2.

One of the main targets of this study is to determine price elasticity of gasoline demand, therefore we should give a definition of price elasticity before starting our research. Price elasticity of demand shows the degree of influence of price of an item on demand for that item and is calculated with the formula:

$$E_p = - \frac{\Delta Q_d}{Q_d} : \frac{\Delta P}{P} \quad (2.1)$$

where Q_d is the amount of demand for the item;

P is the price of the item.

For simplicity we will omit the minus sign in the formula to be consistent with the previous authors who researched the issue of price elasticity of gasoline demand.

Determining the factors which influence demand helps to understand consumer behavior and evaluation of significance of each factor gives an opportunity to forecast the future demand.

The main non-price determinants of demand are:

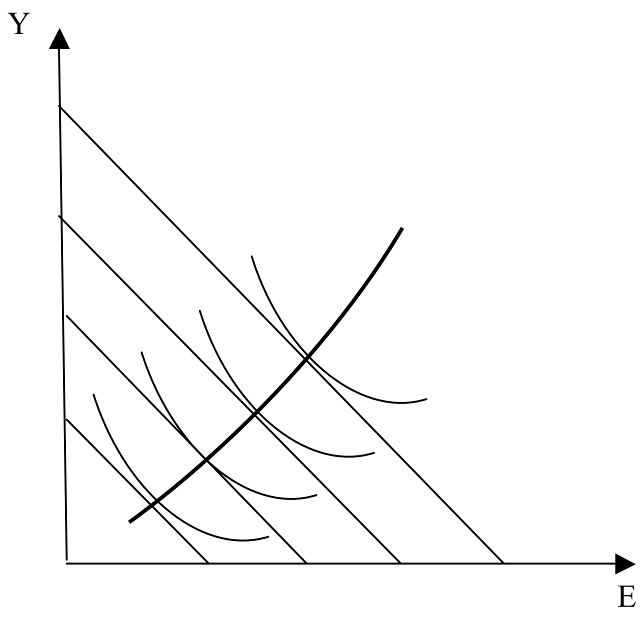
- **Personal incomes**. It will be considered in the section 2.2

- **Tastes and preferences.** Changes in consumer preferences under the impact of advertisement or marketing strategies by producers or changes as a consumer willingness to follow the common trends in fashion also affect demand. In gasoline market, a desire of a consumer to lead a sportive life might bring him to switch to ride bicycle and forgo from driving a car or at least reduce its usage.
- **Nature of commodity.** Goods are classified into luxuries, comforts and necessities. Demand for luxuries is mostly elastic, as its consumption can be postponed, demand for necessities is inelastic, as their consumption is essential for every-day living and they don't have many substitutes, and demand for comfort goods is between luxuries and necessities. We can refer gasoline as a comfort good, as people can restrict their driving and change their habits, when the price of gasoline changes.
- **Expectations of the future.** If consumers envisage price increase for a definite good, they might start purchasing it, or the expectations of future income growth might stimulate consumers to spend more money today. In anticipation of gasoline deficit or its price increase due to current interruptions in oil supply because of weather disasters or due to political unstable situation, people might want to fill their cars for future use, and a sharp total increase in demand for gasoline might lead to its price increase as a reaction of retail gasoline sellers.
- **Proportion of income spent.** If the consumption of a given commodity makes up a significant share in consumer's budget, an increase in its price might make consumer reduce or forgo from its consumption. And vice versa, the smaller the proportion of income spent on a commodity, the less will be elasticity of demand, since the increase in price for such goods does not considerably affect consumer's budget. For poor countries and for countries where gasoline prices are high, the expenditures on gasoline might make up a substantial fraction in consumer's income, so gasoline price increase might induce consumers to reduce their consumption and try to find another alternatives, but for countries with rather low gasoline prices or for economically developed countries with high population incomes the changes in gasoline prices will not affect consumer's budget significantly, so people will be not very motivated in reducing their gasoline consumption.
- **Population changes.** Considering aggregate market demand we can conclude that growing population causes an increase in demand. In countries with positive population balance due to high birth rate or migration surplus, we can expect a rise of demand, on

the contrary, a decrease of population reduces the number of consumers. Also the age of population should be taken into account, when considering demand changes. The high fraction of children in the total population might become a reason of higher gasoline consumption in the future.

2.2 Engel's Law

Economic law, formulated by the German scientist Ernst Engel and bears his name, states that consumer behavior is closely tied with the income size, and with rising income the consumption rises disproportionately. The share of expenses, spent on food products, is declining gradually with income increase, the share of expenses on purchasing new clothes and shoes remains more or less constant, but the share of expenses on purchasing durables, luxuries, education, traveling, entertainment and saving is increasing in consumer's budget. This law also shows that the share of expenses for food in consumer's budget is the indicator of the level of well-being of a consumer and of a country as a whole.



Graph 2.3 Engel's curve

This relationship can be depicted graphically on the graph 2.3. The ordinate axis represents income level and the absciss axis represents the money expenditure on a given good.

On the basis of Engel's law, we can predict that increasing income of consumers will normally stimulate them to drive more, as they will have a possibility to spend more money for travel and leisure. But if we consider households with very low incomes and on the contrary, the households with very high income, an increase of income probably will not have such effect, as in the first case, an increased income will be channeled for purchasing necessities and only considerable increase in income can be regarded to be spent on traveling or driving more, and in the second case, an increased income will probably not expand consumer's expenditures on driving more, as it was completely satisfied with the previous income level.

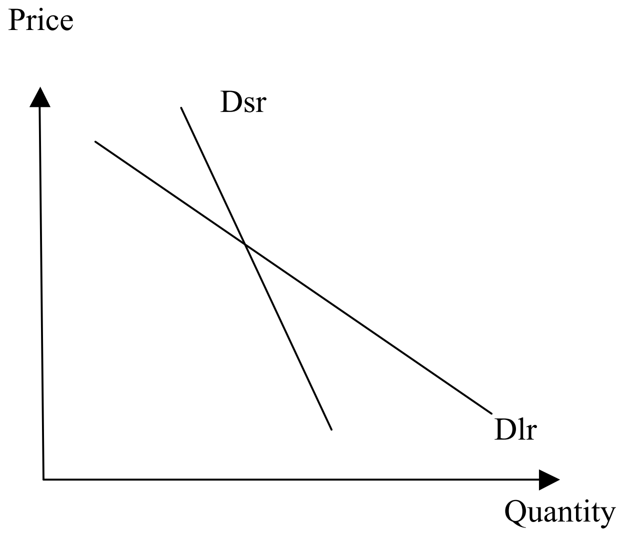
2.3 Time factor in estimating demand

Time factor is one of the main factors that affect elasticity and shape the demand curve. Price elasticity of demand for nondurables in the short-run is almost always less than in the long-run. When the consumption of a good cannot be postponed or if consumers have a strong habit of buying a good, they would rather tend to continue buying it, despite the price increase, so in brief time the demand will be inelastic. In the long-run high prices will stimulate a consumer to search for other alternatives and find out methods to cut the consumption of those goods, probably by purchasing substitutes of those goods that might be lower in price. The longer the time, that the consumers have to adjust, the bigger will be the response on changes in external factors that influence the demand.

Goodwin (1992) marked out crucial implications when studying short and long-run elasticities. He emphasized that if a price changes, a response to such changes takes time. He stated that in case of price volatility, the data taken at a particular space of time cannot be interpreted properly, as demand might be in disequilibrium with the current price. He also maintained, that within a long time there is much more alternatives that are disposed for consumers, than if they have to take a decision right away. The alternatives that were not taken into account earlier might be brought to a consumer today.

As it is defined, long-run elasticities capture the entire changes in consumption, while short-run elasticities show the immediate changes in consumption as a consumer's reaction to changes in external factors. Since it is enough difficult to distinguish between short-run and long-run and no exact time limits exist between them, there is an intermediate-run elasticity, which absolute value is higher than the short-run and lower than the long-run.

So the more time a consumer has to change his purchasing habits, the more elastic will be demand. The longer gasoline prices are held high, the more alternatives a consumer will consider in response, as persistent high gasoline price will affect consumer expectations about future prices. In the short-run, if gasoline price rises, it seems very difficult for drivers to cut back their gasoline consumption, so price increase will have a small effect on the changes of quantity of demanded gasoline. Consumers might reduce driving, but they have fewer opportunities to change a kind of car they used to drive. In the long-run, if the high price persists, motorists will probably shift to smaller and more fuel-efficient cars, or will switch to using public transport, or will move closer to their work, and demand will be more elastic. For visual presentation short and long run elasticities of demand is depicted on the graph 2.4.



Graph 2.4 Short and long-run demand curves

The exception can refer to storable products that can be purchased at irregular intervals, which implies that consumers might want to buy them in bigger quantities as soon as the price goes down. So the price decrease will cause an immediate effect on demand for storable goods in the short-run and demand elasticity with respect to price might be higher than in the long-run. Thus drivers might be willing to fill their car tanks when the price of gasoline falls, but certainly they would not buy gasoline for stockpiling.

2.4 The influence of high gasoline price on consumer demand for more fuel-efficient cars

In this section we will try to explain how fuel prices influence consumer choices over car characteristics, namely fuel efficiency, using hedonic price theory. By the fuel efficiency we mean an average number of kilometers that a car is able to run using one gallon of gasoline.

2.4.1 Hedonic pricing model

Many economists contributed to the development of hedonic pricing theory. The most significant findings belong to Lancaster (1966) who developed the new approach to consumer theory and Rosen (1976) who presented hedonic pricing model.

Lancaster (1966, p.133) assumed that "consumption is an activity in which goods, singly or in combination, are inputs and in which the output is a collection of characteristics." He suggested considering a good as a bundle of inherent attributes and pointed out that a consumer derives utility not directly consuming a good but from its attributes. He asserted that jointly consumed goods might have different attributes from the singly consumed goods.

In this section we will briefly explain the main ideas of hedonic pricing theory and will present Rosen's hedonic model.

Thus, hedonic pricing theory presents the goods as a set of characteristics. Since there are no explicit markets of product characteristics, there is a problem of estimation the demand for product characteristics in such implicit markets. The hedonic pricing approach aims to estimate how the consumers value different attributes of a given good and to determine the price of the attributes of the good. Purposely, the price of a good is decomposed into different elements that bring utility to a consumer, which determine the price; as characteristics of a good might change over time, the price will probably also change. Hedonic pricing model allows estimating the difference in price of goods which have different characteristics to understand how much a consumer pays for these characteristics and to evaluate the impact of each product characteristic on its price.

Rosen (1974, p.34) based his model on the assumption of the hedonic theory that "goods valued for their utility-bearing attributes".

The author suggested estimation the dependence of a price of a commodity p on its characteristics (z1,….zn) in a perfectly competitive market. Assuming that there is a good X and z is the vector of its characteristics, X can be defined as X = X(z1….zn) where n represents the number of attributes. The differentiated products presented on the market reflect various combinations of z characteristics and offer a consumer a lot of different alternatives. Z are characteristics of good X, assuming that all buyers have similar perceptions of characteristics of good X, however subjective assessments of substitutive goods might be different. The function p(z) can be determined if there is a demand-supply equilibrium on the market. Assuming that market is in equilibrium and Pi(z) is the hedonic price for an attribute Zi, the author derived the following demand-supply model:

Demand: Pi(z) = Fi (z1,…., zn, Y1)
Supply: Pi(z) = Gi (z1,…., zn, Y2)
where Fi (z1,…., zn, Y1) is the marginal demand price of zi
Gi (z1,…., zn, Y2) is the marginal supply price of zi
Y1 and Y2 are exogenous demand and supply shift variables.
Rosen's model suggests fulfillment of two successive stages, 2SLS method is applied to solve the system of equations. First, one regresses the price of a product on its characteristics to estimate the price p(z) without taking into account Y1 and Y2, the regression can be presented as a function of price and characteristics of a good $P = \alpha_1 + \alpha_2 z_1 + \alpha_3 z_2 + \ldots + \alpha_{n+1} z_n + e$; the regression coefficients show the changes of the price of a good X when the z characteristics change. It is called hedonic price regression which is obtainable through the comparison of prices of goods with various attributes. If there are two products that have the identical characteristics but have different prices, a consumer would choose that one which is sold for lower price. Then one computes implicit hedonic prices of corresponding attributes for every product as derivatives of the price of a given good to its characteristics, ðP/ ðzi. Second, one can use these implicit marginal prices to estimate the demand for each i attribute separately (Rosen, 1974, p.50).

The problem of consumer decision for differentiated goods is described by the author assuming that a consumer decides to buy one unit of a product with value z. Rosen determined utility function as U(a, z1, z2,….zn) where a is the consumption of other goods with the price equal to 1. The author defined the budget constraint as y= a + p(z), where p(z) is the price of a good with value z. To maximize the utility the first-order condition must be fulfilled, the ratio of the utilities for z and a must be equal to the ratio of the marginal costs of z and a: U_{zi}/U_a = ðP/ ðzi, and p(z) should not be too concave (Rosen, 1974, p.38).

2.4.2 The influence of gasoline price on consumers' choice over car characteristics

On the basis of Rosen's approach a car can be expressed as a set of inherent attributes: fuel efficiency, power, comfort, safety, acceleration. The price of a car reflects all these characteristics and is the amount of all its implicit or hedonic prices, which can be estimated through the given approach.

In this section we will try to explain how the price of gasoline influences consumer's choice over car characteristics, namely fuel economy, on the basis of the study Atkinson & Halvorsen (1984), who developed a new approach to the hedonic price procedure. They mentioned that the previous studies that researched the gasoline price influence on demand for car characteristics turned to estimate a regression:

$$C = C(E,z1,\ldots zn) \tag{2.2}$$

where C is capital costs of an automobile, E is fuel economy and z1…zn represent other car attributes. Atkinson and Halvorsen pointed out that fuel efficiency and other car characteristics are explained by the same technical parameters, which might strongly correlate with each other. Simply because a car has two main physical parameters: horsepower and weight, therefore all the derived characteristics are the different combinations of these two parameters (Bernard & Gilbert, 2007). Due to collinearity problem the estimates of consumer demand over car characteristics might be biased. To get rid of the collinearity problem Atkinson and Halvorsen proposed to estimate the dependence of fuel efficiency on car characteristics and the dependence of capital costs of automobile on the same car characteristics separately:

$$E = E(z1,\ldots, zn) \tag{2.3}$$

$$C = C(z1,\ldots, zn) \tag{2.4}$$

Equation (2.3) reflects the relationship between fuel economy and other car characteristics, while equation (2.4) shows the influence of car attributes on capital cost.

The researchers based their model on the precondition that a consumer chooses a car, taking into account automobile characteristics and the costs of gasoline for the whole period of using a car. In the majority of cases an additional unit of a desired characteristic will cause a decline in fuel efficiency parameter.

