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Abstract

Energy is one of the basic prerequisites for an economy to prosper. However, the energy crisis has turned into a concern of society at large and the prices of energy sources are rapidly increasing. Accordingly, a solid energy policy has become fundamentally important.

Since electricity is one of the most widespread energy sources, it requires special attention. At the moment, the electricity price in Latvia is one of the lowest in the whole of Europe. Apparently, such a situation is not sustainable; yet it is hoped that the recently initiated electricity market deregulation will reduce the rate of increase in the electricity price.

Households certainly are the most vulnerable with respect to changes in the electricity price as compared to industrial or commercial consumers. Nevertheless, it is evident that electricity market deregulation will not affect the residential sector for several years.

In order to quantitatively assess the potential effect of a change in the electricity price, knowledge of its elasticity is necessary. This paper is the first attempt to estimate the short-run residential demand for electricity in Latvia. Consequently, both price and income elasticity are computed.

Results suggest that the electricity price does not significantly influence residential electricity demand, at least in the short-run. On the other hand, it is estimated that in the short-run a 1% increase in household income is associated with a 0.28% increase in electricity consumption.

List of Abbreviations

AT……………….. Transmission System Operator JSC Augstprieguma Tīkls (Latvia)

CHPP…………….Combined Heat and Power Plant

CPI……………….Consumer Price Index

CSB……………… Central Statistical Bureau of Latvia

EU……………….. European Union

HPP……………… Hydro Power Plant

INNP……………..Ignalina Nuclear Power Plant (Lithuania)

PUC………………Public Utilities Commission

TPP……………….Thermal Power Plant

TSO………………Transmission System Operator

USSR……………. Union of Soviet Socialist Republics

1. Introduction

The winged words ‘energy crisis’ are increasingly drawing public attention, but this is not just a trendy term. Prices of energy sources are rapidly increasing. While at the end of the nineties the price of oil dropped even under 10 dollars per barrel, today we are experiencing a price that is at least six times higher. Likewise, the price of fossil fuels (gas and coal) is growing at a steady rate. Even the price of firewood is rising sharply. Besides, it is anticipated that the prices of energy sources will grow at a rapid pace also in the upcoming years. Under such conditions it is clear that a solid energy policy is crucial for each and every country. Latvia is not an exception.

Since electricity is one of the most widespread types of energy, it requires special attention. Electricity in general is distinctive because it cannot be stored (at least at a reasonable cost) and therefore has to be consumed literally at the same moment when it is produced. In addition, the electricity sector is usually characterized as a natural monopoly, so that a special regulatory body is established to prevent abuse of the monopoly power and to provide consumers with a service of adequate quality for a sensible price. At the same time, the electricity sector as such and the stability of electricity provision in particular is vitally important for every economy to prosper. Hence, any decision regarding the electricity market has to be well considered and economically justified.

The European Union (EU) in 2000 decided to change its policy towards the structure of energy markets and called for rapid work to be undertaken to complete the internal market in both the electricity and gas sectors and to speed up the liberalization of these sectors. As a result, in 2003 Directive 2003/54/EC establishing common rules for the generation, transmission, distribution and supply of electricity was passed (2003). The deregulation of the electricity market provoked much discussion in the countries and regions where it already came about. That was the case, for example, in Austria, Great Britain, Sweden, and Norway (among others see Aune *et al* (2004), Green and Newbery (1992), Andersson (1995)). That seems to be the case also in the other Baltic States (see Velička and Žaldokas, 2003). In Latvia only the first steps to liberalize the electricity market have been taken. So, since September 1, 2005 the functions of the Transmission system operator (TSO) are performed by JSC Augstsprieguma tīkls (AT), which was separated from the previously vertically integrated utility Latvenergo. The next step will be to separate the Distribution system operator (DSO) by July 1, 2007; thereby, the electricity sector will be divided into its parts according to their functions: generation, transmission, distribution and supply of electricity.

In turn, competition would prevail in the generation and supply of electricity – parts in which a natural monopoly is not present.

At the moment, consumers in Latvia are paying one of the lowest prices for electricity in the whole of Europe[1]. The main reason behind this is that current prices reflect the short-run marginal costs of production and do not account for the huge initial investments and the expected reconstruction costs as Latvia has inherited a magnificent energy production capacity from the former Soviet Union (Paegle, 2005). Such a situation is not sustainable; yet, it is hoped that deregulating the electricity market will reduce the rate of increase in electricity prices.

Households are certainly the most vulnerable with respect to changes in price as compared to industrial or commercial consumers. Hence, any decision regarding the price of electricity has to be especially well justified when dealing with households. In order to draw any quantitative predictions on how price increases could affect the consumer surplus of end-users, an estimate of price elasticity of the demand for electricity is needed. However, to the best of the authors' knowledge, hitherto there has not been any study examining the residential electricity demand function in Latvia or even in the other Baltic States[2]. Accordingly, the price elasticity of demand has not been estimated so far. Thus, in order to fill this gap, **the authors in the scope of this study will aim to estimate the price elasticity of residential demand for electricity in Latvia**. In addition, the authors will aim to obtain the income elasticity that can be estimated along with price elasticity. Income elasticity - similarly to price elasticity - can then serve as the base for analyzing residential demand in more detail.

The rest of the paper is organized as follows. The second part provides the background to the study. Next, an insight into previous studies is offered. Then a regression model is developed throughout the fourth section. Further, section five describes the data. Preliminary tests on data constitute the sixth part. Accordingly, the results are presented in the seventh section. Sequentially, the interpretation of the results is presented. Finally, section 9 concludes.

[1] Despite the fact that just recently, the Public Utilities Commission (PUC) has allowed raising the electricity price and starting from March 1, 2006 consumers have to pay on average approximately 6.7% more than before.
[2] The only known study is that by Kalinauskas *et al* (2000) who estimated the Slutsky elasticity of household demand for public utilities in Lithuania to be -0.251. This figure, however, in addition to electricity includes flat rent, water, gas and other fuel (qtd. in Velička and Žaldokas, 2003, 21).

2. Background of the Study

Before estimating the price elasticity of residential electricity demand, electricity market structure and the changes it is currently undergoing were inspected. It has been argued that the deregulation process could limit the meaning of elasticity estimates[3]. Thus, the authors conducted qualitative research consisting of a number of interviews[4] with specialists in the electricity market in order to examine how deregulation might change market structure and what effect it would bring to end-consumers of electricity (especially households). In this chapter an overview of the Latvian electricity market is presented. Secondary data is used along with results from interviews.

2.1. Origination and Development of the Latvian Electricity Market

In this section the authors examine the development of the Latvian electricity market for the last couple of years, which provides an insight into the market.

The development of the electricity market in Latvia has to be described together with the whole region of the Baltic States and Russia. The Latvian Electricity market was developed during the forties of the last century (Latvenergo Homepage), when the Baltic States were part of the Union of Soviet Socialist Republics (USSR). At that time, the Soviet republics were perceived as a part of one united economy and consequently the countries operated in close cooperation with each other. Therefore, the electricity market of one country strongly depended on the situation in the neighbouring markets. That was also the case with the Baltic States – the whole energy system was built on structural and technological efficiency, regardless of territorial division (Sarma, 2005).

Currently, the Lithuanian Ignalina Nuclear Power Plant (INPP) alongside the Lithuanian and Estonian Thermal Power Plants (TPPs) are the source for the base of electricity produced in the Baltic States. Nevertheless, thermal and nuclear power plants are highly inelastic regarding variability of production level. On the other hand, Latvian Hydro Power Plants (HPPs) are characterized by their high elasticity and capability of an immediate on-demand increase in production level. Therefore, INPP and TPPs supply the Baltic region with a base of needed electricity, while HPPs in Latvia satisfy peaks in demand for electricity.

[3] As pointed out by Stevens and Lerner, the prospect of unbundled electricity services, time of use pricing and the choice of suppliers via bilateral contracts suggest that demand elasticity derived from consumer behavior in a regulated electricity market could have limited meaning as deregulation is implemented (1996, 1).

[4] For a full list of interviewees refer to Appendix 10.

Consequently, the electricity system in the Baltic States has been developed so that it can transmit up to 90 - 100 % of consumed electricity amounts (Sarma, 2005). The last characteristic strongly separates the electricity markets of the Baltic States from the rest of Europe, as cross-border congestion is a common problem in most EU countries[5] (Bariss, 2005). Non-existent cross-border congestion in the Latvian electricity market and its close cooperation with the other Baltic States and Russia are the main reasons why deregulation will not have the same effects as in Western markets (Bariss, 2005).

The development of the electricity markets of the Baltic States explains the electricity balance of the Latvian market. In the next section, the authors examine this electricity balance.

2.2. Electricity Balance

In general, the sources of electrical power supply are three HPPs, two Combined Heat and Power Plants (CHPPs), a number of independent producers, and imports. Independent producers and CHPPs have supplied a constant amount of electricity over the last couple of years. Changes in the level of the other two sources, imports and HPPs, have a strong interrelation because electricity generated in HPPs depends on the water level in the Daugava, whereas electricity demand that is unsatisfied by local production is imported. Imports on average account for 30% of electricity consumed. Meanwhile, 90% of domestically generated electricity is produced by the former state monopoly Latvenergo (Latvenergo Homepage)[6].

Figure 1 shows that the level of domestically produced electricity does not have any stable trend since 1990. More than 60% of electricity produced at Latvenergo is generated by HPPs, which are strongly dependent on weather conditions in the particular period (Bariss, 2005). Similarly, electricity produced at CHPPs depends on the temperature, because electricity is a byproduct of the generation of heat.

[5] In essence, deregulation in EU countries was imposed to reduce excess capacities, which in turn caused cross-border congestion.

[6] For a more detailed overview of the Latvenergo electricity balance for 2004 see Appendix 1.

