CHARLES UNIVERSITY IN PRAGUE

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Institute of Economic Studies

Jana Hortová

Price elasticity of household water demand in Czech Republic

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Author: **Jana Hortová**

Supervisor: **PhDr. Ladislav Krištoufek**

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Abstrakt

Během posledních desetiletí se v České republice stále zvyšují ceny vody, což vede k následnému snižování její spotřeby. Tomuto tématu se věnuje velké množství studií, ale dle našich zjištění se žádná z nich nezabývá Českou republikou. Obecně lze říci, že hlavním cílem této práce je nalezení krátkodobé a dlouhodobé cenové elasticity poptávky po vodě v České republice a následně v Kladně. Při zkoumání poptávky po vodě v Kladně vyšetřujeme cenovou elasticitu v závislosti na odlišném počtu členů v domácnostech. V obou případech dojdeme k závěru, že poptávka je neelastická v krátkém i dlouhém časovém období. Dále zjistíme, že cenová elasticita roste s klesajícím počtem členů domácností v obou časových obdobích. Naše výsledky jsou v souladu se závěry ostatních studií.

Klíčová slova cena vody, spotřeba vody, cenová elasticita, domácnosti, Česká republika, Kladno

E-mail autora `Janca.Hortova@seznam.cz`

E-mail vedoucího práce `kristoufek@ies-prague.org`

Abstract

In the Czech Republic, during last decades, water price steadily increases causing water consumption to steadily decrease. A great deal of literature is devoted to the price elasticity of water demand but to the best of our knowledge, no similar study has been devoted entirely to the Czech Republic. The general purpose of this thesis is finding the short and long-run price elasticities of water demand in the Czech Republic and in Kladno. In the latter case, we analyze the short and long-run price elasticities of water demand across different household sizes. In both cases water demand appears to be inelastic with respect to water price regardless of the time period. Moreover, we find evidence that both the short and long-run price elasticities increase with decreasing household size. Our inferences are in line with previous findings.

Keywords water price, water consumption, price elasticity, households, Czech Republic, Kladno

Author's e-mail `Janca.Hortova@seznam.cz`

Supervisor's e-mail `kristoufek@ies-prague.org`

Declaration of Authorship

I hereby proclaim that I wrote my bachelor thesis on my own under the leadership of my supervisor and that the references include all resources and literature I have used.

I further declare that the thesis has not been used to acquire another academic degree.

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Prague, May 14, 2013

Signature

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Project of Bachelor Thesis

Author of the thesis:	**Jana Hortová**
Supervisor of the thesis:	**PhDr. Ladislav Krištoufek**

Theme: **Price elasticity of household water demand in Czech Republic**

Goals of the thesis:

According to the economic theory, water is normal goods. The consumption of these goods decreases with increasing price. The price elasticity is therefore negative. The water progress and relationship between the price and the consumption in the Czech Republic in the last 12 years will be devoted in the first part of the thesis. In the second part of the thesis household water consumption and price in Kladno will be focused on. In this part we use data provided by SUNNY Kladno s.r.o. správa nemovistostí. In both parts we will try to find out whether water demand is either elastic or inelastic. The econometric models relating water consumption and water price will be used to answer this question. The results will then be compared with economic expectations and findings of previous researches.

Preliminary structure of the thesis:

1. Literature review
2. Water market in the Czech Republic
3. Water market in Kladno

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Jana Hortová

PhDr. Ladislav Krištoufek

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Acronyms

2SLS	Two-stage Least Squares
Avg	Average
CPI	Consumer Price Index
CZK	Czech crown
EU	European Union
GMM	Generalized Method of Moments
LM test	Lagrangian multiplier test
mm	Millimeter
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
Sb.	Sbírky (Coll)
SD	Standard Deviation
s.r.o.	Společnost s ručením omezeným (Limited company)
USA	United States of America
VAT	Value Added Tax

1 Introduction

While the pricing structures vary across countries and sometimes even across different parts of the country, almost everywhere the price increases in time. Each country in the EU is obligated to comply water requirements that ordinarily induce huge costs. These are ultimately transferred to consumers through higher water price. On the other hand, authorities in same countries exploit higher water price to subsequently achieve reduced water consumption. The most widespread reasons why they attempt to contract water consumption are changes in climate, the effort to prevent water wastage, the concern for future water deficit and growing population.

We present the Czech Republic as an example of rising prices. While in 2000 the consumers paid on average 32.98 CZK (including VAT) per cubic metre of water, in 2011 they paid on average 64.57 CZK (including VAT) for the same cubic metre of water. From this follows that during relatively short time period prices are almost twice higher. A similar trend can be found in many other countries.