The utility function can be expressed as $W = W(z,X)$, where z is car characteristics but fuel economy; X represents another goods. Taking into account the practical inseparability of car characteristics from other goods in utility function, the authors rewrote it as $W = W(U(z), X)$, where $U(z)$ implies car subutility function. Since a consumer does not get the utility directly from fuel efficiency, but it has an impact on consumer choice, fuel economy was not included into utility function, but it enters the budget constraint equation, which has the following expression:

$$Y = C(z) + \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E(z)} \qquad (2.5)$$

where Y is the budget constraint or funds allocated on purchasing and exploiting a car;
C(z) is the capital cost of a car;
T is the total period of car exploitation;
E(z) is fuel economy;
P_t is the expected real price of gasoline in t year;
M_t is a number of miles that a consumer is expecting to drive in t year;
r is a discount rate.
Thus, the expression $\sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E(z)}$ implies the expected future expenditures on gasoline during the whole period of car exploitation.
The consumer is resolving the task of utility maximization: max U (z1….zn). Following the Lagrangean equation, where utility maximization is defined as an amount of objective function and budget constraint, which equals to zero, the authors derived the expression:

$$L = U(z) + ʎ\,(Y - C(z) - \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E(z)})$$

By the next step they maximize the Lagrangian and take the derivatives, equalizing them to zero. Thus the first order condition takes the following view:

$$\frac{ðL}{ðZ_i} = \frac{ðU}{ðZ_i} - ʎ\,(\frac{ðC}{ðZ_i} - \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E^2(z)} \frac{ðE}{ðZ_i}) = 0$$

$$\frac{ðU}{ðZ_i} = ʎ\,(\frac{ðC}{ðZ_i} - \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E^2(z)} \frac{ðE}{ðZ_i}) \qquad (2.6)$$

On the basis of the equation 2.6 they concluded that marginal benefits of using additional characteristics of a car must equal marginal costs, which consist of marginal capital costs and current expenses on gasoline.

Applying comparative statics they investigated the influence of gasoline price in the base period P_o on the consumer choice of z attributes and fuel efficiency of a car E, using the equation (2.3), (2.5) and (2.6).

The authors derived the following formula:

$$\Theta = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \frac{P_t M_t}{E^2(z)} \qquad (2.7)$$

where Θ is the marginal benefits that a consumer gains due to decrease of gasoline expenditures, caused by increased fuel efficiency.

As a result the researchers found the value of $ðΘ/ðP_o$ which explains an influence of gasoline price changes in the base period on marginal benefits caused by an increase of fuel-efficiency.

Having solved the comparative statics equation for the vector of the partial derivatives of car characteristics with respect to price $\frac{ðZ_i}{ðP_o}$, the authors derived the formula with the help of which one can obtain the estimate of demand elasticity of fuel efficiency E with respect to price in the base period P_o:

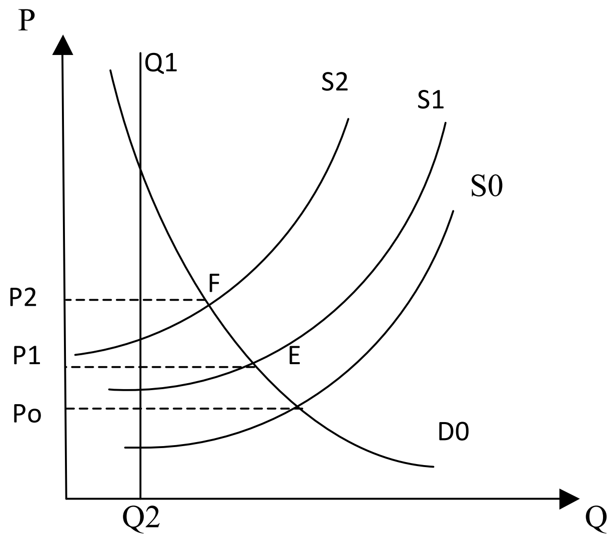
$$\frac{ðE}{ðP_o} = \sum_{i=1}^{n} \frac{ðE_i}{ðz_i} \frac{ðz_i}{ðP_o} \qquad (2.8)$$

The authors pointed out that the effect of gasoline price changes on consumer choice over car attributes and fuel economy depends on consumers future expectations of gasoline price and expressed price as:

$$P_t = P_0\,(1+f)^t \qquad (2.9)$$

where f is expected rate of gasoline price increase.

According to the price expectation mechanism the difference between the real price and the expected price in the preceding period reflects the changes in the price expectation and can be introduced as following: $ΔP^* = P_{-1} – P^*_{-1}$. Assume that an actual price P1 is higher than the consumer price expectation P_0, and point E on a graph 2.5 is the equilibrium between demand and supply and corresponds to the actual price level, Q1-Q2 is the line which represents long-run equilibrium with the right price expectation, then the consumers will adjust their price expectations to the level of P1. If the supply curve shifts upward from S1 to S2 and the equilibrium of demand-supply is established in the point F with the new equilibrium price P2, which will be higher than P1, the consumers will change their price expectations in response to the increase of actual price and expected price will be established at the level P2. If the demand-supply equilibrium is set up to the right of the line Q1-Q2, the actual price will be higher than the expected and the individuals will have to adjust their expectations to the real prices (Frisch, 1980, p.203)



Graph 2.5 The mechanism of price expectation adjustment to the actual price level

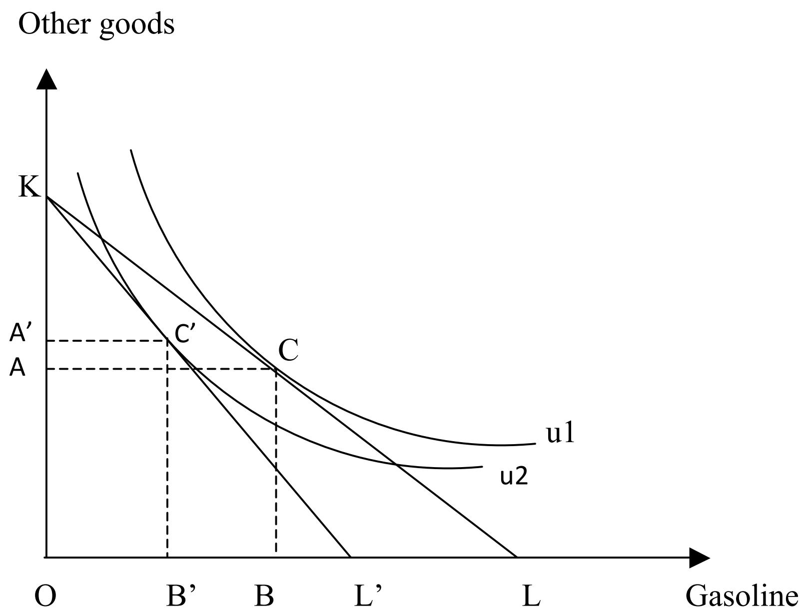
Having substituted the price P_t, expressed in the formula (2.9) into the formula (2.7) the authors obtained the following expression:

$$\Theta = \sum_{t=1}^{T} \left(\frac{1+f}{1+r}\right)^{t} \frac{P_o M_t}{E^2(z)}.$$

To obtain estimates of demand elasticities for fuel efficiency the authors solved an equation (2.8). As a result, the estimate of demand elasticity for fuel efficiency with respect to price was equal to 1,38. The coefficient shows that gasoline price increase will stimulate consumers to purchase more fuel-efficient cars. Since the weight of car and its power are inversely related to fuel efficiency, consequently a gasoline price increase will cause a reduction of demand on such car characteristics like engine power, acceleration, car weight. In other words consumers will be ready to pay more for having more economic vehicles and less for more powerful and weighty.

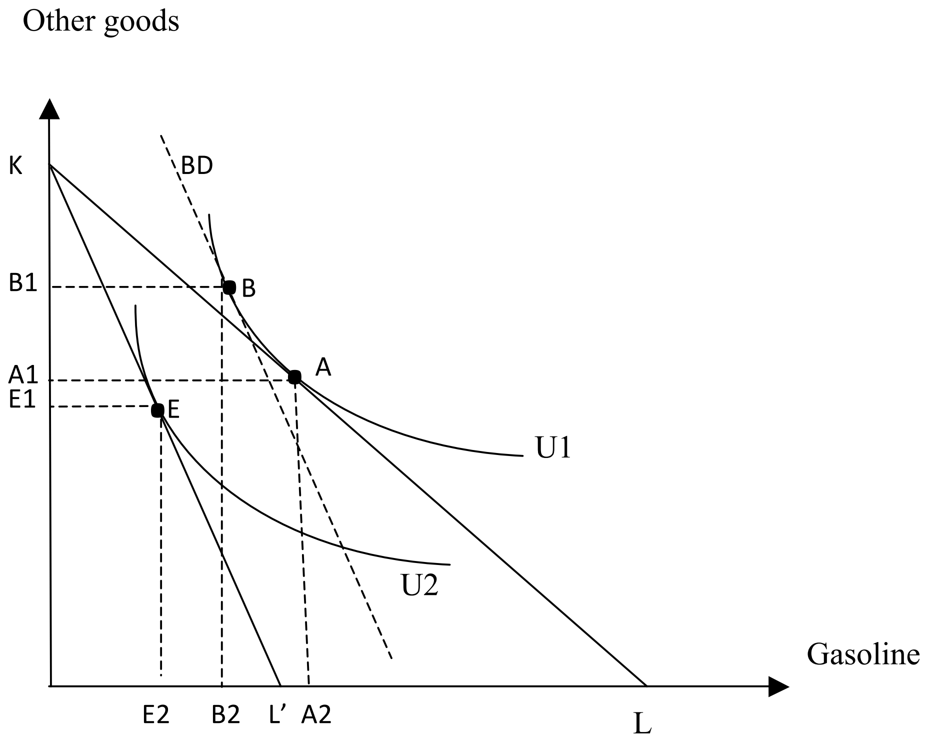
The applied approach allowed the researchers to avoid multicollinearity problems and also to obtain empirical elasticities of demand for fuel efficiency and other car characteristics with respect to gasoline price. The benefit of developed approach is that there is no need to use the data about gasoline price variation.

We can illustrate the consumer's choice with the help of indifference curves, which show different combinations of two different goods, which have the same utility for a consumer, and a budget line. Consumer behavior theory suggests that the maximum utility a consumer can derive is in the point where the budget line is tangent to indifference curve. Let's consider the situation when a consumer chooses between gasoline purchase and other bundle of goods, let's allocate bundle of goods along ordinate axis and gasoline along absciss axis, as it is shown on the graph 2.6, KL is a budget line and u1, u2 are indifferent curves, OL is a maximum quantity of gasoline that the consumer can purchase, if he spends all his income for gasoline, OK is the quantity of other goods, that a consumer can purchase, spending on them all his income, and C is the maximum utility that a consumer can derive, consuming B quantity of gasoline and A quantity of other goods. Let's assume that a price of gasoline goes up, that means that the consumer will be able to purchase only OL' quantity of gasoline if he spends all his income on gasoline. The new budget line will be KL' and new maximum utility point will be in point C', implying that optimal consumer choice set will consist of B' quantity of gasoline and A' quantity of other goods, so we see that gasoline price increase in the short-run will stimulate the consumer to consume more other goods by (OA'- OA) and to reduce gasoline consumption by (B-B').



Graph 2.6 Consumer's choice between gasoline and other goods

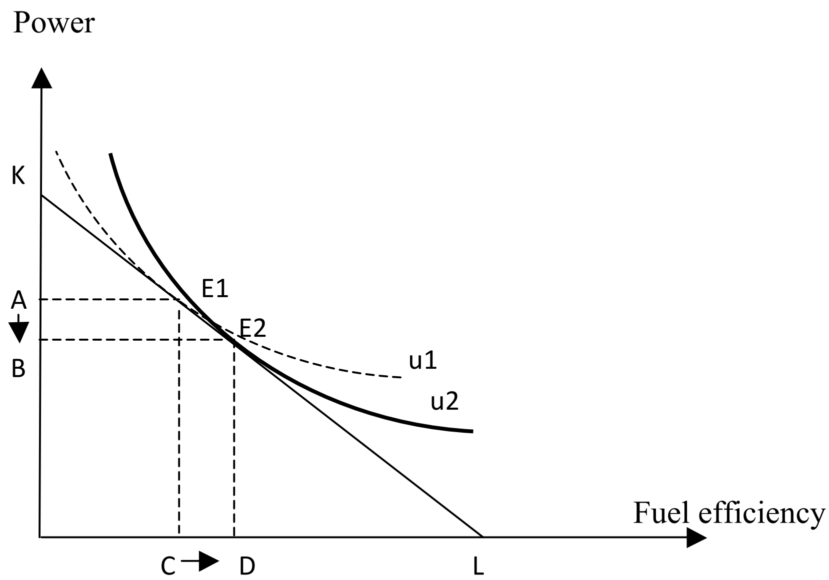
Depending on the indifference curve, the amount of other goods purchased might also decrease or stay on the same level in case of gasoline price increase. Alternatively we can illustrate the changes in demand in case of gasoline price increase by the following way depicted on the graph 2.7



Graph 2.7 An alternative option of consumer's choice between gasoline and other goods

Due to gasoline price increase, the budget line KL will shift to KL' and the new consumption equilibrium point will move from the point A to the point E, implying that the amount of gasoline and other goods purchased will decrease and will equal E2 and E1 respectively. The change in consumption level is explained by substitution effect and income effect. The first we can observe when the decrease in consumption is caused by the price increase. To measure the substitution effect we draw an auxiliary budget line that is parallel to the new budget line KL' and is tangent to the initial indifference curve u1 in point B. The movement from initial optimal consumption in point A to the point B is the substitution effect. The income effect is obtained as the difference between imaginary consumption at B and new consumption at E. The total price effect is calculated as a sum of substitution and income effect and is the movement from point A to the point E. From the picture 2.7 we see that gasoline price increase will cause the decrease in demand for gasoline by (A2 –E2) and the demand for other goods will fall by (A1-E1).

Let's consider the situation when a consumer chooses between two physical parameters of a vehicle power of engine and fuel efficiency. Along the ordinate axis we will allocate power and along absciss axis – fuel efficiency. KL is the budget line, the maximum utility that the consumer can reach is located in the point E1, which will correspond to A points of power and C points in fuel efficiency. If gasoline price goes up, the indifference curve will change its shape and will become much steeper. As it is shown on the graph 2.8 gasoline price increase changes the shape of the initial indifference curve u1 making it steeper, u2 depicts the new steeper indifference curve. We can observe that the maximum utility point will relocate to E2, implying that the consumer's choice will shift in favor of purchasing fuel-efficient car.