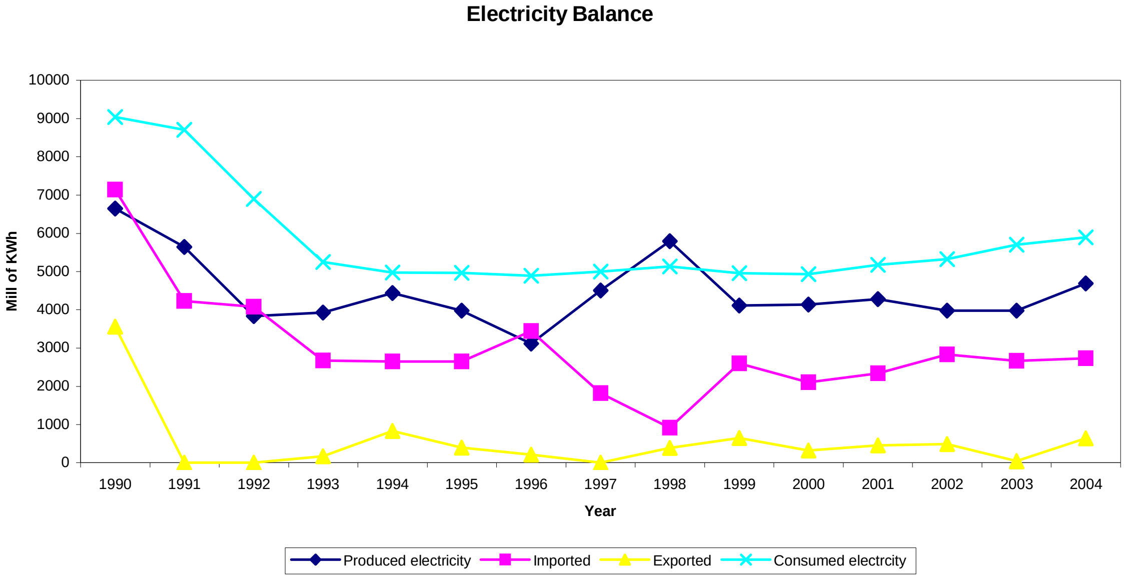

Figure 1. Electricity balance of Latvia
Source: CSB, own calculations

2.3. Consumption

Figure 1 shows that at the beginning of the nineties the consumption of electricity sharply decreased. This decrease was after Latvia gained its independence, and consequently an over-orientation of the economy characterized by a fallback in a heavy production took place. If one takes a look at Figure 2, then the same picture prevails – the consumption for production needs experienced the biggest decrease in the period from 1990 till 1993. Similarly, the agricultural sector experienced a huge restructuring in the early nineties, when the whole system of collective farming became inefficient and output in the sector significantly decreased.

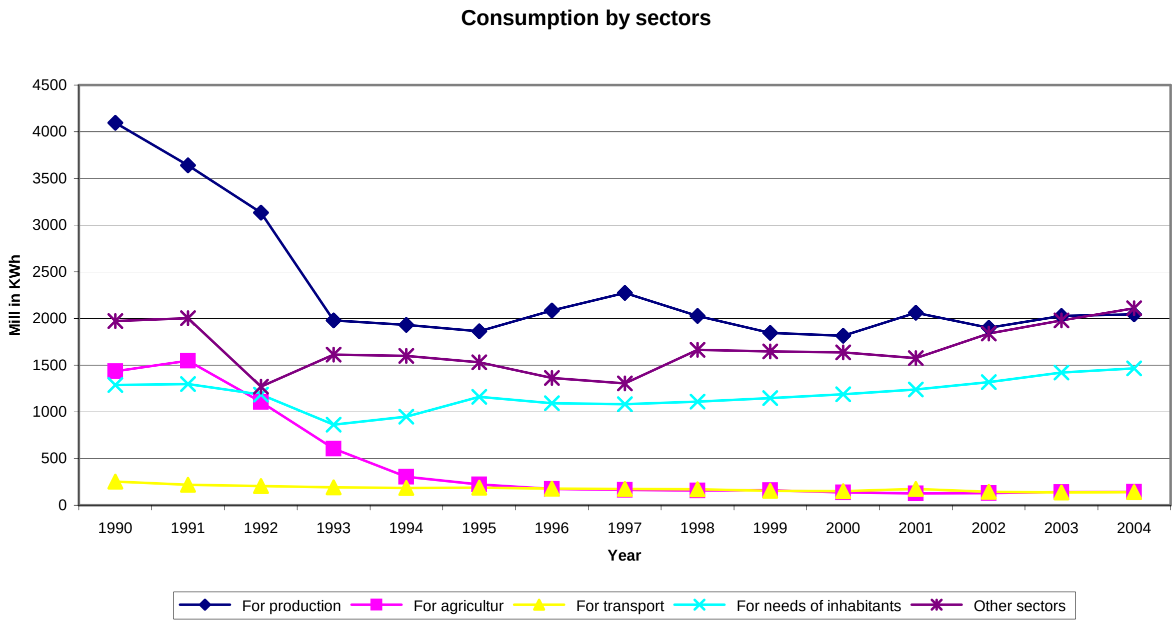

Figure 2. Electricity consumption by sectors
Source: CSB, own calculations

Even though electricity consumption for the needs of inhabitants (residential demand) showed a slight decrease in 1992, in the last decade this sector has experienced the most rapid and stable increase, which has been driven by the overall increase in standards of living and an increase in the capital stock of electric appliances.

2.4. Electricity Market Deregulation

In the previous section the authors touched upon the historical development of the Latvian electricity market. However, contemporarily the market is undergoing deregulation, which might significantly change the market structure and ultimately have a strong effect on the end-consumer. As already stressed, the deregulation process cannot be overlooked and has to be examined.

According to Damsgaard, the electricity market can be characterized as consisting of four vertically separate parts: production/generation, transmission, distribution, and supply/retail (2003). In the past, these four functions were viewed as best performed in vertically integrated companies, but recently there has been a consensus that the generation and supply parts can function as competitive markets, while the two other parts are viewed as natural monopolies in which competition actually is not very desirable from the standpoint of society as a whole.

Unlike most of the deregulated electricity markets in the EU, Latvia is only taking the first steps in the field of bilateral agreements. Currently, only eligible consumers in Latvia (which are the biggest industrial producers) can freely choose a supplier of electricity, while after 2007 all electricity consumers will have this right to participate in the agreement market.

When comparing the two different market structures, before and after 2007, there will be no tied consumers after 2007. Additionally, each consumer will have a choice – whether to continue to buy regulated bundles from the DSO or to participate in the agreement market. At the same time consumers will have to pay the TSO for use of the network.

Until this point, Latvia has not experienced any activity in the market for bilateral agreements (Bariss, 2005). The market did not change because Latvenergo can offer a lower price than any competitor – Latvenergo imports electricity for the lowest prices because it can offer the supplier a contract for larger amounts if compared to a local industrial consumer of electricity.

Similarly, it is expected that after 2007, when all consumers will have the possibility to choose a supplier of electricity, residential consumers will continue to buy bundled electricity products offered by Latvenergo (Sarma, 2005). Reasons for this situation are similar as with large industrial consumers: the ability of Latvenergo to offer cheaper bundled electricity and consumers' unwillingness to bear the costs of finding the most suitable supplier. In general, the electricity market is relatively small from both sides: consumers and suppliers. Thus, it is expected that no liquid market for bilateral agreements will evolve even in the context of the unified market of the Baltic States.

Accordingly, the authors expect that during the next couple of years there will be no significant structural change in the electricity market, and especially regarding residential consumers. Therefore, estimates such as price elasticity of residential electricity demand and income elasticity, that are obtained using historic data, can be used to predict future development.

3. Review of Literature

Income and price elasticity of electricity demand has been studied rather extensively. The reason is that both income and price elasticity serve as a solid base for designing present and future energy policy. Moreover, by using income and price elasticity it is possible to project demand growth for electricity.

The core articles in the area go back even to the early 1950s. Most studies of residential electricity demand were conducted during the 1970s and early 1980s, when energy prices were rising rapidly.

The literature in general differs in the following dimensions[7]: the sector covered (residential, industrial, or commercial sector), the data used (national-level aggregate data versus regional-level data obtained mainly from different kinds of survey), the elasticity examined (price elasticity versus income elasticity), and the nature of elasticity (short-run elasticity versus long-run elasticity). The authors recognize that not all the studies fall in the categories mentioned above; rather, such a grouping should serve as a guide for the reader.

Taking into account the limitations of this thesis, the authors will first try to give an overview of the so-called classic studies of electricity demand as such, and then touch upon studies examining the price and income elasticity of residential electricity demand in developing countries (which Latvia belongs to). These studies are of particular interest for the authors because they serve as a departure point for their research.

The pioneer in studying and modelling demand for electricity thoroughly was Houthakker (1951). His contribution has been recognized and acknowledged by other scholars in the field and therefore his empirical study from time to time is referred to as the classic (e.g. Taylor, 1975, 75; Dubin, 1984, 345). The focus of Houthakker's study was on residential electricity consumption in the United Kingdom. By setting up the double-logarithmic model, Houthakker obtained an income elasticity of electricity demand of 1.17 and price elasticity of electricity demand of -0.89. He was the one who commenced the discussion of using a marginal price rather than an average price in the electricity demand function. However, Houthakker did not distinguish between short-run and long-run elasticity.