According to the economic theory consumers are viewed as rational agents and water is supposed to be normal goods. We therefore expect a decrease of water consumption when the price of water increases and vice versa. The price elasticity, which measures the percentage change in the consumption given the percentage change in the price (Schotter, 2008), has been studied by various researchers from many countries.

Beside price, many other factors affecting water demand have been shown. These include personal income, temperature, precipitation, household size and age composition of the population. The primary interest of the following researchers lies in the price elasticity of water demand and in addition Bartczak *et al.* (2009) and Rinaudo *et al.* (2012) analyze the effect of income on water consumption, Worthington *et al.* (2009) study the impact of temperature and precipitation, Arbués *et al.* (2010) investigate the household size and age composition.

Even though the thesis has two targets, generally it can be said that the primary objective is to find both the short and long-run price elasticities of household water demand. We firstly analyze the Czech Republic and provide the elasticity of household water demand with respect to price in the short and long-run period. Then we concentrate on household water consumption of people living in flats in Kladno. We carry out an empirical estimation to find out the short and long-run price elasticities of household water demand across different household sizes.

Although the vast majority of literature is based on a static approach, we believe that past consumption can affect future consumption and therefore employ a dynamic approach in both the Czech Republic and Kladno case. In investigation of the Czech Republic we use regional data on household water consumption for period 2000 to 2011. The effect of price, income, temperature, precipitation and share of the population aged more than 65 years is analyzed through the log-log model specification. We comment on endogeneity that can be potentially presented in the model and perform tests to decide about the most appropriate technique to estimate the water demand model. In case of Kladno, household level data for period 1997 to 2011 for people living in flats in Kladno are investigated. The log-log model specification is again used. Price is introduced in multiplicative forms with all except one size dummy variables and it is thereby possible for the price elasticity to vary across different household sizes. The proxy for the lagged consumption is also presented in the model in multiplicative forms with all except one size dummy variables. Besides multiplicative forms of price and proxy for the lagged consumption, the area of dwelling enters the water demand equation.

The outcomes from both the Czech Republic and Kladno case suggest that water demand is inelastic with respect to price regardless of the time period. Furthermore, water demand is shown to be more elastic in the long-run than in the short-run. In investigating the price elasticity of water demand in the Czech Republic, the short-run price elasticity is determined to be -0.20 while the long-run price elasticity is -0.54. Having a closer look at Kladno, we determine the price elasticities to decrease with an increasing household size in both the short and long-run period. The short-run price elasticities range from -0.67 to -0.33 and the long-run price elasticities vary from -0.81 to -0.32. The conclusions and estimated values from both the Czech Republic and Kladno case are consistent with findings of previous studies.

The structure of the thesis is as follows: Section 2 provides a review of relevant literature. In Section 3 we briefly describe the water market. The investigation of the Czech Republic is presented in Section 4 where the data and methodology, model specification and empirical results can be found. Section 5 is devoted to Kladno. It again covers the data and methodology, model specification and empirical results. Section 6 summarizes the thesis and brings the concluding remarks.

2 Literature review

A great deal of literature relating to the price elasticity of water demand can be found. Many researchers have been engaged in this issue mainly during the last decades. Unfortunately, the majority of studies is devoted to the United States of America (USA) and fewer of them focus on European countries. In these papers slightly different techniques, approaches, variable selections and sampling periods are used. It is thus not surprising that the estimated price elasticities vary substantially across distinct studies. In spite of this fact, all the researchers find out water demand to be inelastic with respect to water price. The following section presents a brief summary of the relevant studies. We mainly focus on literature introduced in European countries. To the best of our knowledge, no similar study has been devoted entirely to the Czech Republic.

The evidence of study's diversities is reviewed in Arbués *et al.* (2003) where the main researches relating to water demand are surveyed. At the beginning, the typology and objectives of several different kinds of water pricing are presented. Then literature is sorted and compared according to variable selection, model specification and estimation, data set and econometric problems. According to the paper, the most common used variables are water price, income, weather variables (temperature, precipitation) and household characteristics (household composition and size, number of bathrooms, ownership of various devices). The survey concludes that despite the great varieties in study's approaches water demand is rather inelastic with respect to water price.

Most of the papers related to the water demand model are based on a static framework. Musolesi & Nosvelli (2007) proposed to apply a dynamic framework since they assume it can characterize the household behaviour much better. The sampling period is from 1998 to 2001 and the panel data consists of 102 Italian municipalities. The generalized method of moments (GMM) is applied for the log-log model specification with the consumption as the dependent variable and the lagged consumption, the average price of water, the average per-capita income and share of population older than 65 years as the independent variables. The main goals are the short and long-run price elasticities. According to the model outcomes, these turn to be -0.27 and -0.47, respectively. In absolute values, the short-run elasticity is approximately by 1.7 lower than the long-run elasticity. This implies that water demand is less elastic in the short-run than in the long-run which is the main contribution of this study.