Graph 2.8 Consumer's choice between fuel efficiency and engine power

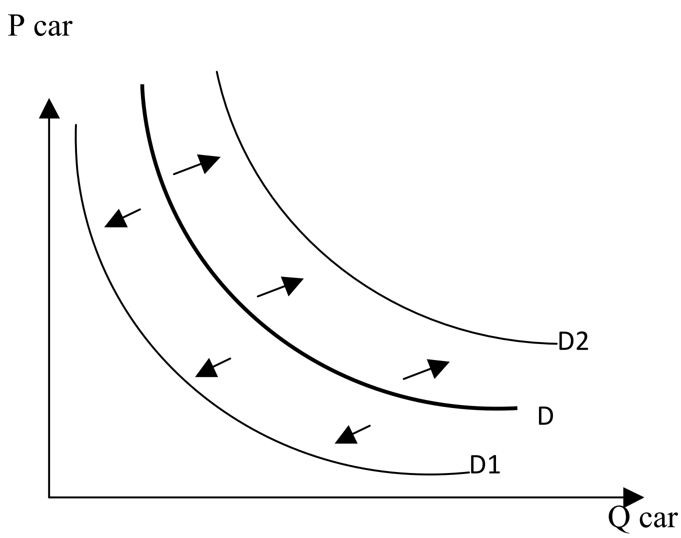
This illustration reinforces the idea that an increase in fuel price will stimulate people to switch to more fuel-efficient cars to economize money for gasoline. But we can expect such consumer reaction in response to high gasoline prices only in the long-run. An increase in average vehicle fuel efficiency decreases the fuel cost per mile, so with new more economic cars drivers will be able to raise their vehicle mileage despite high gasoline prices. We also should add that such substitution of high power engine-car to small fuel-efficient can be attributed to middle-class consumers with restricted budget, wealthier consumers mostly orient on other automobile characteristics when purchasing a car and do not take into account fuel-economy parameter, so fuel price increase will not change their preferences much. Also an increase in consumer incomes and lower interest rates on consumer credits will cause additional demand for more expensive and powerful cars.

Also we should mention the fact that consumers cannot respond to fuel price increases quickly and normally price increase will not cause an immediate increase of demand on more fuel-efficient cars, it will take place with time delay, so the conclusion about willingness of consumers to switch their gas-guzzlers to smaller economic cars can be applicable only in the long-run. In the short-run, changes in fuel prices can be considered by consumers as temporary price volatility and with expectations on future price decrease consumers will probably not undertake any such actions.

Thus among the other ways of consumers reaction to gasoline price growth, as forgoing from driving or decreasing driving amount, changing an existent car for more fuel efficient one considers it as an efficient way of reduction the expenditures on gasoline.

2.5 The interrelation of demand for durables and non-durables

From economic theory one knows that if two products are complementary, there might be a negative relationship between a price on one product and the demand on its complementary. So if there are two goods X and Y and they are said to be complementary, this means that a decrease in price of X usually leads to an increase of demand for Y and vice versa, an increase of price Y will cause a decline in demand for X. The classic example of such complementary goods is cars and gasoline. An increase in gasoline price causes a decrease in demand for cars, and vice versa a decline in gasoline price might cause an increase in demand for cars. We can see a possible responsiveness of demand for vehicles on gasoline price changes on a graph 2.9.



Graph 2.9 Demand curve for cars

As we can see from the above graph 2.9, gasoline price changes shift the demand curve: in case when gasoline price rises, the demand for cars declines and the original demand curve D shifts to the left to D1, inversely, if the price of gasoline decreases, the demand for cars rises and the demand curve for cars D shifts to the right to D2.

Higher gasoline prices will increase the cost of producing vehicle miles traveled and families will have to reduce their driving. Fewer miles traveled will imply the reduction of gasoline consumption and also the reduction of demand for new cars and used cars, though such effect might be temporary. The decrease in demand volume on vehicles will depend on consumer's expectations about future prices and their fuel costs. Considering the fact that on vehicle demand influence many other factors, as prices on new and used cars, transport infrastructure, public transport and rail prices, traffic congestions, personal incomes; vehicle sales depend not only on current gasoline prices, but also on consumers' anticipations about future prices and also submitted to the influence of seasonal effects, an estimation of the direct impact of fuel price on vehicle fleet is a rather hard task. Higher gasoline prices might discourage a consumer from purchasing a new car or replacing the old one, persistent high fuel prices will reduce new and used car sales, as the consumer will consider his future expenses on fuel as considerably high, observing current high prices on gasoline. Car owners might also decide to sell or scrap their cars, so the stock of vehicles will fall within time. On the contrary, considerable decrease in gasoline price might stimulate a potential buyer to purchase a new car, as he will compare his future expenses of using a car with current prices, which might seem to him attractive. As a consequence, an increase in demand for vehicles will cause gasoline demand to rise and a decline in demand for automobiles will contribute to decrease in gasoline use.

To understand how demand for complementary goods is interrelated, we will consider the study of Conrad & Schroder (1991), where the authors discuss the demand for durable and non-durable goods, examplifying it on energy consumption. They attribute a definite fraction of energy to a durable good to obtain a potential service flow from that durable good. This fraction of energy is regarded as the variable service flow and denotes utility since energy without durables is of no value. They expressed consumers' preferences in the shape of cost prices, which are the prices of a good itself plus all the expenditures that arise while using it. So the price costs of owing a car will include price of a car, gasoline, parking fees, insurance, technical service, etc. The authors suggested dividing the quantity xi of a commodity i into complementary fractions that interrelated with other commodities and substitutable fraction $\widetilde{xi}$ and got the next expression:

$$\text{Xi} = \sum_{j \neq 1}^{m} aij\widetilde{xj} + \widetilde{xi}$$

where the coefficient aij denotes the needed amount of a commodity i when using one unit of durable good j, which is not related to the consumption of another commodity. $\widetilde{xi}$ is the amount of gasoline consumption due to fast driving. Assuming that commodity i is gasoline and j is a stock of cars, $aij\widetilde{xj}$ represents the minimum gasoline consumption.

From the derived formula one may see that an increase in vehicle stock j will inevitably cause an increase in gasoline consumption.

Then the authors express the cost price $\widetilde{pj}$ as a sum of pj the market price of a good j plus *aijpi* the costs of the goods related to the use of good j.

$$\widetilde{pj} = \sum_{j \neq 1}^{m} aijpi + \text{pj}$$

Thus, if a buyer decides to purchase a car he should take into account not only the market price of a car, but also additional costs of using complementary goods, as gasoline, car maintenance and repairing.

We can conclude that a considerable increase in gasoline price might discourage a buyer from purchasing a car, while a cheap gasoline prices will cause an additional demand for vehicles.

3. LITERATURE

In this section we will shortly present the results of previous studies dedicated to gasoline consumption issue. All studies of gasoline demand include price and income variables to estimate their impact on gasoline consumption, applying different methods. Some studies include the stock of vehicles and fuel efficiency factor in the model. The obtained short and long run estimates are presented in the table in appendix of this paper.

Burricht & Enns (1975) estimated gasoline demand in the short run, having included gasoline price, personal income, fuel economy and car stock into the model as the main variables, and also added share of state population in urban locations and share of total of trucks among the total vehicles when estimating short-run elasticities; and in the long run, having considered gas price, income and new and used car prices. They discussed that in the short period of time people may decrease their gas consumption by driving less and driving slower, in the long run consumers might switch to use more fuel-efficient cars or move closer to their work places. Using GLS method, they obtained results that suggest that price elasticity is quite low and equals -0,26, while income elasticity is 0,18 in the short run. In the long-run price elasticities were found at the level -0,64 to -0,68.

Ramsey, Rasche & Allen (1975) pointed out the need to analyze the demand and supply side of the gasoline market simultaneously, even if one is only interested in gasoline demand. In their opinion, such approach will allow to estimate "indentifiability of the demand equation and also to indicate more clearly the precise nature of the partial equilibrium system which is under examination" (Ramsey, Rasche & Allen, 1975, p.502). The authors limited their research to estimating demand and supply of private and commercial consumers using the aggregate data. They defined gasoline consumed during a year and real gasoline price as endogeneous variables for demand equation and real disposable income, the share of people aged 16-24 in whole population as exogenenous variables. They also included price index of train travel as an alternative transport mode into private demand equation and a price index of diesel fuel and index of total ton miles demanded of all freight carriers into commercial demand equation. Supply equation is represented by crude oil amount supply, and wholesale prices of all distillates. Applying two-stage least square method, they obtained gasoline price elasticity for private demand equal to -0,222 and for commercial demand -1,03. They assumed that if the gas and diesel prices change proportionally, obtained the joint price elasticity of demand is -0,61. The authors also discovered that even the slightest change between gas and diesel prices have huge impacts on their demand: if a gas price rises by 0,5% and diesel price falls by 0,5%, commercial demand declines by 2,7% and total demand by 1,2%.

Eskeland & Feyzioglu (1994) estimated gasoline consumption in 31 states and federal districts in Mexico for the period 1982-1988, annual aggregate panel dataset was used for analysis. They presumed that number of vehicles doesn't influence gasoline consumption per vehicle, because an increase in number of cars grows faster than road infrastructure is being developed, which inevitably leads to traffic jams. It causes an increase in gasoline consumption per mile and decrease in traveling. Short run price and income elasticitties can be obtained from running regressions, as estimation coefficients, long run elasticities are calculated from the dynamics of the utilization equation, solving the difference equations that are determined by equating the errors to zero. To estimate elasticity OLS method cannot be applied because of "unobservability of the state specific individual effects, the dynamic specification that allows for habit persistence and measurement errors in the data set" which might lead to biases and inconsistency in results (Eskeland & Feyzioglu, 1994, p.15). A suitable method that enables to get rid of all these problems is instrumental variable method. To apply this method variables that are highly correlated with the explanatory variables, but not with the errors must be found. Eskeland and Feyzioglu took the lags of gasoline consumption and income as such variables. As a result they obtained short run price and income elasticity equals -0,785 and 0,822, long run price and income -0,799 and 0,836. The short and long run results do not differ too much, which testifies that consumers completely adjust their behavior and adapt to new prices and income very fast.

Johansson & Schipper (1997) based his research on the twelve OECD countries (Australia, Denmark, Finland, France, Germany, Japan, Italy, the Netherlands, Norway, Sweden, USA, UK) and estimated the period 1973-92. They determined total consumption as a product of driving mileage, fuel intensity (gallons per mile) and number of cars per capita, which enables them to estimate the share of changes of gasoline consumption due to gasoline price as a result in changes of vehicle ownership, driving mileage and fuel intensity. They first estimate fuel intensity, driving mileage and vehicle stock and then using the obtained estimates, applying different estimation methods, they derive fuel demand elasticities. The authors estimated driving mileage as a function of fuel intensity and the car stock using recursive system method, in turn fuel intensity and vehicle stock are regressed on fuel price, income, taxation and population density using dynamic model with included lagged independent variable. For estimation of fuel demand they used pooled cross-section time-series model, which gave them a long-run price elasticity of about -0,7 in which the biggest share is due to changes in vehicle fuel intensity, though the fuel demand elasticity is two times higher than the elasticity of travel demand. Long-run income elasticity is found to equal 1,2 which is almost all due to vehicle stock; population density and non-fuel taxation variables were -1,0 and -0,11 respectively.

Espey (1998) analyzed hundreds of estimates for the period 1929-1993. In this meta-analysis there were estimated four models: short-run and long-run models for analyzing a variation in the magnitude of price elasticities and short-run and long-run models for understanding a variation in income elasticities. The author defined a short-run price elasticity median value to be -0,23, while the median long-run elasticity equaled to -0,43. According to the conducted analysis short-run price elasticity estimates are found to vary from 0 to -1,36, while long-run estimates vary from 0 to -2,72. She also found out that short-run gasoline demand elasticity with respect to price tends to decrease with time, while the long-run demand elasticity is increasing. The author explains it as the gasoline price started increasing after 1970, people had less opportunities to respond to price increase, they had to change their consumptive behavior and buy vehicles which use less fuel, while during long-run time period price elasticities tend to be higher due to fuel efficiency improvement. According to the study results long-run income elasticities range from 0,05 to 2,73, with the median value 0,81, while short-run income elasticities fall in the range from 0 to 2,91, with the median value 0,39. The researcher found no considerable difference between long-run elasticities that are based on annual, quarterly or monthly data, but short-run estimates based on monthly data are found to be higher. There was not found any serious difference between the estimates obtained from models that use aggregate and non-aggregate data. She also concluded that American consumers are less price sensitive than non-US consumers in the short-run, while in the long-run there wasn't found any significant difference. Analyzing long-run income elasticities, she found out that they tend to decline over time, while short-run elasticity doesn't seem to change considerably. The author emphasized the importance of stock of vehicle as a variable that have an impact on gasoline consumption, depending on its inclusion or exclusion the parameter estimates might change considerably. The researcher also pointed out that static models give lower long-run estimates and higher short-run estimates, comparing to dynamic models, so she concluded that they probably give intermediate-run results.

Graham & Glaister (2001) in their survey of price elasticities focused on comparing the effects of price in the short and long run. They concluded that the obtained estimates might vary greatly depending on the estimation methods and dataset that are used, thus time series, cross section and pooled data might give different results. In this survey long run price elasticities that are in turn based on the surveys of previous researches (Drollas, 1984, Sterner, 1990, Sterner and Dahl, 1992, Goodwin, 1992) are found to be in the range from -0,6 to -0,8, while average short run price elasticity of gasoline demand ranges from -0,2 to -0,3. According to the survey, the short run income elasticity of gasoline consumption varies from 0,35 to 0,55 and in the long run from 1,1 to 1,3.

Goodwin, Dargay & Hanly (2003) investigated the price elasticities of demand focusing on short and long-run distinctions. The authors made the summary of price elasticities of gasoline demand based on 13 previous studies and found that price elasticities produced by time series and cross-section data do not differ much: times series data gave the average short-run and long-run elasticities of -0,27 and -0,71 respectively, while short and long-run price elasticities obtained from cross-section data are -0,28 and -0,84 respectively. They emphasized that short run estimates are almost always smaller than the long-run ones, since in the longer time consumers have wider opportunities than during the brief period of time. They concluded that price changes have a smaller effect on miles driven than on gasoline consumption in the short as well as in the long-run, which indicates that people might drive slower and change their driving habits so that to produce the same miles, but to spare some gasoline in the short-term. The researchers compare the effects of price increase on traffic level and gasoline demand and explain that a 10 % increase in gasoline price leads to 3 % decrease in gasoline demand and 1,5% in miles driven in the short-run and a decrease in traffic level by 3 to 5 % and 7 % in gasoline consumption in the long-run.