The first to distinguish between short-run and long-run elasticity were Fisher and Kaysen (1962). The short-run was defined by the condition that electricity-consuming capital stock is fixed, while in the long-run the stock appliances are flexible. The study of Fisher and Kaysen (1962) was one of the earliest authoritative attempts to form an electricity demand model in the United States. Nevertheless, it has also been one of the most ambitious and controversial (Taylor, 1975, 84). Fisher and Kaysen (1962) estimated residential and industrial electricity demand using a data set that consisted of observations for 47 states (from 1946 to 1957). They suggested a two-stage model. Demand (D_t) in the short-run (the first stage) was said to

[7] The authors disregard differences in the specifications and functional forms of the models due to their vast variety.

depend on the average appliance stock during the period t (K_t) and the utilization rate of appliance stock (u_t):

$$D_t = u_t * K_t = u_t(Y_{t,} P_t) * K_t \, , \qquad (1)$$

where u_t in turn depends on the average price of electricity and per capita personal income Y_t. In estimating long-run demand (the second stage), Fisher and Kaysen tried to find the factors which affect the capital stock. In essence, they regressed the growth rate in the appliance stock on such variables as income, price of electricity and gas, population, marriages (!), number of houses wired for electricity, and others. The estimated price and income elasticity led them to meaningful conclusions about the electricity market in the United States.

Houthakker *et al* (1974) was one of the first to examine short-run price elasticity of electricity demand in more detail. Houthakker *et al* estimated residential electricity demand using pooled time series annual data for the years 1960 to 1971 from different states in the United States. In the analysis they used the flow-adjustment model of demand, developed by Houthakker and Taylor (1970), in which the stock of energy-using capital is assumed to be fixed over the short run, so that its utilization is consequently assumed to be a function of normal economic influences.

Credit should be given also to Barnes *et al* (1980). They attempted to estimate residential short-run price and income elasticity based on micro data from the United States. Barnes *et al* developed a model of short-run electricity demand which incorporated a fixed configuration for a household's stock of electrical appliances and demographic profile, and also explicitly treated the multi-part nature of electricity rate structure (1980). It was the first attempt to analyze micro data combining "specific rate information, a broad geographic focus, and substantial sample variation in the important determinants of electricity demand" (Barnes *et al*, 1980, 541). Moreover, they analyzed not only total electricity consumption, but also the distribution of consumption over different end-use categories (e.g. heating, cooling). This overall resulted in new evidence on electricity demand parameters. They concluded that the overall response of a household is made up of a complex set of responses which varies significantly across appliances.

While there have been quite many studies of electricity demand in developed countries (especially in the United States), rather few have been conducted in developing economies. Diabi (1998) in his study used cross-sectional regional data covering a period from 1980 to 1992 in order to obtain the short-run and long-run price and income elasticity of demand for electricity in Saudi Arabia. Diabi did not distinguish between classes of customers but rather estimated the total demand for electricity in Saudi Arabia. He developed a standard electricity demand function including not so frequently used variables as urbanization rate and also temperature. Overall, the empirical results suggested that the demand for electricity in Saudi Arabia is price- and income-inelastic. A more interesting conclusion drawn by Diabi was that the influence of urbanization on electricity consumption is clearly larger than that of real income.

Holtedahl and Joutz (2000) went even further than Diabi and modified the model developed by Fisher and Kaysen to take account of the features of developing countries. They proposed an alternative means for conditioning demand on the capital stock. Holtedahl and Joutz claimed that "the degree of urbanization is a reasonable proxy for electricity-using equipment since cities are electrified sooner than rural areas and are on the forefront of adopting modern household appliance" (2000, 4). They examined residential demand for electricity in Taiwan as a function of the price of electricity, household income, population growth, and the degree of urbanization. Short-run and long-run effects were separated through the use of an error correction model. As a result, Holtedahl and Joutz found that in the long-run income elasticity is unitarily elastic while price elasticity is negative and inelastic. The short-run estimates were smaller than the long-run effects.

Another study examining electricity demand in a developing economy was that of Politukha (2002). Politukha estimated the price and income elasticity of short-run demand for electricity, distinguishing between residential and industrial demand. The situation in Ukraine at the time of Politukha's research was similar to the present situation in Latvia. Ukraine had one of the lowest tariffs for electricity, the base of electricity producing units was inherited from the Soviet Union (including Chernobyl nuclear power station), and an increase in tariffs was inevitably approaching. The results were obtained using a demand function developed by Hsiao and Mountain (1985) as the base and adjusting it for Ukraine-specific factors. The results proved to be consistent and showed that both industrial and residential demand for electricity is inelastic, at least in the short-run.

This condensed review of literature would not be complete if the authors left out the much-discussed issue as to whether the marginal price or the average price should be used as an explanatory variable in estimating demand for electricity. Many studies have been devoted to arguing for and against each of these prices (e.g. Houthakker 1951; Houthakker *et al* 1974; Taylor 1975; Smith 1980). However, most economists interested in electricity demand have concluded that it is the marginal price, and not the average price, which determines the amount of consumed electricity (Diabi, 1998, 16). Under a declining block-rate schedule when the price of electricity depends on the amount consumed, the difference between marginal and the average prices can be quite large. However, although economic theory would dictate the use of the marginal price, the average price is often the only price measure available. Even more, there is some behavioural evidence that householders do not notice marginal prices and rather respond to average prices[8]. In the scope of this study it is also important to note that the use of the average price is justifiable for estimating price elasticity from aggregate data as argued by Foster and Beatty (qtd. in Diabi, 1998, 16).

4. The Model

In its fundamental nature, economic theory suggests that household demand for a commodity is a function of the costs of available commodities (and/or services) and of household income (Anderson, 1973, 528). However, one should be careful when trying to define the demand function for electricity because the demand for electricity itself is derived. Electricity provides the energy input for electric appliances, which in turn are used to satisfy demand for light, a warm house, cooked food, hot water, television, and so on. In other words, electricity does not yield utility in and of itself, but rather is desired as an input in other processes or activities that do yield utility (Taylor, 1975, 80). Therefore the demand for electricity is a derived demand[9]. Consequently, the demand for electricity is also dependent on the costs of alternative energy sources which can be used in order to satisfy demand for output of the processes in question. These energy sources are mainly gas and coal in the case of households. The cost of oil and thermal energy, though, are factors to consider as well.

However, before setting up the base model the authors believe it is worth devoting a few sentences to elaborating on the difference between short-run and long-run electricity demand. As already mentioned, electricity demand is a derived demand. In essence, it is dependent on the stock of electrical appliances and the utilization rate of this stock. Because electrical appliances by nature are durable goods, it is important to distinguish between short-run demand for electricity and long-run demand. Short-run with respect to electricity demand in general is defined by the condition that the stock of electrical appliances is fixed, while in the long-run the appliance stock is assumed to be variable (Taylor, 1975, 80). Therefore, in the short-run the demand for electricity can be seen as arising from a choice of the utilization rate

[8] For a thorough discussion of behavioral factors influencing households' response to the price, refer to Stern (1984).

[9] Later in this work the authors will still use the more convenient "demand for electricity", though keeping in mind that in essence it is a derived demand.

of the fixed stock of electrical appliances, whereas in the long-run the demand for electricity is dependent on the capital stock itself (ibid, 80).

4.1. The Base Model

As discussed by Berndt, there are two principal approaches in modelling electricity demand: (1) econometric models of electricity demand with equipment stocks included *explicitly* and (2) econometric models of electricity demand with equipment stocks included *indirectly* (1991, 312-320). Both methods have their pros and cons. The first approach suffers from the disadvantage of requiring data on equipment stocks, which is not always available. On the other hand, by including equipment stocks indirectly it is no longer possible to distinguish observed changes in electricity demand between that coming from shifts in equipment stocks and that coming from shifts in the utilization rate. Therefore, the second approach is more applicable in estimating long-run demand for electricity when capital stock is not fixed. Since this study is concerned with estimating short-run effects on electricity demand from changes in its determinants, the authors decided to use the econometric model of electricity demand with equipment stocks included *explicitly*.

One of the first models of short-run demand for electricity with the stock of electric appliances included explicitly is due to Fisher and Kaysen (briefly discussed already in the previous chapter). This model has served as the base for a number of researches and this study will not be an exception. Besides, valuable comments on their model have been provided also by Taylor (1975, 80-83). So, following Fisher and Kaysen, and Taylor the authors denote the amount of electricity consumed in the short-run at time t by D_t. Furthermore, denote by W_t the average aggregate electrical appliance stock at time t measured in units of kilowatts per hour the stock can potentially use. And denote the utilization rate of this equipment stock by u_t. Then the amount of electricity consumed can be expressed as

$$D_t = u_t * W_t . \qquad (2)$$

Since the capital stock is fixed in the short-run, specifying demand for electricity in the framework of this study is reduced to specifying the functional form of u. In essence, the utilization rate is assumed to depend upon the price of electricity (PE_t), the level of household income (Y_t) and other economic, social, or demographic factors that might be relevant (Taylor, 1975, 81). If the latter is denoted by Z_t, then (2) can be rewritten as

$$D_t = u_t(PE_t, Y_t, Z_t) * W_t. \quad (3)$$

Furthermore, let us assume that u_t is given by

$$u_t = \alpha_0 + \alpha_1 * PE_t + \alpha_2 * Y_t + \alpha_3 * Z_t. \quad (4)$$

Consequently, the short run demand for electricity can be expressed as

$$D_t = (\alpha_0 + \alpha_1 * PE_t + \alpha_2 * Y_t + \alpha_3 * Z_t) * W_t. \quad (5)$$

As a result, the residential demand for electricity is formulated as the function of electricity price, household income, and other factors which might be relevant while holding the stock of electric appliances fixed. Therefore,

$$D_t = f(PE_t, Y_t, Z_t, W_t). \quad (6)$$

Holtedahl and Joutz, on the other hand, as already mentioned proposed an alternative because of “the problem of correctly capturing electricity-using capital stock (..) when working with developing countries” (2000, 4). They introduced the degree of urbanization as the proxy for electrical appliances. If this proxy is denoted by DU_t, then (6) virtually becomes

$$D_t = f(PE_t, Y_t, Z_t, DU_t). \quad (7)$$

However, preliminary research revealed that in the case of Latvia obtaining the degree of urbanization on a monthly basis is troublesome. Hence, the authors decided to stick to the demand function specified in equation (6) and use the available data on the stock of electrical appliances.