The aforementioned diversities can be also observable in Worthington & Hoffman (2008). It brings another investigation of literature relating to water demand published predominantly since 1980. More than a half of analyzed studies is devoted to the USA, a quarter to Europe and the rest comes from Australia. The most frequently used independent variables including price, income, weather, seasonal factors, household composition and other factors (such as campaigns for water conservation) are discussed. Beside the specification of variables, the estimation techniques and model results are surveyed. Likewise Arbués *et al.* (2003), also this paper finds out water demand to be inelastic with respect to water price. Moreover, the price elasticity is concluded to be higher in the long-run than in the short-run, both in absolute values. Finally, water demand appears to be inelastic with respect to income but the effect is rather small in magnitude.

The empirical study of Bartczak *et al.* (2009) analyzes water demand model of our neighbouring country Poland for the time period 2001 to 2005. A panel of municipal districts with more than 50 000 people is used in the study. The random effect model shows up to be more appropriate through the Hausman test. The model's dependent variable is average water consumption per capita per day and the independent variables are total water price (the sum of water and sewage tariffs), the average income per capita and the number of household members. In a static model the price elasticity is predicted to be -0.22 whereas the income elasticity is predicted to be 0.12.

Residential water demand in Germany is explored by Schleich & Hillenbrand (2009) using the cross-sectional data set. In their study average water consumption is regressed on price, income, squared term of income, household size, the age of the population, the share of wells and weather variables. Besides the log-log model, another two functional forms are specified including semi-elasticities. In the first one, the dependent variable is in natural form rather than in logarithmic while in the second one, the independent variable price is in natural form rather than in logarithmic. The outcomes are almost identical when estimating them by the ordinary least squares (OLS). For these models the estimated price elasticities are -0.24, -0.25 and -0.23, respectively. On the other hand, the resulted income elasticities are 0.36, 0.37 and 0.35, respectively.

Worthington *et al.* (2009) study residential water demand in Queensland, Australia from 1994 to 2004. The study employs data on household water consumption and connection in eleven local governments. The model uses average monthly household water consumption as the dependent variable. The increasing block pricing is commonly applied in Queensland and the paper thus proposes to include the marginal and average price. At first the marginal price is used as the independent variable and then the model is reestimated using the average price. Another two independent variables entering the model are daily average maximum temperatures and the amount of rainfall. In the paper the common, the fixed and the random effects regression model are employed to estimate the price elasticity. Under the marginal price model only common effect provides significant result and the price elasticity is estimated to be equal to -0.11. Under the average price model the fixed effect is assessed to be used through the Hausman test. The resulted price elasticity is -0.13. The main outcome of this paper is that residential water consumption is more sensitive to the average than marginal price.

Arbués *et al.* (2010) examine how the household responds to the changes in water price differ among different household sizes. With the use of a panel of Spain households the period from 1996 to 1998 is examined. The paper studies the water demand model of the semi-logarithmic form. The model's dependent variable is daily household water consumption and the independent variables are two-lagged average price, percentage of days where the temperature is above 18°C, fiscal value of the dwelling, dummy variables linked to the age composition of household members, dummy variables that account for the number of household members. It is concluded that all households adjust their water consumption regardless of the household size. The semi-elasticities vary in a range from -1.32 (for households with a single member) to -0.26 (for households with more than 5 members) suggesting that households with fewer members are more sensitive to the changes in water price.

Grafton *et al.* (2011) enrich the literature by cross-country survey. The household level data on ten OECD countries are used in this study. Apart from the Czech Republic, Australia, Canada, France, Italy, South Korea, Mexico, the Netherlands, Norway and Sweden are analysed in 2008. The changes in weather and growing population bring higher water consumption. Authorities in many countries are thus concerned with possible future water deficit. They effort to decrease water consumption by introducing volumetric water prices, subsidising water-saving devices or organizing campaigns to encourage people to conserve water. The paper concludes volumetric water prices to be the most efficient way how to achieve this goal. More relevant findings are the price elasticity equal to -0.43 and the income elasticity equal to 0.11. These are obtained by regressing household water consumption on average water price and set of other characteristics including for example income, household size and weather variables. The paper indicates the same trends as prior shown, consumption is negatively related to water price but positively related to income.