Radchenko & Tsurumi (2004) applied the Bayesian limited information using Markov Chain Monte Carlo algorithms for estimation simultaneous equations with white errors and autocorrelated errors to analyze demand and supply equations in the USA. The authors defined two variants of supply equation, where they capture the impact of oil price changes on gasoline price and where they neglect oil price changes. In the course of their research they rejected asymmetric effect of oil price changes on gasoline price changes with obtained estimation coefficients: 0,233 and 0,276 for oil price decrease and rise respectively assuming that error terms are autocorrelated and for white noise error terms the coefficients of oil price increase and decrease are 0,239 and 0,225 respectively. They also pointed out a significant negative effect of oil stock on gas prices with the elasticity -1,6 with white noise error terms and -0,24 with autocorrelated errors. They concluded that a rise in oil stock by 1% causes a decrease in gas prices by 0,24 to 0,3%. The researchers observed that autocorrelated error terms approach delivers robust results estimating the supply equation, but white noise error terms method does not produce robust estimators. Supposing that error terms are autocorrelated, price elasticity of demand is found to be -0,543, with white noise error terms, price elasticity is on the contrary positive and equals 0,184, which is quite illogical, since with price increase, demand is expected to fall down and vice versa, so autocorrelated errors assumption gives more plausible results. When testing supply side on a weak exogeneity, autocorrelated error approach shows endogeneity, while white noise error term approach found exogeneity. In this paper the Bayesian approach with TSLS method were also compared, as a result, it is revealed that the results obtained from Bayesian and TSLS approach are similar with white noise error terms, but for autocorrelated error terms they differ much. According to the obtained results the Bayesian procedure with autocorrelated error terms can be considered as more appropriate method which gives price elasticity of demand of -0,54, and income elasticity of 1,685.

In the study of **Brons, Nijkamp, Pels & Rietveld (2006)** the authors used meta-analytical techniques in estimation price elasticity of gasoline demand in the USA, Canada and Australia.

They considered that changes in fuel price have an impact on fuel demand through fuel efficiency, car stock and mileage per car and expressed gasoline demand as a product of these three variables. To estimate the impact of price changes on gasoline demand first the impact of these variables on the price elasticity is tested. To this purpose, the researchers use a meta-analytical model based on a system of fixed effects equations. Using this model the mean price elasticity of fuel demand is found to be -0,53; price elasticities of fuel economy, car ownership and mileage per car found to be 0,22; -0,22 and -0,1 respectively. These elasticities show the changes in fuel efficiency, car ownership and driving mileage in response to a change of gasoline price. The method based on decomposition of an elasticity into a range of elasticities and is simple enough in application. The authors asserted that this method gives more accurate results and can be employed instead of conventional meta-analytical methods. The results showed that the absolute value of fuel economy and car ownership are the highest, so exactly these factors drive gasoline price which then affects gasoline consumption. The second issue that the authors investigate is the effect of study characteristics on the elasticity, based on the system of fixed effects regression equations. The obtained results from the research indicated that coefficients of price elasticities tend to be higher among cross-section data than the time series. The reaction of driver on price changes depends on time. The authors found out that in the longer run price elasticities tend to be higher. In the short run when a price increase takes place, consumers mostly can decrease the amount of driving, while in the long-run they might purchase more fuel-efficient cars or sell their car. The consumers of USA, Canada and Australia are very reluctant in parting with the cars they possess. So comparing to the other countries, the whole impact of the price change on fuel demand is lower in the regarded countries, though gas demand became more price elastic during 1949 – 2003.

Hughes, Knittel & Sperling (2007) analyzed gasoline consumption in the USA for the period from 1974 till 2006 and found that using OLS method, short-run price elasticity was much higher in the period from 1975 to 1980 (-0,31;-0,34) than for the period 2001-2006 (-0,041; -0,043). The prices in the period 1975-1980 have risen and were retained high for a long time due to economic recession in the USA which probably led to higher elasticity, as people usually need time to adapt to new prices. Income elasticity varies from 0,47 to 0,49 in the period 1975-1980 and from 0,53 to 0,54 for the period 2001-2006. The authors pointed out that the period of 1975-1980 is characterized by the decline in economy, so to obtain the truthful estimates the variables of unemployment, interest rate and inflation rate must be included, as a result the obtained price estimates were found at level -0,22; 0,21 and income estimates 0,33; 0,38. The researchers suggested estimating simultaneous equations model of demand and supply, since treating price exogeneous might lead to biased and inconsistent results. As instrumental variables they chose crude oil quality and disruptions in production of crude oil. Crude oil quality was represented by sulfur content and American Petroleum Institute specific gravity. Crude oil disruptions were defined for three countries USA, Venezuela and Iraq as a difference between its real production and anticipated. 2SLS method gave the price elasticity of -0,077 for the period 2001-2006. According to the results of the price income interaction, recession data model and SEM, that were applied to estimate short-run price elasticities, it ranges from -0,21 to -0,22 for the period 1975-1980 and -0,034 to -0,077 for the period 2001-2006. They concluded that since the short-run price elasticity is lower today, so to decrease gasoline consumption gasoline tax rate should be higher. The authors also pointed out the importance of improving fuel economy on the way to achieving the goal of decreasing gasoline consumption.

Bhascara & Gyaneshwar (2008) selected five alternative methods to estimate gasoline consumption in Fiji during the period from 1970 to 2005. They estimated the gasoline demand dependence on gasoline price and income, for estimation they used aggregate data of demand and income. All the methods gave out very close results for the long run price and income elasticities that averaged to -0,2 and 0,45 respectively. The adjustment coefficient is about 1, which indicates that the long-run estimates do not drift apart from the long-run ones and equilibrium is very quickly restored. The authors pointed out that taxation policy might not be a good instrument in reduction gasoline consumption.

Wadud, Graham & Noland (2009) analyzed the yearly time series data for the period 1949-1974 and 1978-2004 and estimated the relationship between fuel demand and gas price and real disposable income. They failed to find a cointegration between the variables for the period 1949-1974 because of vague unit root results, but the results for the period 1978-2004 indicated that gasoline consumption, price and income variables cointegrate. All three variables for the period 1978-2004 appeared to be non-stationary, but having applied difference method they became stationary I(1) at first difference, the residuals are found to be stationary, that also indicates cointegration between variables. Using Engle-Granger two-step procedure they obtained long and short-run estimates of price and income: they found that long-run price elasticity is equal to -0,102, while the short run is -0,065; long-run income elasticity is also larger (0,565) than the short run elasticity (0,473). Dynamic OLS procedure of the model, with inclusion three lag variables of gas demand, provided the following estimations: -0,118 and -

0,091 for the long run and short run price elasticity, and 0,593 and 0,457 for the long run and short run income elasticity. Since dynamic model produced the lowest standard errors and the highest R square, the obtained estimates from this model can be considered as the most reasonable. The application of single stage non linear least squares to estimate the elasticities, gave pretty similar results of long-run estimates with the dynamic model.

Sultan (2010) applied an autoregressive distributed lag cointegration method in analyzing the short-run and long-run price and income elasticities of gasoline demand in Mauritius. ARDL method can be applied to the model without testing the variables on stationarity. The short and long-run price elasticity were found at the levels -0,21 and -0,44 respectively, and short and long-run income elasticity were estimated 0,37 and 0,77, indicating the gradual growth economic welfare in the country which leads to an increase of demand for driving. The obtained ECM coefficient, which equals -0,48, meaning that 95% of the changes in consumption take place during five periods. The author mentions the growing ethanol production from sugar in island, which is blended into gasoline in proportion 95% gasoline and 5% ethanol, can contribute to energy saving to some extent.

Gonzalez-Marrero, Lorenzo-Alegria & Marrero (2011) used dynamic panel data model for estimating gasoline and diesel demand in Spain during the period 1998-2006. They included fuel prices and GDP per capita into the model, and also the traffic jams (the total vehicle stock divided by the total length of road) and the level of motorization, represented by per capita diesel-engine and gasoline-engine fleet. Taking into account the endogeneity and weak instruments problem, they chose one-step system Generalized method of moments (GMM) as an estimation method, they found short-run gasoline price elasticity to be -0,292. Price of diesel as it was found influences gasoline consumption with the coefficient 0,212. As diesel fuel is mostly used in trucks and heavy vehicles, technical characteristics of which are different from passenger cars, that indicates that gasoline and diesel markets should be estimated separately. The diesel consumption price estimates were found insignificant. GDP per capita appeared also to be insignificant for both models. Per capita gasoline fleet estimation coefficient for the gasoline model is 0,639, but per capita diesel fleet is found to be negative -0,083. The coefficients of traffic congestion are -0,059 for gasoline and -0,048 for diesel, which means that the solution of traffic jams problem along with improvement and development of road infrastructure might cause an increase of gasoline consumption.

Havranek, Irsove & Janda (2011) made a review of journal articles where they analyzed price elasticity of gasoline demand estimated by previous researchers. They took into consideration “publication selection bias using the mixed-effects multilevel meta-regression”. It is considered to be an appropriate method for the meta-analysis since it takes into consideration “the unbalancedness of the data” and “allows for nesting multiple random effects” (Havranek, Irsove & Janda, 2011, p.5). As the authors pointed out, obtained positive price elasticities are rarely published, but implausibly large negative price elasticities that might be the result of misspecification error take a considerable place in the transport literature dedicated to the issue of price elasticity research, thus the average published price elasticity estimate is biased downwards. The authors corrected results taking into account positive and unreasonably high negative results and got the mean estimates that are -0,09 for the short-run price elasticity and -0,31 for the long-run obtained from many countries, time periods and applied methods, while the misspecified results were averaged to -0,23 and -0,69, so more than two times higher. The authors came to conclusion that about 40% of all the obtained results on price elasticity were not published, since they were positive or insignificant.

4. U.S. GASOLINE MARKET

Gasoline consumption

According to the data for the period of the year 2010 published by U.S. Energy Information Administration gasoline consumption in the USA constituted 138,6 billion gallons, which means that around 9 million barrels of gasoline was consumed daily. Gasoline consumption in the USA exceeds its consumption in Europe, Asia, Africa and South America combined. Continuing population growth, increasing popularity of sports cars, slow paces of fuel-saving technology development contributed to increase in gasoline consumption, which rose by 243,78% for the 60-years period, from 0,954 billion barrels in 1950 to 3,282 billion barrels in 2010.

Gasoline consumption decreases with more and more widely usage of new advanced technologic vehicles with gasoline engines, designed to use fuel more efficiently. Some analysts predict the subsequent decrease in gasoline consumption, declaring that American gasoline consumption has reached its peak point, and due to wider usage of biofuel, made mostly from corn, gasoline demand will cease its growing. Other forecasters do not believe in decreasing of gasoline demand, referring the growing flow of immigrants and increasing American population. Increasing oil prices and limited oil supplies require the reliable and wise solution in favor of using alternative sources of energy in the nearest future. The scientists see the solution in using ethanol and biodiesel as a substitution to oil-based fuel. All cars produced in the USA since the late 1970s can be filled with ethanol blend, called gasohol. Most of purchased gasoline contains a definite amount of ethanol, which varies from region to region, in most cases ethanol share doesn't exceed 10%. Ethanol contains 33% less energy than gasoline, so the mileage of vehicle declines by 3,3% when using ethanol blended in gasoline in proportion 1 to 9 (U.S. Energy Information Administration).

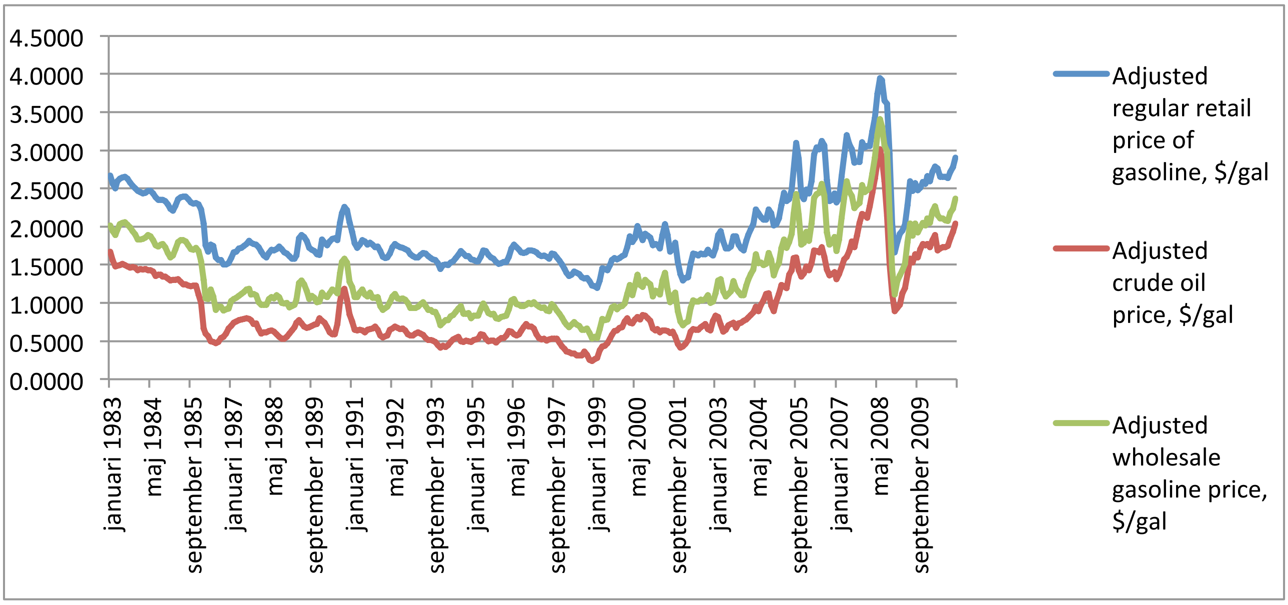
The U.S. government has concerns about growing gasoline consumption. George W. Bush, the American president (2001-2009), in 2007 State of the Union address, called American society for gasoline reduction by 20% till 2017 by declining oil imports from the Middle East region by 75%. He insisted on developing national output of alternative and renewable fuels, reforming fuel economy standards for cars, saving that way up to 8,5 billion gallons of gasoline by 2017. (The Washington Post, 2007).

Dependence on foreign oil

The U.S. domestic oil production cannot meet the increasing amount of gasoline U.S. economy needs, therefore the gap in demand and domestic supply is covered by gasoline import. The USA as the world's largest gasoline consumer, imports about a half of crude oil and petroleum products needed for the economy. The imported crude oil and refined petroleum products constituted 11,8 millions barrels per day in 2010, while net import made up 9,4 millions barrels per day (U.S. Energy Information Administration). The main importers of crude oil and petroleum products are Canada, Saudi Arabia, Nigeria, Venezuela and Mexico. The dependence on oil import started reducing since 2005. Wider consumption of biofuel (ethanol and biodiesel) and rapid development of domestic oil fields increased domestic supply and shortened the imports.

Oil price affects gas price

Gasoline price consists of four main components: crude oil price, federal and state tax, refinery costs and their profits, transportation and distribution costs and profits of gas stations. Crude oil is the main component that influences gasoline price in a most significant way. Most of gasoline price spikes can be explained by high crude oil prices, which rise due to civil unrest, war, terrorism, labor strikes, and also due to increasing demand on oil products in the whole world. If a crude oil price goes up, it causes an immediate response of gasoline price, if oil prices go down, a decrease in gasoline prices is coming very slowly. A $1 increase in price for a barrel of oil raises a price for a gallon of gasoline by 2,5 cents on average (Rosenberg, 2010). Gasoline prices follow crude oil prices, the difference between wholesale prices and crude oil prices reflect refinery costs and profits and the difference between wholesale gas price and retail price reflect the distribution costs, price markups of retailers and taxes. The more the gap between the prices the higher profits get the refiners or sellers. The correlation between oil and gasoline prices on the U.S. market we can observe on the graph 4.1. We clearly see that when crude oil price increases sharply, gasoline prices soar in response, making a pattern.