Accordingly, in setting up the econometric model for residential electricity demand the authors should start with the base model which apparently follows from the discussion above, that is,

$$D_t = c + \alpha_1 * PE_t + \alpha_2 * Y_t + \alpha_3 * Z_t + \alpha_4 * W_t + \varepsilon_t, \quad (8)$$

where c is a constant and ε_t is a random error term.

4.2. The Augmented Model

While three of the independent variables in equation (8) have been defined and argued previously, the authors have remained silent on what are the other economic, social and demographic factors (Z_t) which might be relevant in the scope of estimating residential demand for electricity in Latvia. These factors will be discussed in this sub-section.

As already discussed before, the prices of energy substitutes certainly should be included as determinants of electricity demand. Definitely, the price of natural gas has been used the most in previous studies starting with the early classic of Houthakker (1951). Being an important determinant of electricity demand, the price of gas was also included in the model considered in this study. Thermal energy (i.e. heating) also serves as a good substitute for electricity although its price has previously been used less than the price of gas when estimating residential demand for electricity. Still, the authors believe that excluding the price of thermal energy would lead to less reliable results than including it, and therefore decided to include it in the final model. Furthermore, the authors are confident that the price of solid fuel in the case of Latvia is an important variable in explaining variations in electricity demand, although it has been used quite rarely before (e.g. Anderson, 1973). Solid fuel serves as a substitute for electricity, especially in the countryside where about one third of the inhabitants of Latvia are living (32% as at the start of 2005, Central Statistics Bureau).

The authors used the average prices of electricity and its substitutes rather than marginal prices, keeping in mind their validity, at least in the scope of this study[10]. This choice to a large extent was dictated by limitations of data, because marginal prices were not available for all the variables and the whole time-span under consideration. The authors are aware of the fact that short-run elasticity estimates obtained using average price as the explanatory variable tend to be larger than those using marginal prices. This was proved by Espey J. and M. Espey in their recent study in which they carried out a meta-analysis "to quantitatively summarize previous studies of residential electricity demand in order to determine if there are factors that systematically affect estimated elasticities" (2004, 65). While they found that the choice of price matters when estimating short-run elasticity estimates, no significant difference was discovered between long-run estimates across studies using marginal price and average price (ibid, 73). Therefore, the authors admit that elasticity estimates obtained could be higher than those prevailing in real life.

Additionally, the authors allowed households to adjust for changes in the price of electricity and its substitutes with a plausible three-period (i.e. quarter) lag (similar to, e.g., Politukha, 2002). A quarter is a reasonable time frame for a household to change its habits and conventions especially when holding fixed the stock of electrical appliances. Finally, income and prices of electricity and its substitutes were deflated by the consumer price index (CPI) in order to express them in real terms.

The authors also introduced an independent variable to account for clear seasonal factors influencing household electricity consumption, which is particularly important when dealing

[10] As discussed in the previous chapter.

with data which is observed more frequently than on an annual basis. There have been various approaches employed in previous studies of electricity demand. One way to go is to include some measure of temperature. Temperature is typically presented as the number of degree days (e.g. Wilson, 1971) or as the mean temperature for the period of interest (e.g. Anderson, 1973). Another option is to include either peak and off-peak dummy variables or quarterly dummy variables (see, for instance, Akmal and Stern, 2001, and Politukha, 2002). However, the authors believe that introducing quarterly dummy variables would not be sufficient to account for seasonality in respect of this study, in which monthly data are used. Therefore, it was decided to include average monthly temperature as an independent variable in the model. Nevertheless, due to possible estimation problems[11] the authors also constructed a daylight variable expressed as the average number of minutes per day in each month when the sun is up. Accordingly, these two variables were used interchangeably in estimating electricity demand.

To end with, it is assumed that household stock of electrical appliances consists of refrigerators, TV sets, vacuum cleaners, washing machines, and microwave ovens. Imposing this restriction was driven by the availability of data.

Consequently, the final model of residential demand for electricity to be estimated[12] is:

$$D_t = c + \alpha_1 * PE_{t-3} + \alpha_2 * Y_t + \alpha_3 * P_{i,t-3} + \alpha_4 * W_{j,t} + \alpha_5 * Temp_t + \varepsilon_t, \qquad (9)$$

where

t = 1998:1, 1998:2, (…), 2005:9;

i = i-th fuel: gas, solid fuel, thermal energy;

j = j-th electric appliance: refrigerator, TV set, vacuum cleaner, washing machine, microwave oven;

D_t = electricity consumption by all households per capita during period t;

P_t = the real average price of electricity in period t;

Y_t = the real per capita household income in period t;

$P_{i,t}$ = the real average price of the i-th fuel in period t;

$W_{j,t}$ = the average stock of j-th electric appliances per 100 households in period t;

$Temp_t$ = the average air temperature in period t;

ε_t = the random error term.

[11] If demand is estimated using the convenient double-log functional form, then the observations of temperature which is below zero are not suitable.
[12] The coefficient estimates are obtained using the Ordinary Least Squares regression procedure.

Coefficients α_1 and α_2 will be of particular interest because they will be used to calculate price and income elasticity. In order to calculate elasticity, the authors use the conventional formula[13]

$$\varepsilon = \frac{p}{q} \times \frac{\Delta q}{\Delta p} . \tag{10}$$

Since the estimated coefficient α inherently is $\Delta q/\Delta p$, equation (10) becomes

$$\varepsilon = \frac{p}{q} \times \alpha . \tag{11}$$

Similarly to Houthakker and Taylor (1970), elasticity estimates are computed at the mean values of the period.

4.3. Hypothesis

To sum up expectations regarding coefficients of independent variables (as transformed to elasticity estimates) and their signs, the authors propose the following two hypotheses:
H1: the own-price price effect of electricity is negative, inelastic, and is close to zero[14];
H2: higher income is expected to increase electricity consumption since electricity is a normal good.

5. Description of Data

In the previous part the authors developed the model, while in this section the dataset is introduced and the main variables of interest are described. Recognition of past trends in the development of those economic variables can help in the interpretation of results.

The dataset consists of 93 observations – monthly data for the period from January 1998 to September 2005. The necessary data were collected from different types of sources and in this section the authors will describe what measures were used and what kind of adjustments were made.

The dependent variable of the model is household **consumption** of electricity, also referred to as residential demand for electricity. Since on a monthly basis this data is not publicly available, obtaining it was troublesome. However, finally data on monthly

[13] See Varian (1993, 266).
[14] Therefore, obtaining a non-significant coefficient on the electricity price is possible. However, the coefficient should be at least consistent, i.e., negative.

consumption of electricity was provided by Latvenergo, as they have shown interest in the results of this thesis[15]. The data consisted of an aggregate consumption, divided by groups of consumers. The authors took the aggregate consumption by households and divided it by the number of inhabitants in Latvia to obtain monthly household consumption of electricity per capita in KWh – this measure was ultimately used in the regressions. The monthly data on population was collected from CSB's monthly issues. The authors chose residential demand per capita because electricity consumption depends on the number of consumers, thus regression results with aggregate data would not show the real explanatory power of the independent variables.

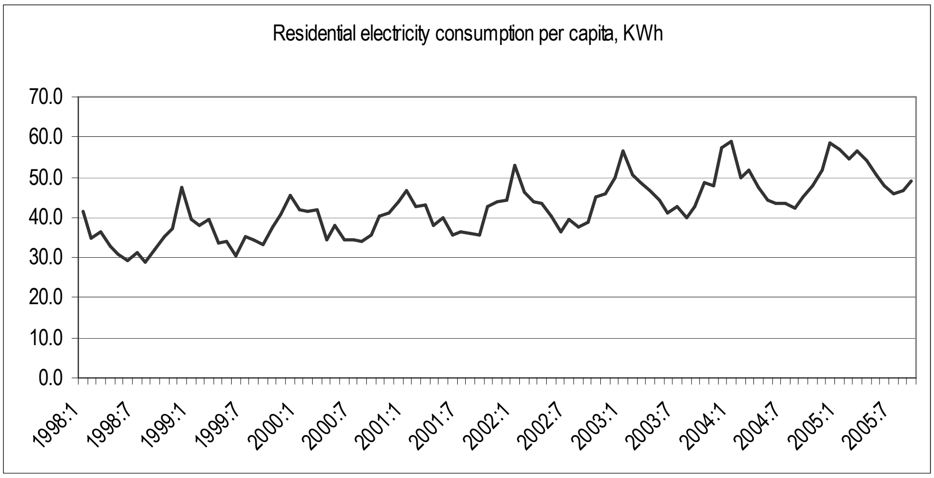

Figure 3. Residential electricity consumption per capita
Source: Latvenergo, CSB, own calculations

Residential electricity consumption per capita reveals strong seasonal trends (see Figure 3), but on average it is increasing – consumption in a given period on average is higher than it was in the respective month a year ago. Seasonality patterns could be affected by a fraction of the dark time in the day when electricity is used for generation of light. Additionally, the shortest days are during the coldest days of winter when some households use electricity to heat up their homes. Therefore, one would expect that residential demand for electricity shows strong seasonality effects.

The **price of electricity** was obtained by adjusting the nominal price of electricity over the period for inflation as expressed by CPI.

[15] However, due to confidentiality issues the authors do not report a full set of data.