Graph 4.1 The interrelation between crude oil and gasoline prices

Gasoline taxes

European gasoline prices are 2,2 times higher than American, exactly low gasoline prices and American living style makes the USA the biggest gasoline consumer-country in the world. Though the raw gasoline price is pretty much the same as European, high European fuel taxes contribute to higher price of gasoline. According to Europe's energy portal recent data the highest gasoline prices among European countries were in the Netherlands and Denmark and made up 1,660 and 1,652 euros per litter correspondingly which constituted 8,633 and 8,596 USD per gallon, comparing to average U.S. retail price 3,476 USD per gallon. For every consumed litter of gasoline the Dutches have to pay the excise taxes of 0,769 euro per litter or 3,75 USD per gallon and VAT of 0,268 euro per litter or 1,31 USD per gallon, comparing to the U.S. average tax rates 40,34 cents per gallon, which makes around 11,2% of the pump price. American tax rate on gasoline consists of Federal tax 18,4 cents per gallon, which wasn't changed since 1997, and state tax averaged to 22,68 cents, with the highest total tax rate in the state of Washington equals 55,9 cents and the lowest in Georgia 25,9 cents per gallon. Low gasoline taxes make USA one of the cheapest places to fill a tank of a car, which contributes to high gasoline consumption. (U.S. Energy Information Administration)

Supply disruptions and their effect

Price is also defined as a market equilibrium price through the balance in demand and supply. Suppliers define prices based on current and anticipated demand, gasoline stock helps suppliers to satisfy consumers' need in gasoline when the volume of produced or imported gasoline doesn't respond to increasing demand in it.

Temporary disruptions of gasoline or oil supply shift gasoline prices upward. In August 2005, after hurricanes Katrina and Rita, which caused much damage to several U.S. states, destroyed oil and gas platforms, damaged gas pipelines, many motorists were left without gasoline and gasoline prices soared over $3 per gallon in response of oil supply failures. Due to oil production stoppages, difficulties in gasoline distribution, gasoline shortages at fill-up stations, gasoline retailers had to raise the prices. In fear to be left without gasoline, drivers began topping their tanks, which provoked higher demand for gasoline in different areas of the country and created gas lines. Dramatic price rise is explained by market reaction as the only possible way to respond on supply shortage and the only way to restrain drivers from driving more, in this case all government attempts to take control over prices would only discourage producers. (Mouawad, 2005). So soared prices were the result of oil supply disruptions, caused by natural disaster and as soon as supply stabilized, gas prices went down.

Share of income spent on gasoline

If we consider how much money an American driver spends on gasoline and which share of his budget gasoline occupy, we will obtain that an average American spent on average 3,5% of his annual income for gasoline. Visually we can see how shares of income spent on gasoline changed during the period 1984-2008 on a chart 4.2:

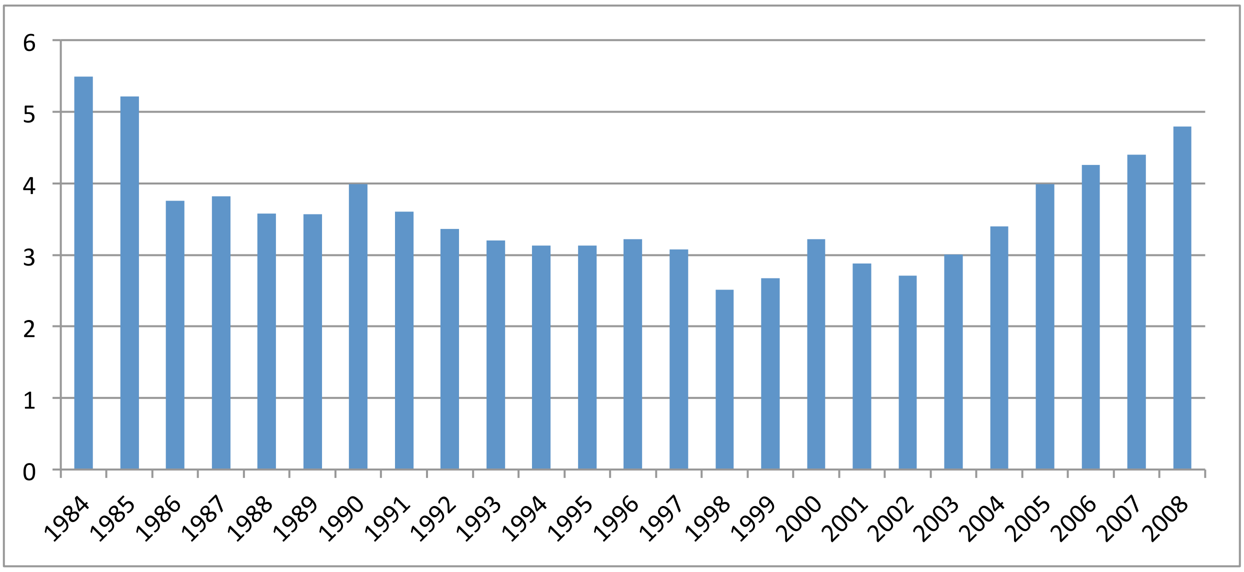


Chart 4.2 Percentage of gasoline expenses in personal incomes

5 METHODOLOGY

5.1 Econometric models

The estimation of demand for energy might be problematic, since energy is a "derived demand", not final, as it is needed in a combination with other means to bring utility to a consumer. (Nordhaus, 1975). This means that the factors that influences its demand, define the demand for final products, like traveling. A lot of studies were dedicated to the problem of gasoline demand estimation and new estimation techniques and new models were developed within time. The econometric models which are considered in this paper are based on the previous researches of the issue of gasoline demand. The standard variables that have an impact on gasoline demand are gasoline price and personal incomes. Some previous studies of gasoline demand use cross sectional and panel data models and some studies base their analysis on time-series data. Depending on the data type, different methodologies and estimation procedures can be applied. In this paper we will consider annual time series data to estimate the U.S. gasoline market for the period 1984 to 2010. Since traditional procedures as OLS are considered to be inappropriate in estimating demand equations, as they might produce a bias, we will apply two stage least square method to estimate simultaneous equations of demand and supply and cointegration method.

Based on the law of demand, we know that price increase on a good leads to a decrease in demand. The same rule can be applied to gasoline market. Earlier researchers estimated demand for gasoline using “flow adjustment model”, assuming that gasoline demand in current period depends on gasoline price, personal incomes and gasoline consumption in the previous period. (Burricht & Enns 1975).

As the main determining factors that affect gasoline demand we can distinguish:

Price of gasoline is the key factor that has an impact on gasoline consumption, as an increase in gas price makes motorists to drive less;

Income also affects gasoline demand, first its growth leads to an increase in automobile ownership and second growing economic prosperity of society stimulates people to travel and to drive more, using less public transport;

Fuel efficiency of vehicles is also important in explaining gasoline demand, since car manufacturers striving to attract more clients have to improve the vehicles they produce, equipping them with more fuel efficient engines, that contributes to gasoline saving.

An increase in **car sales and automobile ownership** causes gasoline consumption increase. Since gasoline demand is dynamic, as there is a time delay between changes of its determining factors and fuel consumption response to these changes, the inclusion of **demand lag** is the necessary variable in gasoline demand model.

All the variables used in the model were logged for better precision of demand elasticities.

The final model, which will be estimated using cointegration method, has the following view:

Model A

$$lnQd_t = \beta_0 + \beta_1 lnP_t + \beta_2 lnY_t + \beta_3 lnFec_t + \beta_4 lnV_t + \beta_5 lnQd_{t-1} + ut_1$$

where Qd_t is gasoline consumption in year t per capita;

P_t is real retail gasoline price per gallon including taxes in year t, in dollars;

Y_t is real disposable annual income in year t, in dollars;

Fec_t is fuel efficiency of vehicles in year t, miles per gallon;

V_t is vehicle stock in year t on the U.S market;

ut_1 is error term.

Although the objective of this paper is to estimate fuel demand, we should specify the supply side of the market, which will enable us to estimate the elasticities of gasoline demand more precisely, applying simultaneous equations method. The simultaneous equations system (SEM) in this paper is given by demand and supply functions.

Demand equation in the SEM is specified the same way as in model A. Supply equation includes gasoline price, world oil consumption per capita and time trend, which represents the technological progress.

Model B

$$\ln Qd_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln Y_t + \beta_3 \ln Fec_t + \beta_4 \ln V_t + \beta_5 \ln Qd_{t-1} + ut_1$$

$$\ln Qs_t = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \ln WoilQd_t + \gamma_3 Tt + ut_2$$

where Qs_t is gasoline supply in year t;

$WoilQd_t$ is world consumption of crude oil per capita;

Tt is time trend;

ut_1, ut_2 are stochastic disturbances, which represent measurement error

We assume that Qd_t and P_t, as well as Qs_t are the endogeneous variables, while income, fuel efficiency, vehicle stock and consumption lag are treated as predetermined for demand equation, world consumption of crude oil per capita, time trend are exogeneous variables. Since the equations are over-identified by counting rule, we will apply 2SLS procedure to estimate the parameters of demand equation.

We expect the following signs in regression: $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$, $\beta_4 > 0$, $\beta_5 > 0$.

Many additional variables that explain fuel demand might be included in equation, like taxation of new cars, share of driving population, the rate of unemployment, quality of public transport infrastructure, etc, but we will focus on main widely-used only.

5.2 Data description

In this paper we use annual dataset for the time period from 1984 to 2010. The data on gasoline consumption, retail gasoline prices, fuel efficiency and world oil consumption are taken from U.S. Energy Information Administration (EIA). Annual personal disposable income data is from U.S. Bureau of Economic Analysis. U.S. population data was taken from the U.S. Census Bureau. Gasoline prices and per capita disposable incomes were adjusted to real (2010) dollars with the CPI index. Gasoline taxes were taken from U.S. Department of Transportation. The data on number of registered vehicles are from Bureau of Transportation statistics. Per capita gasoline consumption was obtained dividing the total consumption by the total population, the same technique was used for obtaining vehicle ownership per capita.

5.3 Estimation methods

5.3.1 Simultaneous equations

Most previous researchers ignored the issue of price endogeneity, considering single equation models where gasoline demand was presented as a function of explanatory variables. Kenan (1988) pointed out that there might be a correlation between the price and the stochastic error term in an individual demand equation, even if consumer has a negligible impact on the market price. Therefore considering price exogeneous might produce biased coefficients. We will focus in this section on simultaneous equation model (SEM). Each equation presented in SEM explains how individuals respond to shifts in the exogenous variables, all other conditions being equal. The variables are assumed to be determined only when the model is in equilibrium. As an example demand curve reflects the range of price which corresponds to the quantity demanded, but under the market equilibrium when demand equals supply, there will be only one equilibrium price which will correspond to the definite quantity (Wooldridge, 2009). The market clearing mechanism generates the necessity of estimating demand and supply equation as simultaneous equation model. The idea of such approach is that not only explanatory variables in the model have an impact on dependent variable, but also the dependent variable might have an effect on some explanatory variables and the aim of this approach to take into account such effect. Simultaneous equation system consists of two or more equations, each of them contains jointly endogeneous variables (Gujarati and Porter, 2009, p.673-75). In this system the explanatory variables of each of equations cannot be estimated separately, ignoring the other equations. Since the procedure of estimation of equations infers that the explanatory variables are independent of their error terms, estimating each of equation separately, one undertakes the risk of obtaining the parameters of equation which would be biased and also inconsistent. Gujarati and Porter (2009) examplified that considering the system of demand-supply simultaneous equations:

$$Qd_t = \alpha_1 + \alpha_2 P_t + ut_1$$

$$Qs_t = \beta_1 + \beta_2 P_t + ut_2$$

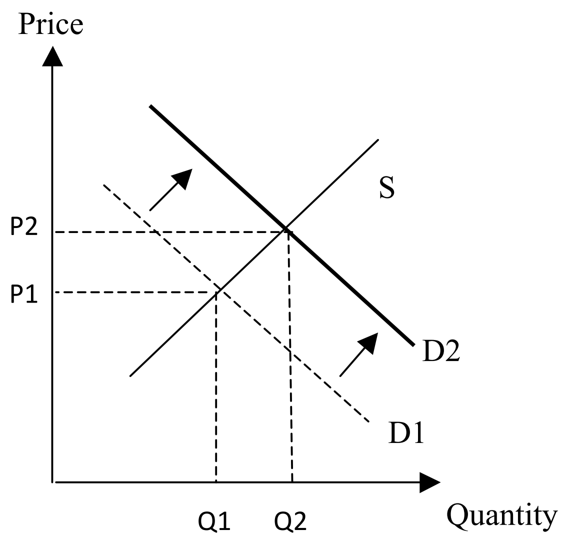
where Qd_t, Qs_t are demand and supply respectively;

P_t is a price of good;

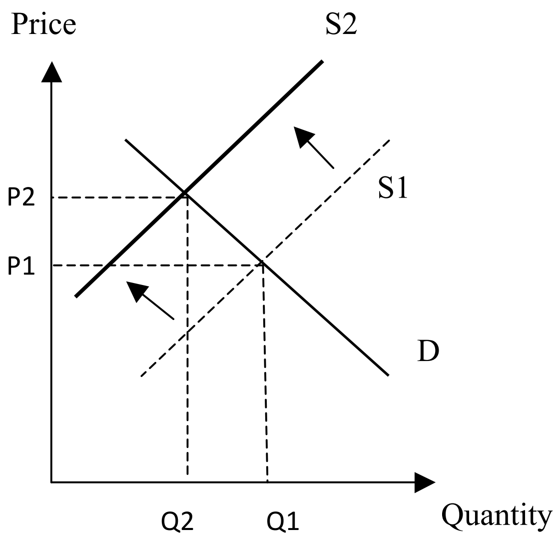
ut_1, ut_2 are stochastic disturbance terms.

Market price and quantity demanded and supplied are considered as jointly determined variables.

According to the law of demand and supply the market price is determined by demand and supply quantity. The changes of other explanatory variables that determine demand, like income, tastes, will change stochastic disturbance term ut_1. By negative ut_1, the demand will decrease and positive ut_1 will make the demand increase. By the same token, changes in ut_2 due to import/export changes or other factors that have an impact on supply, will cause changes in supply. These changes can be illustrated on a graph for visual effect. On a graph 5.1 we see that positive stochastic term ut_1 causes the demand curve to shift upward and price will increase together with the demand. Graph 5.2 shows that changes in ut_2 will also cause the supply curve to shift, which will make the price change, which is shown on the graph.