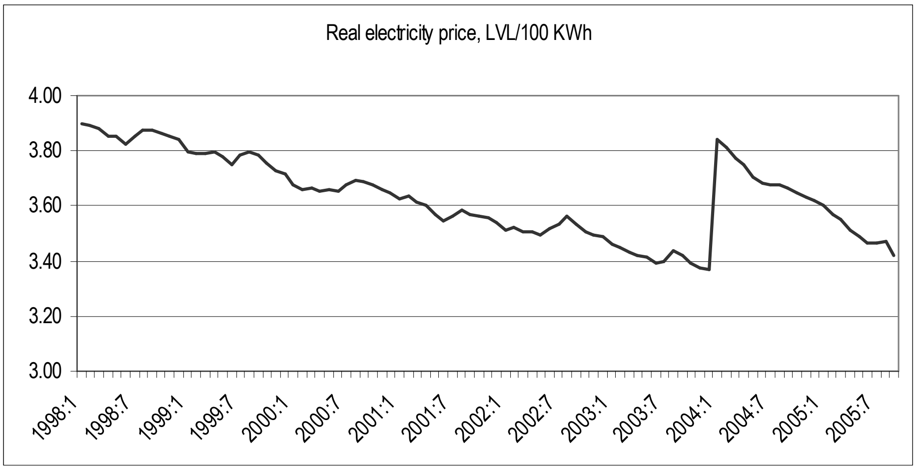

Figure 4. Real electricity price
Source: CSB, own calculations

Since the electricity price is regulated, the real electricity price mostly changes because of inflationary effects, whereas the rapid increase at the start of 2004 comes from the increased regulated nominal price – an increase in tariffs (see Figure 4).

Along with the price of electricity, the prices of potential electricity substitutes, namely **gas, thermal energy** and **solid fuel**, were collected. Since prices were available in nominal values, the authors adjusted values for inflation, identically as for the price of electricity. For historical development of the real price of gas, heating, and solid fuel refer to Appendix 3.

Obtaining data on the income of households in Latvia proved to be problematic because this is available only on a yearly basis when the CSB makes a comprehensive survey about household budgets. Instead, the authors found that the most suitable proxy for measure of income is net wage. It is believed that in Latvia a big fraction of household income comes from the "shadow economy" (income that is not reflected in official statistics). Since data on residential income is based on the survey, the authors argue that this data would also exclude the part of household income that comes from the "shadow economy". Therefore, while both types of income are growing at a similar pace, net wage can be used as a good proxy for residential income. Similarly as with prices, net wage was adjusted for accumulated inflation since January 1998 to obtain the net real wage, which measures the real purchasing power of households.

The real wage reveals seasonal patterns (see Figure 5), reaching maximum values at the end of the year, when workers receive additional bonuses.

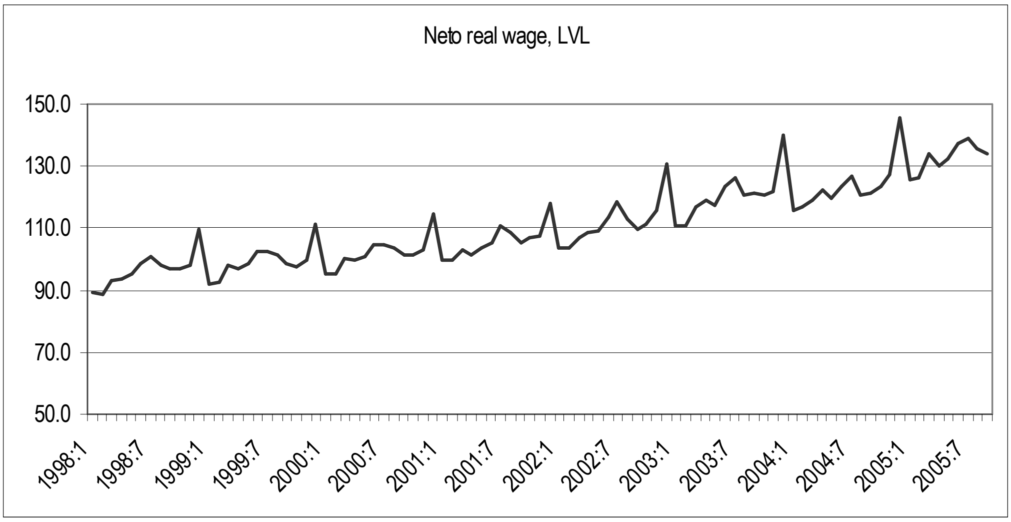

Figure 5. Net real wage
Source: CSB, own calculations

The authors also collected data on monthly average **temperature**. The data was for Riga. Since one-third of the population of the country lives in Riga and the city is located in the middle of Latvia, the authors argue that this is a better measure than average temperature in Latvia.

To capture seasonal trends, the authors also constructed an alternative measure - **daylight** - the number of minutes in a day (on average in a month) when the sun is up. This measure changes along with the seasons, so that including the daylight measure in the regression should capture seasonal patterns in consumption of electricity, increasing the explanatory precision of other variables.

The data about **refrigerators, microwaves, television sets, vacuum cleaners** and **washing machines** was collected from the CSB.

These were the variables to be used in the regressions. In the next section, the authors continue with tests to see whether times series have necessary attributes to be included in the regressions.

6. Preliminary Tests of Variables

In the previous section, the authors described all the variables, but before any time series can be regressed against one another, tests regarding the characteristics of the series have to be conducted.

6.1. Stationarity

An almost indispensable prerequisite for the time series is a stationarity. Therefore, any time series has to be tested against stationarity, where the time series is said to be stationary when “probability distribution does not change over time” (Stock and Watson, 2003, 447).

The authors used the Augmented Dickey-Fuller Test for Non-Stationarity, where the number of lags to be used in the test was calculated using Bayes Information Criterion[16]. If all the time series for the model turn out to be non-stationary and the time series are co-integrated, then no adjustments to the dataset are necessary. In contrast, if some variables are stationary and some are non-stationary, then differences between variables have to be taken and again tested for stationarity.

Augmented Dickey-Fuller Tests for Non-Stationarity showed that the only stationary time series is the dependent variable, residential demand for electricity[17]. When the time trend was included in the test[18], the electricity consumption series were stationary at a 5% significance level. All other variables were far from a 10% significance level. As all variables except for one were non-stationary, differences of the values had to be taken[19].

The authors generated a new time series, where the value at period *t* represented a change in value between the two periods, *t* and *t-1*. The new time series again had to be tested against stationarity and the tests showed that all variables, except for most measures of stock appliances, turned out to be stationary (see Appendix 5). Non-stationary time series of differences were for fridges, vacuum cleaners, washing machines and microwaves; only the time series of differences of TVs turned out to be stationary.

To summarize, the nominal values of the measures specified in the model could not be used in the regressions, as some of the series were non-stationary. In contrast, testing the time series of differences revealed that four of the stock appliance measures were non-stationary and all others were difference stationary. In the next section, the authors will test for another important characteristic - correlation.

[16] For an excerpt of the results see Appendix 6. For a description of the Bayes information criterion, refer to Stock and Watson (2003, 453)

[17] For a summary of Dickey-Fuller Tests for the main variables see Appendix 5.

[18] It is plausible to assume that consumption patterns have a time trend - see the previous section of the data description for a graph plotting the consumption of electricity over time.

[19] The theory would suggest using the logarithmic functional form of the model, but as some of the logarithmic time series turned out to be non-stationary and the differences of logarithms are harder to interpret, the authors decided to reject the logarithmic functional form.

6.2. Correlation Tests

In the previous section, the authors found out that from five measures of stock appliances only data on TVs was difference stationary, while others were difference non-stationary. This suggests that the measures of fridges, vacuum cleaners, washing machines and microwaves cannot be used in the regression. In order to see how much of the information (explanatory power) might be lost with the exclusion of the four time series, the authors conducted correlation tests between the stock appliances (see Table 1).

	tv	fridges	vacclean	washmach	microw~e
tv	1.0000				
fridges	0.9312	1.0000			
vacclean	0.9264	0.9843	1.0000		
washmach	0.9308	0.9771	0.9553	1.0000	
microwave	0.9446	0.9682	0.9703	0.9392	1.0000

Table 1. Correlation between the stocks of electric appliances
Source: STATA output

The correlation table shows that all measures of stock appliances are correlated for more than 90%, which implies that by including only TVs, of all five stock appliance measures, in the final regression the authors would not lose the explanatory power of stock appliances.

Because of the problems that correlation causes, the authors tested difference stationary independent variables for the correlation (see Table 2).

	d_pele~r	d_pgas	d_psol~l	d_pthe~n	d_tv	d_income	d_dayl~t
d_pelectr	1.0000						
d_pgas	0.0542	1.0000					
d_psolidfuel	0.0488	0.2849	1.0000				
d_pthermalen	0.0740	0.1719	0.0386	1.0000			
. d_tv	-0.0815	-0.0578	0.1932	0.0999	1.0000		
. d_income	-0.2909	0.2705	0.0595	0.0617	0.0508	1.0000	
. d_daylight	-0.0376	-0.2029	-0.2649	-0.2658	0.0069	-0.0266	1.0000

Table 2. Correlation matrix
Source: STATA output

None of the tested time series were correlated for more than 30%. If the temperature variable is used instead of the daylight variable in the correlation matrix, then the only correlation over 30% is between the temperature and the price of thermal energy (corr. coef.

= -0.3639); an outcome that can be explained by simple logic. Consequently, and taking into account that temperature and daylight are strongly correlated for both nominal and difference time series (a correlation of 86% and 44% respectively), the authors decided to use only one of the two measures in the final regression, namely, daylight.

6.3. Multicollinearity

The final regression equation was tested also for multicollinearity. To see if there is multicollinearity, the authors followed Hamilton and examined Variance Inflation Factors (2004, 166). The test showed that the sample under consideration does not exhibit multicollinearity (for results please refer to Appendix 7).

To sum up, after the tests the authors decided to use the time series of differences in the regressions, to use only the TV variable to account for the stock of electrical appliances, and to keep only one of the measures of seasonality, namely, the daylight variable.

7. Results

7.1. Inspection of Relationship

Before providing results of the regression, the authors examine two relationships of main interest: the relationship between electricity price and electricity consumption, and the relationship between household income and electricity consumption.

Figure 6 plots the price of electricity against household consumption of electricity. The plotted line shows a negative relationship – an increase in price is accompanied by a decrease in consumption. In contrast, high diffusion is a result of strong seasonality patterns in consumption and rare changes in price.

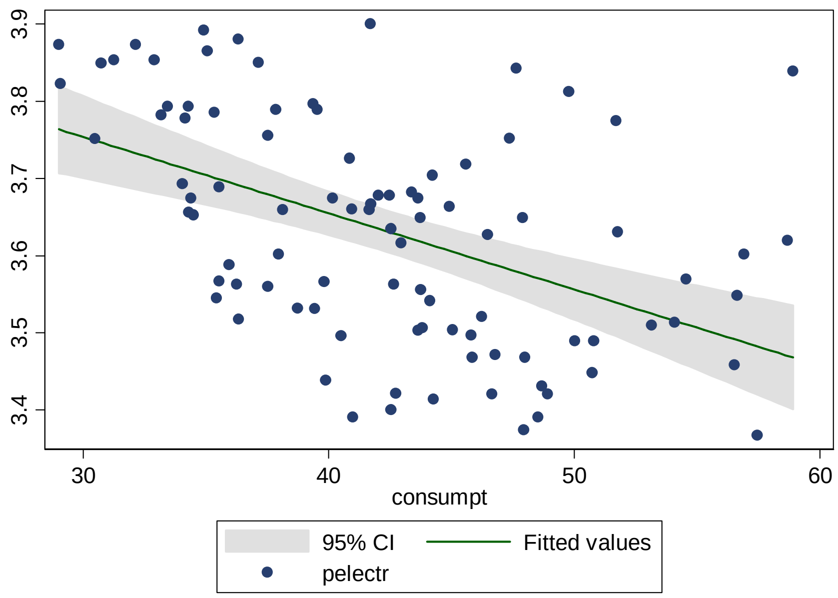

Figure 6. Electricity price against electricity consumption
Source: STATA output

A different relationship is observed between income and consumption of electricity (see Figure 7) - an increase in income is accompanied by an increase in consumption.

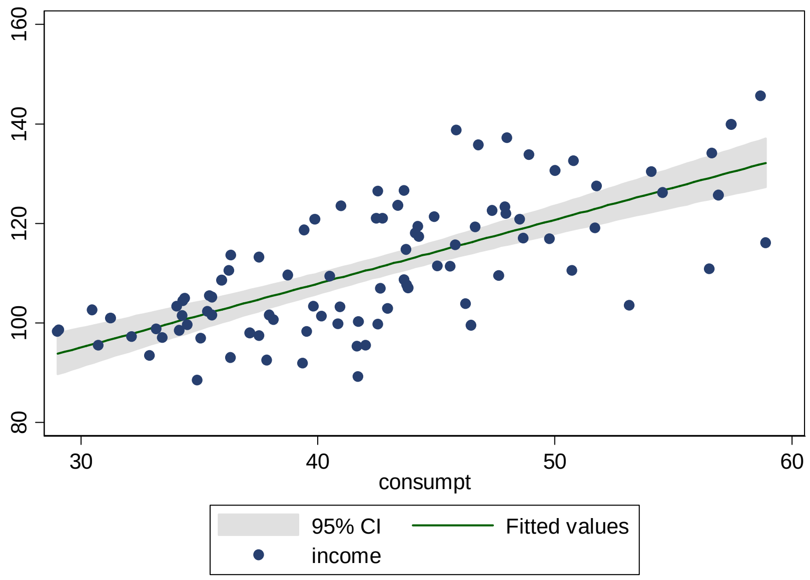

Figure 7. Household income against electricity consumption
Source: STATA output

7.2. Regression Results

Taking into account the limitations imposed by the preliminary tests, regression equation (9) was estimated. Unfortunately, it turned out that the price of solid fuel does not determine electricity consumption as was expected by the authors. To repeat, it was expected that the price of solid fuel would influence electricity consumption since a relatively large proportion of households in Latvia are located in the countryside, where potentially solid fuel is a close substitute for electricity. However, the coefficient on the price of solid fuel was insignificant independent of either the temperature or the daylight variable being used as a factor that controls for seasonality. Intuitively, the reason behind this kind of result could be that in general households actually do not choose between solid fuel and electricity but rather are concerned with the choice between solid fuel and such energy sources as gas. Accordingly, the price of solid fuel was dropped from the electricity demand equation.

Furthermore, the preliminary regressions yielded an insignificant coefficient on average temperature. Instead, as argued before, the authors used the daylight variable to account for seasonality in electricity demand. Consequently, the estimated residential electricity demand equation is (standard errors in parenthesis)[20]:

$$\underset{}{\Delta D_t} = \underset{(0.52)}{-0.39} - \underset{(6.44)}{3.10} * \Delta PE_{t-3} + \underset{(0.05)}{0.11} * \Delta Y_t + \underset{(34.05)}{44.58} * \Delta PG_{t-3} + \underset{(3.65)}{6.27} * \Delta PTE_{t-3} + \underset{(1.38)}{0.82} * \Delta TV_t - \underset{(0.003)}{0.016} * \Delta DL_t$$

Before turning to interpretation of the regression coefficients, a few words have to be said about insignificant variables included in the estimated residential electricity demand equation.

First, the price of natural gas is significant only at a 20% significance level. However, being the closest substitute for electricity (at least for households), the price of natural gas has been an important determinant of electricity demand in most previous studies. Accordingly, the authors here also decided to include it in the electricity demand equation, although it is significant only at a 20% significance level.

The coefficient on the stock of TV-sets turned out to be insignificant. However, theory (as discussed before) postulates that electricity demand is dependent upon the stock of electrical appliances. Moreover, the exclusion of TV-sets from the regression changed the coefficients

[20] The regression was estimated using the Ordinary Least Squares regression approach. For STATA output please refer to Appendix 3.

of interest. Therefore, TV-sets - although insignificant - are included to control for the stock of electrical appliances.

Because of the scope of this study, the authors do not concentrate on the interpretation of explanatory variables other than the price of electricity and income. However, a superficial inspection shows that estimates are in general in line with economic theory. Estimates of the price of gas and solid fuel are positive, which in turn means that cross-price elasticity is positive. This shows that electricity and natural gas (or equivalently, thermal energy) are substitutes. The sign of the coefficient on TV-sets is positive, meaning that an increase in the stock of TV-sets should be reflected by an increase in electricity consumption. However, this is not necessarily true because the coefficient on TV-sets was insignificant. Finally, the sign on the daylight measure is also consistent with simple logic – the longer the period when the sun is up, the lower the electricity demand.

If turning to the variables of main interest, then the results in general are as expected, and both proposed hypotheses can be accepted. The price of electricity turned out to be an insignificant determinant of residential electricity demand. However, the sign of the coefficient on electricity price is consistent, i.e. it is negative. The coefficient on the income variable, on the other hand, is significant at 5%.

8. Interpretation of Results

At this point, the authors stress once again that differences of values were used in the regression. Therefore, a coefficient on a measure shows the effect that an increase/decrease in a change in values over periods (change rate) for independent variables would have on the change in the dependent variable, holding all other effects constant. The intuition behind the coefficients of the regression is rather confusing[21], hence the authors turn to the main purpose of the research - estimation of price elasticity of electricity demand and income elasticity.

To repeat, price elasticity measures a percentage change in demand from a 1% increase in the price of the good. The authors calculated the price elasticity of electricity demand using average values (means) of the price of electricity and consumption for the observed period since Jan 1998. The short-run price elasticity of residential electricity demand thus is[22]:

[21] The authors here do not explain how a change in a change of the regressor influences change in a change of the regressed.
[22] Calculation of price elasticity is made only for representative purposes. The authors remain extremely cautious about this because an insignificant coefficient is used. Rather, they postulate that price elasticity is zero.

$$\varepsilon = \frac{3.63}{42.35} \times (-3.10) = -0.266.$$

Similarly as with price elasticity of demand, the regression coefficient is used to obtain income elasticity. The short-run income elasticity of residential electricity demand is:

$$\varepsilon = \frac{110.92}{42.35} \times (0.11) = 0.288.$$

Only estimated income elasticity can be compared with other studies that have touched upon the residential market and short-run estimates, because the coefficient on the electricity price variable was insignificant and the authors estimate price elasticity to be zero. The income elasticity obtained seems to be quite similar to that in other countries; however, it is also the highest (see Table 3). This indicates that in Latvia the residential demand for electricity in the short-run is more dependent on income that households have at their disposal than in other countries. Other studies show that in general price elasticity in the short-run it is close to zero.

		Short-run	
Authors	**Country**	**Price elasticity**	**Income elasticity**
Fisher & Kaysen	U.S.	-0.15	0.10
Houthakker & Taylor	U.S.	-0.13	0.13
Mount, Chapman, & Tyrrell	U.S.	-0.14	0.02
Politukha	Ukraine	-0.16	
McFadden	U.S.	-0.37	0.20
Diabi	Saudi Arabia	–0.12	0.14
Holtedahl & Joutz	Taiwan	-0.14	0.25

Table 3. The comparison with other studies
Source: Taylor (1975); Politukha (2002); Diabi (1998); Holtedahl and Joutz (2000).

9. Conclusions

The results of this study suggest that residential electricity consumption is independent of price changes, at least in the short-run. Based on monthly data from 1998 to 2005, the authors found price elasticity to be an insignificant determinant of residential electricity demand. The authors believe that this result is feasible, for two reasons. First, consumption of electricity in Latvia starts from a relatively low base, meaning that electricity expense constitutes only a small portion of household budget. Second, the price level of electricity is very low and does not represent the costs it should. Consequently, households are not concerned with increase in the price as long as the electricity expense constitutes a small portion of their budget and as long as the relative change in price is small. However, the increasing level of living standards will lead households to change their position with respect to changes in electricity price, as the experience of other countries has shown.