Graph 5.1 Shift of demand curve due to increase in stochastic term ut_1



Graph 5.2 Shift of supply curve due to decrease in stochastic term ut_2

Due to this mutual interdependence between demand and price, price will be correlated with stochastic terms ut_1 and ut_2, consequently the demand equation cannot be estimated individually without taking into account the supply side, otherwise it will produce inconsistent estimates. Because of correlation between error terms and price, OLS estimates become biased. Kenan (1988, p.8) examplified in his study paper that in the case when the market supply is elastic at a random price that does not correlate with the demand shocks, the regressing demand or supply on price will produce consistent estimate for demand equation and bias will tend to zero. But this can be the case only if market supply is infinitely elastic, which is in real world where competition rules, is practically unrealistic. In a competitive world price is jointly determined by demand and supply, therefore price, quantity demanded and quantity supplied are dependent variables and small fluctuations in supply or demand will lead to small shifts in price, which will inevitably cause simultaneity bias.

An ideal instrument variable to determine gasoline demand is that one that would be highly correlated with gasoline price but not with unobserved shocks of gasoline demand. Ramsey, Rasche & Allen (1975) defined the relative prices of other refinery products like kerosene and residual distillates as instrumental variables. Hughes, Knittel and Sperling (2007) criticized this approach suggesting that the prices of refinery products might be highly correlated with gasoline demand shocks via the price of crude oil. The authors suggested using crude oil production disruptions of Venezuela, Iraq and the USA as instrumental variables.

The demand-supply model which will be considered in this paper is specified as the following. As it was already mentioned, we relate demand side to gasoline price, and additional factors that might have an impact on gasoline demand: personal income, fuel economy and the demand in the previous period. Supply equation is defined as a function of gasoline price, world oil consumption and time trend. If the market clears, demand equals supply, so we can equalize the two equations. Since OLS method is considered to be inappropriate, we will try to use instrumental variables technique. As both equations are overidentified we will apply Two stage least square method for the consistent estimation of the parameters of equation. Since the purpose of this paper is to estimate demand elasticities, we will focus on demand equation only.

Two-stages least squares (2SLS)

2SLS method assumes that there exist instruments, which are correlated with the endogeneous explanatory variable but not with the disturbance term. This method suggests that the endogenous variables on the right-hand side of each equation are instrumented with the predetermined variables from all other equations. If we consider the demand-and-supply system of equations:

$$Qd_t = \alpha_0 + \alpha_1 P_t + \alpha_2 K_t + ut_1$$

$$Qs_t = \beta_0 + \beta_1 P_t + \beta_2 M_t + ut_2$$

where K_t and M_t are exogeneous variables and ut_1 and ut_2 are error terms.

Price will be regressed on the instrumental variables, and then its predicted value will be used in place of its actual value when estimating demand and supply equations. To estimate the parameters of demand equation one should do the following things:

1) To regress endogeneous variables on the exogeneous variables in the whole system:
   $P_t = \gamma_0 + \gamma_1 K_t + \gamma_2 M_t + ut_1$
   and obtain predicted value of $\widehat{Pt}$
2) To estimate the structural parameters one regresses original demand equation, replacing endogeneous variable P_t with predicted value $\widehat{Pt}$
   $Qd_t = \alpha_0 + \alpha 1\ \widehat{Pt} + \alpha_2 K_t + ut_2$
   Thus obtained predicted value $\widehat{Pt}$ doesn't correlate with stochastic error term ut_2 and obtained parameters estimates will be unbiased and consistent, and what is more important efficient.

5.3.2 Partial adjustment model (PAM)

There are several methods in econometric literature to distinguish long and short estimates. One of them is the partial adjustment model, developed by Marc Nerlove. The model contains lag of dependent variable.

To apply this method one should derive the coefficients of parameters from the original model and divide them by the expression of unity minus lagged dependent variable. Since the long-run estimates adjust to the equilibrium within time, the considered approach releases long-run estimates.

$$Y_t = \delta\alpha_0 + \delta\alpha_1 X_t + \delta\alpha_2 Z_t + (1-\delta)Y_{t-1} + \delta u_t \qquad (5.1)$$

In other words, the model (5.1) produces the short-run estimates $\delta\alpha_0$, $\delta\alpha_1$, $\delta\alpha_2$. The adjustment coefficient δ measures the speed of adjustment, which assumes the values from 0 to 1. Long-run relationship implies that the equilibrium is completely reached and the coefficients of elasticities show the magnitude of total adjustment towards an equilibrium. Long-run estimates can be obtained by diving short-run estimates by the coefficient of adjustment δ. Thus, long-run estimates for X and Z variables are calculated as $\frac{\alpha 1}{\delta}$ and $\frac{\alpha 2}{\delta}$ respectively.

5.3.3 Cointegration technique

Regressing non-stationary variable on other non-stationary might give spurious results, unless there is cointegration relationship between variables. When time series individually are found to be integrated of the same order, say I(1), but their linear combination is of lower order, I(0), they are said to be cointegrated, and the regression results of such combination will not be spurious. If the variables are found to be cointegrated, we can expect a statistically significant long-term relationship between them. So if the variables in a model tend to have some long-term relationship, test on cointegration will allow us to find it out. Sorensen (1997) gives the definition of cointegration if two time series Xt and Yt integrated of order one I(1) they are cointegrated if there exists a parameter α such that

$$u_t = Y_t - \alpha X_t,$$

is a stationary process.

Thus the purpose of cointegration test is to detect and analyze the long-run relationship among time series variables.

To apply the Engle-Granger cointegration test, first, one should run the original regression and obtain the residuals, then test whether residuals of regression have a unit root:

$$\widehat{\Delta u_t} = \beta \widehat{u_{t-1}}$$

Engle and Granger (1987) calculated the critical values for this test. If the residuals are found to be stationary, one can conclude that there is cointegration between the considered variables and cointegrating regression can be estimated with OLS method to get long-run estimates.

5.3.4 Error Correction Mechanism

An application of this method aimed to get the short-run elasticities of a dependent variable and to find the speed of adjustment towards long-run equilibrium. The idea of ECM is that the proportion of the disequilibrium caused by changes in explanatory variables in the current period is corrected in the next period. ECM is a technique that allows to estimate the speed at which a dependent variable reaches the equilibrium in case when the explanatory variables changed.

To derive short–run estimates we include the lagged residuals obtained from long-run regression into equation:

$$\Delta Y = \beta_1 + \Delta\beta_2 X + \beta_3 u_{t-1} + ə_t,$$

where u_{t-1} is lagged value of the residuals from the cointegrating regression;

$ə_t$ is a white noise error term.

We expect β_3 to be negative, implying that the term β_3 u_{t-1} is negative, which means that ΔY must be negative to re-establish the equilibrium, which in turn means that Y will start decreasing in the next period. On the contrary, if u_{t-1} is negative, consequently β_3 u_{t-1} must be positive, which will turn ΔY to have positive sign and Y will be increasing in the period t (Gujarati and Porter, 2009).

If the coefficient of residuals is found to be significant, it implies the existing short-run relationship, and its coefficient will show how the discrepancy between short-run and long-run is corrected within the regarded period, in other words, it shows how short-run variables restore themselves to their long-run equilibrium.

6 ECONOMETRIC PROCEDURES

Several preliminary actions must be done prior to using the times series in econometric analysis. Before an equation can be defined as prepared for estimation, the data must be tested to check for stationarity, autocorrelation, multicollinearity, cointegration and simultaneity. All these tests are detaily described by Gujarati and Porter (2009).

6.1 Test of stationarity

Naturally, time series are non-stationary and might contain a unit root, the use of such data might cause serious econometric problems. Many earlier researches which analyzed demand elasticites, using time series, ignored the possible problem of non-stationary nature of data. But the most recent researchers found the times series used in the demand model to be non-stationary, which means that its mean and variance are non-constant over time, which if employed in estimation procedure might give spurious results and as a result estimates of variables obtained from the regression will be untruthful. There are two types of non-stationary processes: difference stationary, when the times series become stationary after differencing, and trend stationary, when times series are stationary about a deterministic trend. If times series are found to be nonstationary, they must be transformed into stationary before been estimated, so testing on stationarity is a compulsory procedure. To detect unit root problem, ADF test can be applied. The lag length is determined on the basis of Akaike Information Criteria.

6.2 Test of autocorrelation

Since we are dealing with times series it is necessary to check whether the data doesn't suffer from autocorrelation problem. If autocorrelation is found it implies that the error term of the equation is correlated with the error term of the earlier period:

$$u_t = \rho u_{t-1} + e_t$$

If autocorrelation exists in a model, it distorts the regression results, making standard errors lower and correspondingly t statistics larger and also exaggerates R square. Though OLS estimators remain unbiased and consistent, they become no longer efficient. As a consequence, t test cannot be applied to the model.

In this paper we will implement Durbin-Watson test to detect the problem of autocorrelation. Since in autoregressive models with a lag structure Durbin d test might be inappropriate, in such models we will employ Breusch-Godfrey test and Durbin h test.

6.3 Test of Multicollinearity

Multicollinearity implies a linear relationship among some explanatory variables of regression model. If multicollinearity is present in the times series, OLS estimators will be still BLUE, but tend to have large variances and covariances, so that the estimation is becoming less accurate. Since confidence intervals become larger one might accept the wrong hypothesis. Moreover, in the presence of multicollinearity the OLS estimators and their standard errors might vary even if small changes in the data take place. However, multicollinearity does not bias the results, it makes standard errors larger, and consequently t statistics become smaller which make coefficients less statistically significant. So before estimating the regression it is necessary to be confident that independent variables are not correlated with each other.

To test on multicollinearity we employ Tolerance (TOL) and Variance inflation factor (VIF). The decision rule: if TOL is larger than 0,1, and VIF is lower than 10, there is no multicollinearity.

6.4 Test of simultaneity

Considering simultaneous equation model of demand and supply, prior to estimate the parameters in equations, it is necessary to test the model on simultaneity problem. If a variable on the right-hand side and dependent variable mutually affect each other, one can suspect that there is simultaneity in the model. If simultaneity problem is present in the model, implying that an endogeneous variable is correlated with the error term, we cannot apply standard OLS method, instead the two-stage least square method or instrumental variable method must be used to obtain efficient estimators.

Since consumers change their gasoline demand in response to changes in prices and gasoline producers change price in response to changes in demand, gasoline price P_t is assumed to be endogeneous, as it is jointly determined by demand and supply variables through equilibrium mechanism, while other explanatory variables in both equations are treated as exogeneous. Since price being endogeneous, presented as an explanatory variable in equations, we suspect variable P_t to be correlated with stochastic terms ut_1 and ut_2, so we cannot use standard OLS procedure to estimate the parameters of demand equation because of the risk to obtain inconsistent estimates.

We will apply Hausman specification test for testing on simultaneity problem.

7.RESULTS

To estimate the parameters of the models, first we should test them to define whether the data does not suffer from one of the above-listed problems. In this paper we will consider two models to estimate elasticities of demand and as a consequence specific tests should be done for every model before testing.

7.1 The results of testing models

Test of multicollinearity

Table 7.1 Results of multicollinearity test

Variables	TOL	VIF
LnP_t	0,469	2,130
LnY_t	0,030	33,205
$LnFec_t$	0,289	3,456
LnV_t	0,026	38,671
$LnQd_{t-1}$	0,149	6,701

As TOL for income variable and vehicle stock is less than 0,01 and VIF for this variables is greater than 10, the test indicate that these variables are highly collinear, as an increase in income leads to an increase in vehicle ownership, which might bias the other estimates, we should exclude one of variables and run the test again. As the purpose of this paper to estimate price and income elasticities of demand, as the key factor that impact consumer behavior, we cannot exclude income, so we test the demand equation excluding the variable vehicle stock.

As a result we have:

Table 7.2 The results of multicollinearity test after dropping a variable

Variables	TOL	VIF
LnP_t	0,532	1,880
LnY_t	0,123	8,128
$LnFec_t$	0,284	3,517
$LnQd_{t-1}$	0,375	2,664

After excluding vehicle stock as a variable from demand equation, the test of multicollinearity shows that there is no high correlation between the explanatory variables in the model.

Test of stationarity

Table 7.3 The results of ADF test for stationarity

Variables	Number of lags	ADF statistics	Dickey-Fuller Critical Value at 5% level	Conclusion
$LnQd_t$	1	-2,2854	-2,98	Non-stationary
LnP_t	0	-0,9872	-2,98	Non-stationary
LnY_t	0	-0,7942	-2,98	Non-stationary
$LnFec_t$	5	-5,4297	-3,01	Stationary

According to the obtained results, all the variables are non-stationary, except lnFec, which is stationary at 1% level of significance. To make the data stationary, we employ first difference method. We will take the first difference of variable lnFec also, despite its stationarity at levels, to make it of the same order as the other variables.

Table 7.4 The results of ADF test for stationarity after differencing

Variables	Number of lags	ADF statistics	Dickey-Fuller Critical Value	Conclusion
$\Delta LnQd_t$	0	-2,9175	-2,63***	Stationary
ΔLnP_t	0	-5,1965	-3,72*	Stationary
ΔLnY_t	0	-5,2348	-3,72*	Stationary
$\Delta LnFec_t$	0	-3,9713	-3,72*	Stationary

*Significance 1% **Significance 5% ***Significance 10%

After differencing the variables we obtained stationary time series, that can be used for estimation the parameters of regression.

Test of simultaneity for model B

To find out whether endogeneous variable is correlated with stochastic error term we employ Hausman test. As the variables of demand-supply system were found non-stationary and they were differenced, we will consider demand-supply model with differenced variables in our further estimation.

The model will have the following look:

$$\Delta lnQd_t = \beta_0 + \beta_1 \Delta lnP_t + \beta_2 \Delta lnY_t + \beta_3 \Delta\ lnFec_t + \beta_4 \Delta lnQd_{t-1} + ut_1$$

$$\Delta lnQs_t = \gamma_0 + \gamma_1 \Delta lnP_t + \gamma_2 \Delta lnWoilQd_t + \gamma 3 \Delta Tt + ut_2$$

We treat Qd_t , Qs_t and P_t as endogeneous variables and Y_t, Fec_t, $WoilQd_t$, Tt and Qd_{t-1} as exogeneous. P_t is regressed on all the exogeneous variables and from this equation one obtains estimated predicted value $\widehat{Pt}$ and estimated residuals $\widehat{vt}$. The decision rule about simultaneity is: if the coefficient of residuals $\widehat{vt}$ is statistically significant, there is simultaneity problem, implying that endogeneous variable P_t is correlated with the error term ut_1 (Gujarati and Porter, 2009).

1) $P_t = \Pi_1 + \Pi_2 \Delta lnY_t + \Pi_3 \Delta lnFec_t + \Pi_4 \Delta lnQd_{t-1} + \Pi_5 \Delta lnWoilQd_t + \Pi 6 \Delta Tt$,

   thus $P_t = \widehat{Pt} + \widehat{vt}$
2) $Qd_t = C_1 + C_2 \widehat{Pt} + C_3 \widehat{vt} + ut_1$

The results are the following:

$Qd_t = 0{,}001 - 0{,}25\ \widehat{Pt} - 0{,}31\widehat{vt}$

$t \quad = (0{,}210)\ (-0{,}722)\quad (-1{,}039)$

The test shows that the coefficient of residuals is not significant at 10% level of significance, implying that ΔlnPt is not correlated with error term ut_1. These results seem to be implausible, since they contradict the economic theory, which states that the changes in demand due to its other determinants affect the price, so price is assumed to be correlated with the demand shocks as it was discussed in section 5.3.1.

But before we conclude which method must be applied to estimate the parameters of equation more tests should be done. We employ the exogeneity test and proceed as follows:

$\Delta lnQd_t = -0{,}03 - 0{,}031\Delta lnP_t + 0{,}335\Delta lnY_t - 0{,}23\Delta lnFec_t + 0{,}644\Delta lnQd_{t-1} - 0{,}041\widehat{\Delta lnPt}$

$F = 7{,}256 \qquad R\ sq = 0{,}669$

The applied F test proves our assumption that price is endogeneous, since $F > F_{crit.}$ As the price is found to be endogeneous and other right-hand side variables will be treated as exogeneous, so that they do not correlate with ut and vt for the considered period of estimation we will apply 2SLS procedure to obtain the estimates of parameters.

Thus, the purpose of this method is to find structural estimates of demand equation.

7.2 The results of Engle-Granger cointegration method of model A

The main variables of the model A, namely gasoline demand, price and income are found to be integrated of the first order I(1), we can apply cointegration technique to find whether there is a long-run relationship between variables. To obtain long-run parameters we estimate static equation first, namely we test the long-run relationship between gasoline consumption, price and income:

$lnQd_t = \beta_0 + \beta_1 lnP_t + \beta_2 lnY_t + ut_1$

The results of unit root test for residuals ut_1

	Coefficient	*t*	*p-value*
u_{t-1}	-0,39102	-3,57403	0,07545

The p-value indicates that there is long-run relationship between price, income and consumption.

Table 7.5 The cointegrating regression for these variables is the following:

	Coefficient	*Std. Error*	*t*	*p-value*	
const	0,282492	0,432995	0,6524	0,5203	
LnP_t	-0,037292	0,020044	-1,860	0,0751	*
LnY_t	0,205908	0,042469	4,848	0,0000	***

***Significance 1% **Significance 5% *Significance 10%

R sq = 0,4983 Adj. Rsq = 0,4565 Durbin-Watson = 0,3708

Durbin-Watson d indicates the strong positive autocorrelation in the model, the presence of autocorrelation might distort the estimates of parameters and might lead to the erroneous acceptance of the hypothesis of statistical significance of variables. Banerjee, Dolado, Hendry & Smith (1986) as cited in Wadud, Graham & Noland (2009) suggested using a dynamic model in the form of autoregressive distributed lag model to obtain long-run estimates. We will include the lag of dependent variable Qd_{t-1} and will test the cointegration between four variables.

The results of unit root test for residuals ut_1

	Coefficient	*t*	*p-value*
u_{t-1}	-0,96628	-4,41449	0,08358

The p-value is less than 0,1, therefore we reject the null hypothesis about unit root in residuals at 10% level of significance. The residuals are stationary, therefore there is a cointegration in the model.

Table 7.6 Cointegrating regression for model A with the lagged demand variable

	Coefficient	*Std. Error*	*t*	*p-value*	
const	-0,083372	0,30233	-0,275	0,7853	
LnP_t	-0,034629	0,01335	-2,593	0,0166	*
LnY_t	0,049423	0,03877	1,275	0,2157	
$LnQd_{t-1}$	0,830223	0,12609	6,584	0,0000	***

***Significance 1% **Significance 5% *Significance 10%

R sq = 0,8188 Adj. Rsq = 0,7941 Durbin-Watson = 1,097

As we see Durbin-Watson coefficient is in zone of indecision, therefore we cannot treat the obtained estimates as true and have to use autoregressive error model to get rid from the risen problem. Breusch-Godfrey serial correlation test also testifies the presence of autocorrelation. To correct for autocorrelation we include autoregressive error term AR(1) into the model.

Table 7.7 The estimates of model A after correcting for autocorrelation

	Coefficient	*Std. Error*	*t*	*p-value*	
const	-0,746751	0,724230	-1,031097	0,3148	
LnP_t	-0,050787	0,016983	-2,990480	0,0072	***
LnY_t	0,155839	0,090790	1,716476	0,0982	*
$LnQd_{t-1}$	0,649946	0,243973	2,664005	0,0149	**
AR(1)	0,624946	0,255731	2,443767	0,0239	

***Significance 1% **Significance 5% *Significance 10%

R sq = 0,8813 Adj. R sq = 0,8575 Durbin-Watson = 1,8212

As a result we resolved the problem of autocorrelation, the obtained Durbin-Watson statistics and Breusch-Godfrey test proves that, so the estimates of the above regression have a valid inference. Since static model is the long-run consumption function, inclusion of lagged dependent variable tends to produce the short or intermediate-run results. To get the long-run

estimates as an option we can use the partial adjustment model, dividing price and income elasticities by the difference between unity and the coefficient of lagged dependent variable.
The long-run demand estimates of model A:

$$P_t^L = -0{,}0781$$

$$I_t^L = 0{,}2397$$

7.3 The results of ECM of model A

To estimate short-run effect we can use Error Correction Model (ECM).

Including lag of residuals from cointegrating regression into the model with the first-differenced time series, we obtain the short-run estimates.

Table 7.8 The results of ECM for model A

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	-0,005629	0,00312405	-1,8020	0,08744	**
ΔP_t	-0,028247	0,0144543	-1,9542	0,06555	**
ΔY_t	0,498702	0,168186	2,9652	0,00795	***
ΔFec_t	-0,093897	0,104447	-0,8990	0,37991	
ΔQd_{t-1}	0,791813	0,244292	3,2413	0,00430	***
u_{t-1}	-0,574276	0,273903	-2,0966	0,04964	***

***Significance 1% **Significance 5% *Significance 10%

R sq = 0,6431 Adj. Rsq = 0,5492 Durbin-Watson = 1,8977

Conclusions:

- Short-run gasoline demand elasticity with respect to price is found to be inelastic and is equal to -0,028, implying that an increase of gasoline price by 10% decreases gasoline demand by 0,28%;
- Gasoline demand elasticity with respect to income is inelastic and equals to 0,498, meaning that 10% increase in personal income will cause an increase in gasoline demand by 4,98% in the short-run;
- Price elasticity in the long-run is found to be -0,0781, which indicates that price increase of gasoline by 10% will lead to a decrease of gasoline demand by 0,78%;

- Long-run income elasticity is 0,239, which implies that demand for gasoline is inelastic in the long-term period and an increase in personal incomes of U.S. citizens by 10% will increase gasoline demand by 2,39%.

The lagged residuals are significant at 5% level of significance, implying that demand for gasoline does not move too apart from its equilibrium and reached it in the long run. The estimated coefficient -0,574 shows the speed of adjustment, meaning that about 57,4% of discrepancy between short and long-run is corrected within a year.

7.4 The results of 2SLS of model B

We develop and estimate the following demand-supply system which is based on annual U.S. time series data:

$$\ln Qd_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln Y_t + \beta_3 \ln Fec_t + \beta_5 \ln Qd_{t-1} + ut_1$$
$$\ln Qs_t = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \ln WoilQd_t + \gamma 3Tt + ut_2$$

To define the appropriate method that can be applied to the considered system of equations, we must first consider identification problem, the details of its solution are presented in appendix of this paper. As the equations are found to be overidentified, we apply 2SLS method.

The variable $\ln WoilQd_t$ was found non-stationary in levels, so had to be differenced to become stationary.

Table 7.9 The results of 2SLS for model B

	Coefficient	*Std. Error*	*z*	*p-value*	
const	-0,00514	0,003405	-1,510	0,1310	
ΔP_t	-0,05476	0,032794	-1,670	0,0949	*
ΔY_t	0,392041	0,206706	1,897	0,0579	**
ΔFec_t	-0,047712	0,121598	-0,3924	0,6948	
ΔQd_{t-1}	0,664763	0,258912	2,568	0,0102	***

*** Significance 1%; ** Significance 5%; * Significance 10%

R sq = 0,597 Adj.Rsq = 0,512 Durbin-Watson = 2,099

All variables possess theoretically appropriate signs and are statistically significant, except fuel economy, which wasn't found significant at 10% level of significance. But since this variable is related to the considered model according to the economic theory, we will keep it in the model. The Durbin-Watson coefficient equals 2,099 shows that there is no indication of autocorrelated disturbances.

However 2SLS procedure might produce not proper estimates of the true standard errors and usually they require correction, but since the R square of the first-stage regression was found high enough 0,563, which is close to the R square obtained in the second regression, we are allowed conclude that the true predicted $\widehat{Qdt}$ is pretty close to the true Qd_t and hence the obtained standard errors are close to the true ones and do not need to be corrected. Sargan χ^2 test validated the choice of instrumental variables. Thus obtained estimates of gasoline demand can be treated as true and efficient.

7.5 The results of PAM of model B

Long-run demand elasticities for model B derived from short-run equation using PAM:

$$P_t^L = -0{,}163$$

$$I_t^L = 1{,}164$$

Conclusions:

- Short-run gasoline demand elasticity with respect to price is found to be inelastic and is equal to -0,054, implying that an increase of gasoline price by 10% decreases gasoline demand by 0,54%;
- Gasoline demand elasticity with respect to income is inelastic and equal to 0,392, meaning that 10% increase in personal income will cause an increase in gasoline demand by 3,92% in the short-run;
- Price elasticity in the long-run is found to be -0,163, which indicates that price increase on gasoline by 10% will lead decrease for gasoline demand by 1,45%;
- Long-run income elasticity is 1,164, which implies that demand for gasoline is elastic in the long-term period and an increase in personal incomes of U.S. citizens by 10% will increase gasoline demand by 16,4%.

Table 7.10 Comparison the results of two econometric methods

	Cointegration (Engle-Granger)		Two stage least square method	
	Long-run	Short-run	Long-run	Short-run
Price	-0,078	-0,028	-0,163	-0,054
Income	0,239	0,498	1,164	0,392

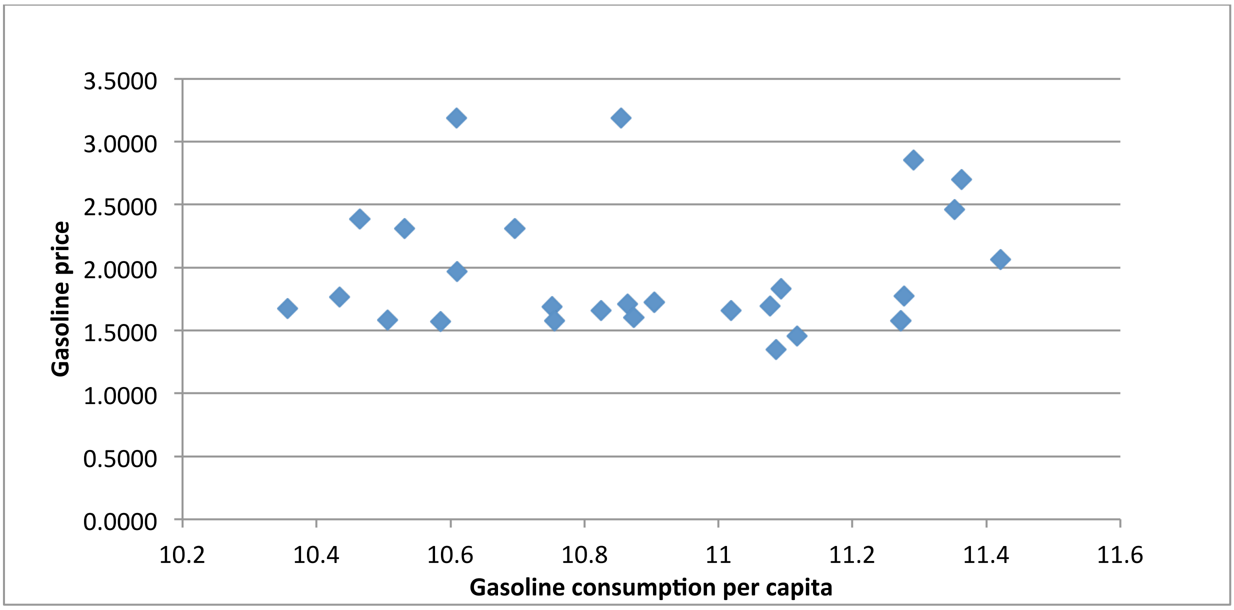
In this paper we wanted to demonstrate the application of the two methods for gasoline demand estimation. The obtained price elasticities from the two methods suggest that consumers are more price-elastic in the long-run, than in the short-run, however the price coefficients are found to be significant in both methods, the magnitude of coefficients are small enough, which means that changes in gasoline prices do not influence consumer decision of driving much. 2SLS method and partial adjustment model produced the higher coefficients of price in the short and the long-run, than cointegration method. The results from 2SLS indicate that long-run income elasticity is larger than short-run, which is more consistent with the theory. The long-run estimate for income from cointegration test on the contrary is lower than the short-run ones, suggesting that changes in personal incomes arouse an immediate reaction of U.S. drivers and they are ready to spend more on driving and travelling. But an income rise in the long-run turned to be a worse incentive in stimulating consumers to increase miles driven and people tend to dispose their risen earnings on buying another goods. The reason of such results on income elasticity might be the exclusion of vehicle ownership when estimate short-run elasticities, which according to the economic theory belongs to the gasoline demand model. This, as it is pointed out in the study of Espey (1998), might magnify income estimates. The results of model B largely depend on the choice of instrumental variables, since Sargan χ^2 test approved the choice of instrumental variables, we are allowed to consider the obtained estimates to be truthful, but the choice of other instruments might have given different results. The final estimated model A doesn't suffer from multicollinearity, autocorrelation, but the limitation of the applied approach is that it neglects the issue of endogeneity of price, which might have led to biases in estimates.