This study reveals that residential demand for electricity is, rather, determined by household income and seasonal factors. Estimated short-run income elasticity turned out to be 0.29. This result is not surprising, because an increase of household income may well be associated with an increasing level of living standards, which in turn leads to higher electricity demand. In contrast, the coefficient on the daylight variable was significant even at 1%, which means that the results of this study once more have proved that electricity demand exhibits a clear seasonal trend.

Some results were also surprising, at least for the authors. Firstly, the price of natural gas proved to be a less significant determinant of residential electricity demand than expected based on the results in previous studies. Second, the hypothesis that solid fuel could be a substitute for electricity was rejected. Thirdly and finally, it was surprising that the measure of daylight (introduced and computed by the authors themselves) was a more significant determinant of electricity demand than average temperature, suggesting that households use electricity for lighting rather than heating.

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Appendix 1. Electricity Balance of Latvenergo

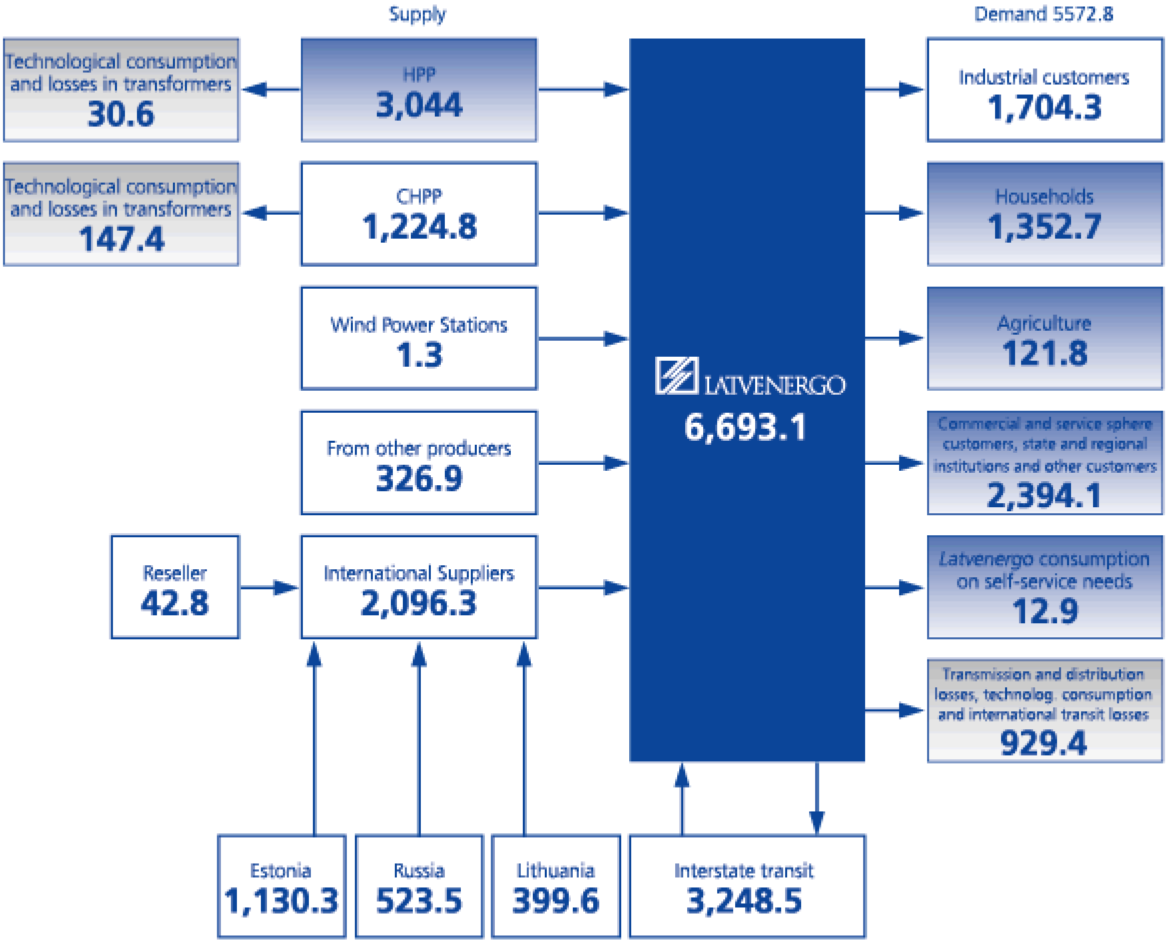

Figure A1. **Electricity Balance of Latvenergo**
Source: Latvenergo Home Page

Appendix 2. Summary Statistics

Variable	Observations	Mean	Standard deviation	Min	Max
consumpt	93	42.35	7.21	29.02	58.90
pelectr	93	3.63	0.15	3.37	3.90
income	93	110.92	13.17	88.44	145.59
pgas	93	0.53	0.04	0.47	0.59
pthermalen	93	15.59	0.32	14.45	16.26
psolidfuel	93	37.70	3.22	33.85	45.11
tv	93	107.98	7.35	92.83	120.75
fridges	93	93.64	3.17	90.00	100.25
vacclean	93	66.62	3.71	61.00	74.25
washmach	93	76.45	4.25	71.00	83.50
microwave	93	8.72	5.23	3.08	20.25
temp	93	7.52	8.00	-6.80	21.40
daylight	93	746.94	222.98	411.58	1065.37
d_consumpt	92	0.08	3.90	-9.11	10.49
d_pelectr	92	-0.01	0.05	-0.05	0.47
d_income	92	0.48	6.98	-23.84	18.12
d_pgas	92	0.00	0.01	-0.03	0.08
d_pthermalen	92	-0.01	0.10	-0.22	0.46
d_psolidfuel	92	0.02	0.65	-2.35	3.84
d_tv	92	0.30	0.27	0.00	0.83
d_fridges	92	0.09	0.13	-0.17	0.25
d_vacclean	92	0.11	0.16	-0.25	0.25
d_washmach	92	0.11	0.20	-0.17	0.42
d_microwave	92	0.19	0.15	0.00	0.50
d_temp	92	100.69	10.70	81.13	123.25
d_daylight	92	3.44	116.95	-145.47	146.74

Table A1. Summary statistics of variables
Source: STATA output

Appendix 3. STATA Output for Estimated Regression

```
. reg  d_consumpt l3.d_pelectr l3.d_pgas l3.d_pthermalen d_tv d_income
d_daylight

      Source |       SS       df       MS              Number of obs =      89
-------------+------------------------------           F(  6,    82) =    7.33
       Model |  461.846134     6  76.9743556           Prob > F      =  0.0000
    Residual |  860.635736    82  10.4955578           R-squared     =  0.3492
-------------+------------------------------           Adj R-squared =  0.3016
       Total |  1322.48187    88  15.0282031           Root MSE      =  3.2397

------------------------------------------------------------------------------
d_consumpt   |      Coef.   Std. Err.      t    P>|t|  [95% Conf. Interval]
-------------+----------------------------------------------------------------
d_pelectr    |
          L3 |  -3.102308   6.436839    -0.48   0.631   -15.90723    9.702615
d_pgas       |
          L3 |   44.58312    34.0512     1.31   0.194   -23.15557    112.3218
d_pthermalen |
          L3 |   6.267604   3.646244     1.72   0.089   -.9859362    13.52114
d_tv         |   .8235368   1.381668     0.60   0.553   -1.925041    3.572115
d_income     |   .1140672   .0507586     2.25   0.027    .0130921    .2150422
d_daylight   |  -.0157507   .0030325    -5.19   0.000   -.0217833   -.0097182
_cons        |  -.0386108   .5231632    -0.07   0.941   -1.079349    1.002127
------------------------------------------------------------------------------
```