8. COMPARISON OF THE RESULTS WITH THE PREVIOUS STUDIES

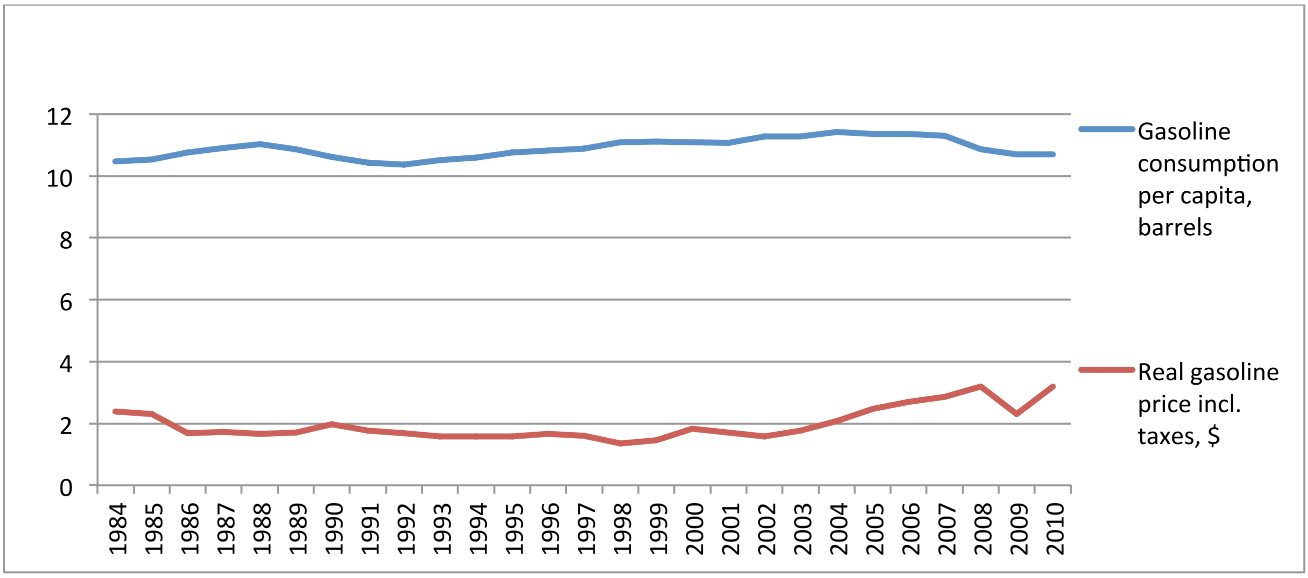
Price elasticities obtained in this paper in the short and long-run are somewhat lower than the previous researchers reported. However in the study of Hughes, Knittel & Sperling (2007) the estimated short-run price elasticities fall in the range from -0,034 to -0,077 for the period 2001-2006, which are similar to our results. Wadud, Graham & Noland (2009) using cointegration Engle-Granger estimation technique defined short- and long-run elasticities to be -0,065 and -0,102, which are also quite close to our results. Espey (1998) in her meta-analysis of elasticities defined that price elasticity fall in the range from 0 to -1,36 with the median value -0,23 in the short-run and in the long-run price elasticity varies from 0 to -2,72 with the median -0,43. Havranek, Irsova & Janda (2011) in their research concluded that the published results on gasoline price elasticities are somewhat exaggerated, as the studies that found price elasticity positive or insignificant usually are not published. The results that we obtained testify that price effect is almost negligible and price increase hardly influences gasoline consumption. If we plot a graph 8.1, depicting interrelation between gasoline consumption and gasoline price, we can observe that higher gasoline price do not stimulate motorists to buy less gasoline considerably and gasoline consumption is not very responsive to price changes. If we illustrate the demand and price changes over the time we can see, that during the last two years gasoline consumption went down, despite the decrease and subsequent increase of gasoline price (graph 8.2). As the previous researchers reported, the responsiveness of gasoline demand to the changes in prices is found to be lower in the United States than in other OECD countries, since the price rises do not affect consumers' budget significantly, as we indicated in the section 4, the expenditures on gasoline constitutes only 2,5 to 4% of an income of an average U.S. consumer, so an increase in prices do not stimulate U.S. drivers to refuse from their habits to drive and have a little effect. Considering the fact that the highest U.S. average retail price of gasoline was observed at the mark of 4,11 USD per gallon in July 2008 (U.S. Energy Information Agency), while the average gasoline retail price for EU countries are at the level of 7,63 USD per gallon (Europe Energy Portal), even a substantial increase in gasoline prices do not effect gasoline demand considerably. The U.S. drivers are more dependent on cars in their daily life than consumers in other countries. More and more Americans prefer to reside in suburbs, that requires driving longer distances to work and besides not properly developed public transportation favor higher gasoline consumption.

Long-run income elasticity is lower than the short-run according to cointegration method, which differs from most previous studies which reported the opposite. However, Altiney (2008) investigating the Turkish oil market found the long-run income elasticity equals to 0,607 which is lower than short-run income elasticity with the value 0,635.

To estimate gasoline demand different econometric techniques and methods were applied, every approach has its strong sides and drawbacks, therefore the obtained results might differ considerably. The difference in results between our paper and previous studies can be explained by the statistical technique, variables included in the model and dataset along with the estimated period and also considered countries used by previous researchers. Given the relatively short sample, the obtained results can be applicable to the considered time period, but cannot be extrapolated to another time period.



Graph 8.1 Interrelation between gasoline price and gasoline consumption



Graph 8.2 Annual gasoline price and demand

9. CONCLUSIONS

The study attempts to estimate gasoline demand in the USA with the help of two methods: instrumental variable method and cointegration and the error correction method, using annual national time series data for the period 1984-2010. As the key factors that influence gasoline consumption were chosen gasoline retail price and personal income adjusted to inflation.

Two-stage least square method was used to correct the possible endogeneity of price variable. Engle-Grager cointegration test revealed the long-run relationship between gasoline demand, price, income and the gasoline consumption in the previous period. Using ECM, short-run elasticities of the model were found. The results of both tests found price and income to be of right signs and statistically significant.

Gasoline price elasticities are found to be inelastic and extremely low, not only in the short-run, but also in the long-run: the short-run price elasticities vary from -0,028 to -0,054, while the long-run price elasticities are in the range from -0,078 to -0,163, which is lower than most of previous researchers reported. But if income rises, the share of gasoline expenditures in consumer's budget decreases and a consumer becomes less responsive to price changes. (Hughes, Knittel, Sperling, 2007). The gradual improvement of vehicle fuel economy by more than 30%, which rose from 17,4 miles per gallon in 1984 to 22,7 miles per gallon in 2010 (U.S. Energy Information Agency), may also further the low demand sensitivity to gasoline price increase. The results of income elasticities are rather vague, since the two methods gave us different results: according to cointegration method long-run income elasticity is lower than the short-run, while 2SLS methods indicate the opposite. In whole, short-run income elasticities vary from 0,392 to 0,498, while long-run income elasticity is in the range from 0,239 to 1,164. The low coefficient of income elasticity in the long-run obtained using cointegration technique means that when a consumer gets a raise in payment, he might want to change the public transportation to driving a car to work, supermarket, travelling, etc, or to drive more than he used to, but in the long-run he prefers buying another goods (property, car, electronic devices) or making investment instead of increasing miles driven. It also indicates that consumers probably are more responsive to increase in income, than to its decrease. Income changes have more effect on gasoline consumption for consumers with rather low incomes, since people with very high incomes are less likely to change their consumer behavior. High incomes and low gasoline prices that are observed in the USA make consumer less price sensitive.

The error correction term is significant and equals 0,574, implying that gasoline consumption adjusts towards the long-run equilibrium with approximately 57,4% of adjustment taking place during the year.

The previous researchers pointed out the three common consumer responses to gasoline price increase: driving less, reducing speed of driving, or change the characteristics of a car, namely to purchase more fuel-efficient car. The first two take place in the short-run, while purchasing more fuel efficient vehicle can be done only in the long-run.

High gasoline consumption can be explained by relatively low gasoline taxes and prices, the preferences of U.S. citizens to reside in suburbs and poor development of public transportation.

We dare to assume that considering the last tendencies on the gasoline market in the United States, the level of gasoline consumption will most probably remain high. Such high demand for gasoline should serve a powerful incentive for the scientists to search actively for the alternative sources of energy. The very low price elasticity coefficients might stimulate the U.S. government to review the taxation policy as a possible instrument to restrain growing gasoline demand.

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Europe's Energy Portal

Bureau of Transportation statistics

U.S. Bureau of Economic Analysis

U.S. Census Bureau

U.S Department of Transportation

U.S. Energy Information Agency

APPENDIX

Identification test for model B

$\Delta lnQd_t = \beta_0 + \beta_1 \Delta lnPt + \beta_2 \Delta lnYt + \beta_3 \Delta\ lnFec + \beta_4 \Delta lnQd_{t-1} + ut1$

$\Delta lnQs_t = \gamma_0 + \gamma_1 \Delta lnPt + \gamma_2 \Delta lnWoilQd + \gamma 3Tt + ut2$

To identify the model, we apply the order condition for identification (Gujarati & Porter, 2009):

If $K - k < m - 1$, the equation is underidentified,

If $K - k = m - 1$, the equation is just identified,

If $K - k > m - 1$, it is overidentified.

where m : number of endogenous variables in a given equation;

K : number of predetermined variables in the model, including intercept;

k : number of predetermined variables in a given equation.

In the model A there are: K = 5, kd=3, ks=2, md=2, ms=2

Demand equation: 5 –3 =2> 1 = 2-1 is overidentified;

Supply equation: 5 – 2 = 3 > 1 = 2-1 is overidentified.

For more accurate results of identification problem we can use reduced-form coefficients. Considering market condition of equilibrium, when demand is equal to supply, we get:

$\alpha_0 + \alpha_1 lnPt + \alpha_2 lnYt + \alpha_3 lnFec + \alpha_4 lnQd_{t-1} + ut1 = \beta_0 + \beta_1 lnPt + \beta_2\ lnWoilQd + \beta_3 Tt + ut2$

If we solve this equation to define price we get:

$lnPt = \Pi 0 + \Pi 1 lnYt + \Pi 2 lnFec + \Pi 3 lnQd_{t-1} + \Pi 4 lnWoilQd + \Pi 5 Tt + vt$,

Thus we expressed endogeneous variable as a function of exogeneous variables. By algebraic manipulations, we derive the associated reduced form coefficients:

$\Pi 0 = \frac{b0-a0}{a1-b1} \quad \Pi 1 = \frac{-a2}{a1-b1} \quad \Pi 2 = \frac{-a3}{a1-b1} \quad \Pi 3 = \frac{-a4}{a1-b1}$

$\Pi 4 = \frac{b2}{a1-b1} \quad \Pi 5 = \frac{b3}{a1-b1} \quad vt = \frac{u2t-u1t}{a1-b1}$

If we substitute obtained price into supply equation we will get the following equation:

$Qs = \Pi7 + \Pi8 \ln Yt + \Pi9 \ln Fec + \Pi10 \ln Qd_{t-1} + \Pi11 \ln WoilQd + \Pi12 Tt + vt$

$$\Pi7 = \frac{a0b1 - a1b0}{a1 - b1} \quad \Pi8 = \frac{-a2b1}{a1 - b1} \quad \Pi9 = \frac{-a3b1}{a1 - b1} \quad \Pi10 = \frac{-a4b1}{a1 - b1}$$

$$\Pi11 = \frac{b2a1}{a1 - b1} \quad \Pi12 = \frac{b3a1}{a1 - b1} \quad wt = \frac{a1u2t - b1u1t}{a1 - b1}$$

The initial demand-supply model contains ten structural coefficients α_0, α_1 , α_2, α_3, α_4, β_0, β_1, β_2, β_3, $\beta 4$ and there are thirteen reduced-form coefficients. So we have thirteen equations to estimate ten unknowns, therefore the equations are overindetified and estimates might be not unique.

As we see b1 can be obtained from reduced-form coefficients in two ways:

$$b1 = \frac{\Pi9}{\Pi2} = \frac{\Pi10}{\Pi3}$$

which means that precise and unique estimation of parameters cannot be done and we should use two-stage least square methods, which finds the structural parameters that best fit the reduced-form parameters.

Reduced-form parameters can be estimated by OLS procedure, since exogeneous variables are not correlated with error terms.

The results of previous studies of gasoline demand

Author	Method	Long-run results		Short-run results		Ambigious	
		Price	Income	Price	Income	Price	Income
Burricht & Enns (1975)	GLS	-0,26		-0,64;-0,68			
Ramsey, Rasche & Allen (1975)	TSLS					(private demand) -0,222 (com.demand) -1,03	
Eskeland&Feysioglu (1994)	Instrumental variable	-0,799	0,836	-0,785	0,822		
Johansson&Schipper (1997)	OLS	-0,7	1,2				
Espey (1998)	Meta analysis	-0,43	0,81	-0,23	0,39		
Graham&Glaister (2001)	ECM	-0,6-0,8	1,1;1,3	-0,2;-0,3	0,35;0,55		
Goodwin, Dargay&Hanly (2003)	Survey Time series Cross-section	 -0,71 -0,84		 -0,27 -0,28			
Radchenko & Tsurumi (2004)	TSLS					-0,543	1,685

Brons, Nijkamp, Pels & Rietveld (2006)	Meta-analytical model based on fixed effecr equations					-0,53	
Hughes, Knittel & Sperling (2007)	OLS TSLS Price income interaction, recession data model; SEM			1975-1980 -0,31;-0,34 2001-2006 -0,041;-0,043 -0,077 1975-80 -0,21-0,22 2001-2006 -0,034-0,077			
Bhascara & Gyaneshwar (2008)	Cointegration methods			-0,196	0,456		
Wadud, Graham & Noland (2009)	ECM OLS NLLS	-0,102 -0,118 0,116	0,565 0,593 0,592	-0,065 -0,091 0,085	0,473 0,457 0,52		
Sultan (2010)	ARDL/ECM	-0,44	0,77	-0,21	0,37		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	10.81055	Prob. F(1,21)	0.0035
Obs*R-squared	8.835883	Prob. Chi-Square(1)	0.0030

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 01/02/12 Time: 21:22
Sample: 2 27
Included observations: 26
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018292	0.243381	0.075156	0.9408
PRICE	-0.004700	0.010878	-0.432099	0.6701
INCOME	0.070055	0.038722	1.809173	0.0848
CONS(-1)	-0.309832	0.141437	-2.190598	0.0399
RESID(-1)	0.793031	0.241194	3.287940	0.0035

R-squared	0.339842	Mean dependent var	2.39E-16
Adjusted R-squared	0.214097	S.D. dependent var	0.011772
S.E. of regression	0.010436	Akaike info criterion	-6.116058
Sum squared resid	0.002287	Schwarz criterion	-5.874117
Log likelihood	84.50876	Hannan-Quinn criter.	-6.046388
F-statistic	2.702638	Durbin-Watson stat	2.039984
Prob(F-statistic)	0.058353		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.086011	Prob. F(1,19)	0.7725
Obs*R-squared	0.112662	Prob. Chi-Square(1)	0.7371

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 11/02/11 Time: 23:28
Sample: 3 27
Included observations: 25
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.014253	0.743094	0.019181	0.9849
PRICE	-0.000364	0.017431	-0.020886	0.9836
INCOME	0.011294	0.100604	0.112258	0.9118
CONS(-1)	-0.054716	0.311744	-0.175515	0.8625
AR(1)	-0.019058	0.269681	-0.070669	0.9444
RESID(-1)	0.130100	0.443610	0.293276	0.7725

R-squared	0.004506	Mean dependent var	-1.60E-11
Adjusted R-squared	-0.257465	S.D. dependent var	0.009699
S.E. of regression	0.010876	Akaike info criterion	-5.999020
Sum squared resid	0.002247	Schwarz criterion	-5.706490
Log likelihood	80.98775	Hannan-Quinn criter.	-5.917885
F-statistic	0.017202	Durbin-Watson stat	1.908487
Prob(F-statistic)	0.999866		