Figure A2. STATA output for estimated regression
Source: STATA output

Appendix 4. Real Prices of Electricity Substitutes

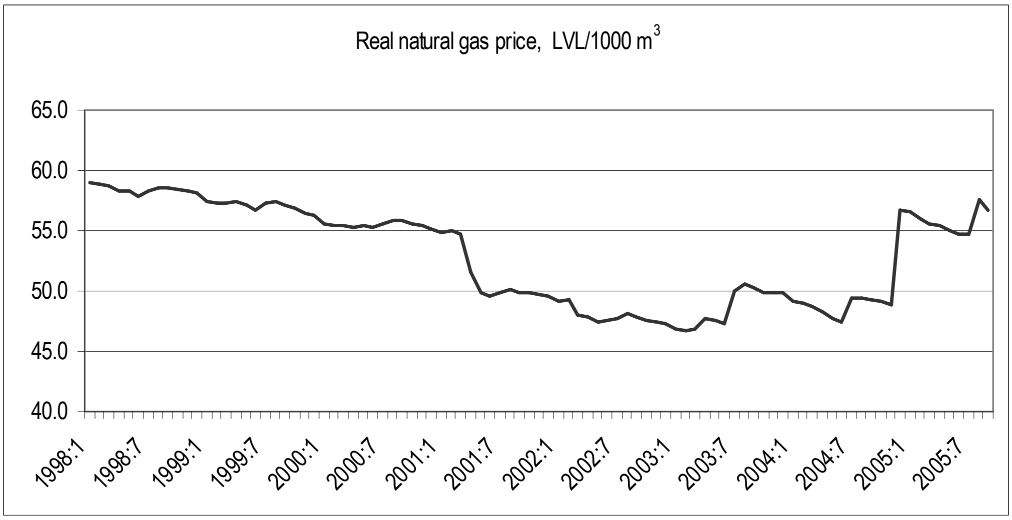

Figure A3. The real price of natural gas
Source: CSB, own calculations

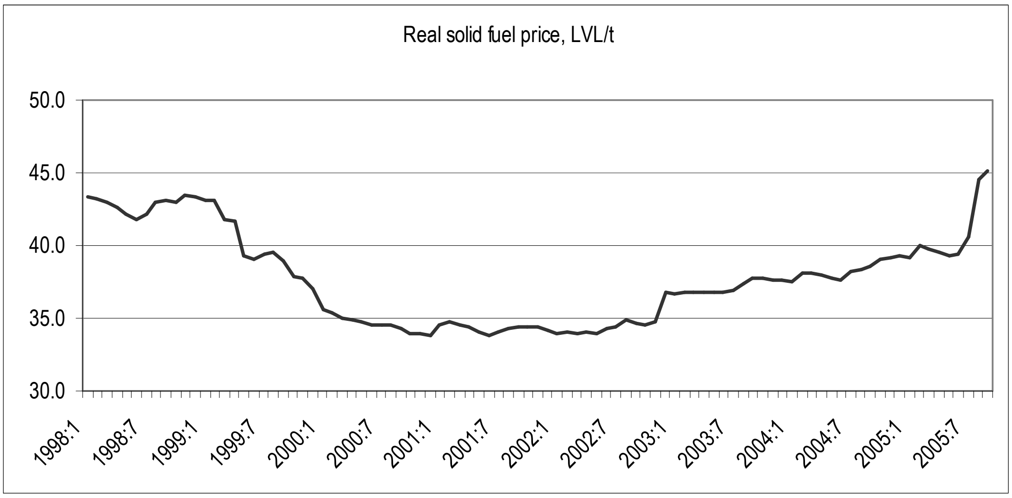

Figure A4. The real price of solid fuel
Source: CSB, own calculations

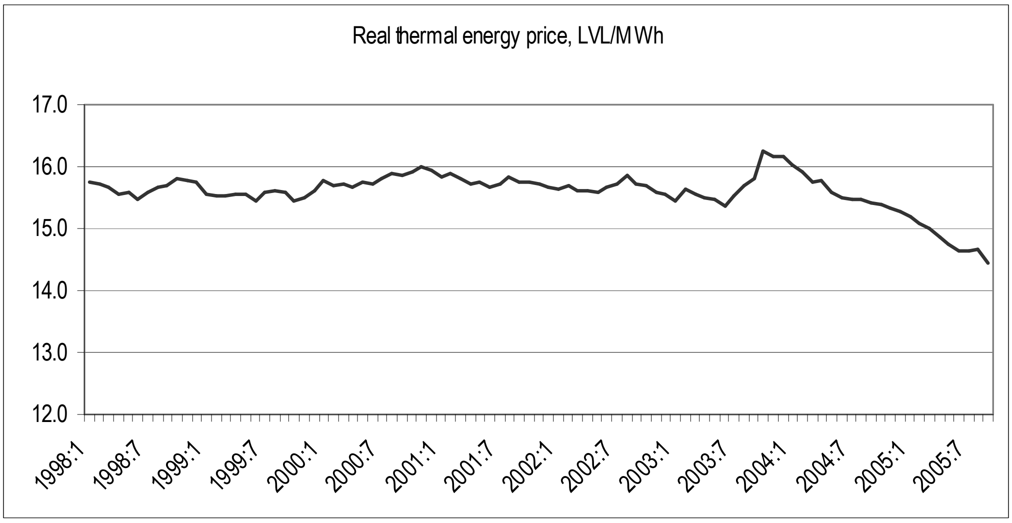

Figure A5. The real price of thermal energy
Source: CSB, own calculations

Appendix 5. Excerpt from Augmented Dickey-Fuller Test for Non-Stationarity

Variable	Values	Lags	Trend	t-statistic	5% crit. lev.	10% crit. lev.	Result
Consumption	Nominal	1	N	-2,458	-2,897	-2,584	Non-stationary
	Nominal	1	Y	-4,127	-3,459	-3,155	Stationary at 5 %
Price Electricity	Nominal	1	N	-1,972	-2,897	-2,584	Non-stationary
	Nominal	1	Y	-2,551	-3,459	-3,155	Non-stationary
Gas Price	Nominal	1	N	-1,543	-2,897	-2,584	Non-stationary
	Nominal	1	Y	-0,589	-3,459	-3,155	Non-stationary
Therm.En.Pr.	Nominal	1	N	0,257	-2,897	-2,584	Non-stationary
	Nominal	1	Y	-0,384	-3,459	-3,155	Non-stationary
Income	Nominal	7	N	1,266	-2,902	-2,586	Non-stationary
	Nominal	7	Y	-1,505	-3,465	-3,159	Non-stationary
Consumption	Differences	1	N	-6,285	-2,898	-2,584	Stationary at 5 %
Price Electricity	Differences	3	N	-5,520	-2,900		Stationary at 5 %
Gas Price	Differences	4	N	-3,690	-2,900		Stationary at 5 %
Therm.En.Pr.	Differences	3	N	-4,574	-2,900		Stationary at 5 %
Income	Differences	6	N	-6,045	-2,902		Stationary at 5 %
TV	Differences	8	N	-3,998	-2,904	-2,587	Stationary at 5 %
Fridges	Differences	6	N	-2,238		-2,586	Non-stationary
Vac. Cleaners	Differences	5	N	-1,919		-2,586	Non-stationary
Wash. Mach.	Differences	6	N	-2,325		-2,586	Non-stationary
Microwave	Differences	5	N	-1,669		-2,586	Non-stationary

Table A2. Excerpt from Augmented Dickey-Fuller Test for Non-stationarity
Source: STATA output

Appendix 6. Excerpt of Results of Bayes Information Criterion

Variable	p	SSR(p)	SSR(p)/T	ln(SSR(p)/T)	(p+1)(ln(T))/T	BIC(p)	R-squared
Consumption	0	4777,1069	51,3667	3,9390	0,0487	3,9877	0,0000
	1	**1289,5031**	**13,8656**	**2,6294**	**0,0975**	**2,7269**	**0,7300**
	2	1240,0416	13,3338	2,5903	0,1462	2,7365	0,7373
	3	1203,3196	12,9389	2,5602	0,1950	2,7552	0,7430
Electricity price	0	1,9998	0,0215	-3,8396	0,0487	-3,7908	0,0000
	1	**0,2500**	**0,0027**	**-5,9189**	**0,0975**	**-5,8215**	**0,8703**
	2	0,2496	0,0027	-5,9207	0,1462	-5,7745	0,8656
	3	0,2489	0,0027	-5,9234	0,1950	-5,7285	0,8611
	4	0,2482	0,0027	-5,9261	0,2437	-5,6824	0,8572
Gas Price	0	0,1584	0,0017	-6,3751	0,0487	-6,3263	0,0000
	1	**0,0102**	**0,0001**	**-9,1185**	**0,0975**	**-9,0210**	**0,9341**
	2	0,0102	0,0001	-9,1211	0,1462	-8,9749	0,9327
	3	0,0101	0,0001	-9,1248	0,1950	-8,9298	0,9313
Therm. En. Pr.	0	9,3970	0,1010	-2,2922	0,0487	-2,2435	0,0000
	1	**0,9276**	**0,0100**	**-4,6078**	**0,0975**	**-4,5103**	**0,9010**
	2	0,9149	0,0098	-4,6216	0,1462	-4,4753	0,9022
	3	0,8767	0,0094	-4,6642	0,1950	-4,4693	0,9062
Income	0	15965,9231	171,6766	5,1456	0,0487	5,1944	0,0000
	1	4123,7156	44,3410	3,7919	0,0975	3,8894	0,7338
	2	3699,3993	39,7785	3,6833	0,1462	3,8295	0,7528
	3	3123,4878	33,5859	3,5141	0,1950	3,7091	0,7864
	4	2892,5928	31,1031	3,4373	0,2437	3,6810	0,7976
	5	2655,8512	28,5575	3,3519	0,2924	3,6443	0,8106
	6	2512,4310	27,0154	3,2964	0,3412	3,6376	0,8184
	7	**2359,2201**	**25,3680**	**3,2335**	**0,3899**	**3,6234**	**0,8279**
	8	2313,7854	24,8794	3,2140	0,4386	3,6527	0,8287
	9	2299,0406	24,7209	3,2076	0,4874	3,6950	0,8268
	10	2180,6924	23,4483	3,1548	0,5361	3,6909	0,8326

Table A3. Excerpt of results of Bayes Information Criterion
Source: STATA output

Note: p is the number of lags in the auto regression and lag length has to be selected where BIC value is the lowest.

Appendix 7. Test for Multicollinearity

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
L3.d_pther~n |      1.13    0.887427
    d_income |      1.08    0.922319
  L3.d_pgas |      1.05    0.949398
  d_daylight |      1.04    0.959203
        d_tv |      1.02    0.980100
L3.d_pelectr |      1.02    0.980422
-------------+----------------------
    Mean VIF |      1.06
```

Figure A6. VIF test for multicollinearity
Source: STATA output

Note: the Variance Inflation Factors show what proportion of an explanatory variable's variance is independent of all the other x variables. A low proportion (for example, .10) indicates potential problems.

Appendix 8. List of Interviewees

- Mr.Ainārs Čunčulis, Head of the Energy Department, Public Utilities Commission (13 Dec. 2005).
- Mr.Andris Cakuls, Head of the Trading Department, Latvenergo (18 Jan. 2005).
- Mr.Juris Ozoliņš, special advisor of European Commission in energy related issues (29 Dec. 2005).
- Mr.Matīss Paegle, ex-member of the Board of Directors, Latvenergo (5 Dec. 2005).
- Mr.Mikus Janvars, Strategic Project Manager, Riga Stock Exchange (10 Nov. 2005).
- Mr.Uģis Sarma, head of the Energy Department, Ministry of Economics (28 Dec. 2005).
- Mr.Uldis Bariss, member of the Board of Directors, Latvenergo (16 Dec. 2005).