Ciomoş *et al.* (2012) investigate the effect of increasing water price on residential water consumption in Romania for period 2002 to 2010. Romania needs to follow the regulations of the European Union (EU) concerning the water and the wastewater quality. To meet them, the water quality needs to be improved and the access to the water and wastewater infrastructure needs to be extended. For this reason, many investment projects largely financed from the EU and the Government sources take place in Romania. A smaller part is paid by water operators. Since they need to take a loan to finance the investments, the tariffs need to be augmented. In 2010 the tariffs are more than twice as high as in 2002. The price elasticity of residential water demand is analyzed by regressing water consumption on price and population served with water. Employing the OLS, the price elasticity of residential water demand is determined to be -0.70.

Rinaudo *et al.* (2012) carry out an empirical study relating to Southern France. A huge water deficit is expected in this part of the country by 2020 caused mainly by population growth and enormous water needs in agriculture. The authorities thus attempt to overtake this situation by water pricing. The cross-sectional data for 300 municipalities in 2005 is used to estimate the regional water model. Usual OLS is performed to estimate the model of log-log form with annual water consumption per capita standing for the dependent variable, and marginal price, average income per household in municipalities, household size, temperature and costs for drilling a well if possible for independent variables. The resulting price elasticity is -0.18 and the income elasticity is 0.42. Beside the price elasticity, Rionaudo and Montgioul brought additional contribution to already existing literature. They create the simulation model to be able to simulate changes in water consumption under various price alternatives. Although this part of the paper is highly interesting, it is not commented on as it is not of our primary interest.

Cyprus is another country where the authorities need to regulate water consumption through water pricing to avoid future water scarcity. Polycarpou & Zachariadis (2013) econometrically assess the price elasticity of water demand using quarterly household level data on tree districts. For period 2001 to 2009 water consumption, income, price, temperature, precipitation and dummies for two districts enter the water demand model where water consumption is of course the dependent variable. Since people are charged according to the increasing block pricing, the water demand model is estimated with the average price and then reestimated with the marginal price. Using the two-stage least squares (2SLS) (where CPI of the previous year, water sales costs in the previous year and forecasted sales costs for the current year are the instruments) the price elasticity is ranging from -0.25 to -0.45. The income elasticity is also in line with previous findings, it takes values between 0.53 and 0.75.

3 Water market

Water is used for a great deal of daily activities. We present a list of such activities together with the volume of water that is involved: flushing the toilet 10 - 12 litres, having a shower 60 - 80 litres, having a bath 100 - 150 litres, one cycle of the dishwasher 15 - 30 litres, one cycle of the washing machine 40 - 80 litres, washing your hands 3 litres, washing a car 200 litres, for drinking 1.5 litres, water used in the kitchen every day 5 - 7 litres. Sometimes an accident happens resulting in higher water expenditures. For example, when the tap is dripping for one hour, then 4 litres of water are wasted and with a leaking toilet even 80 litres (Ondeo Česká Republika, 2008).

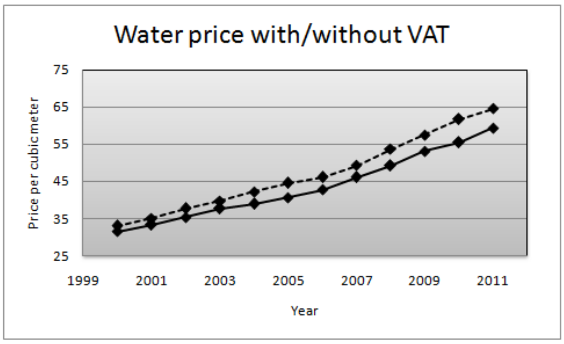
Likewise in other countries, also in the Czech Republic water prices charged by individual water producers are considerably different. Beside spatial distribution of consumers and the degree of utilization of water and sewage capacity, the main reasons for such disparities are the amount of rent and of depreciation, overhead costs, labour costs, construction and reconstruction costs (Ruszová, 2004).

The types of pricing schedules vary substantially across countries. In the Czech Republic, consumers are subjects to a fixed volumetric charging. It means they pay the same price per each unit of water consumed. Water companies charge you not only for water consumption but also for the wastewater treatment. Thus, the total price paid by consumers consists of the sum of water and sewage tariffs and added reduced rate value added tax (VAT). The total price does not increase only due to the growth of water and sewage tariffs. Some portion is caused by an augmentation of the reduced rate VAT. The reduced rate VAT has changed only four times since the Czech Republic was established in 1993. It was 5% until 2007 (act 258/1994 Sb.), then almost doubled to 9% in 2008 and 2009 (act 261/2007 Sb.), from 2010 to 2011 it was 10% (act 362/2009 Sb.), in 2012 it increased up to 14% and this year it is already 15% (act 500/2012 Sb.).

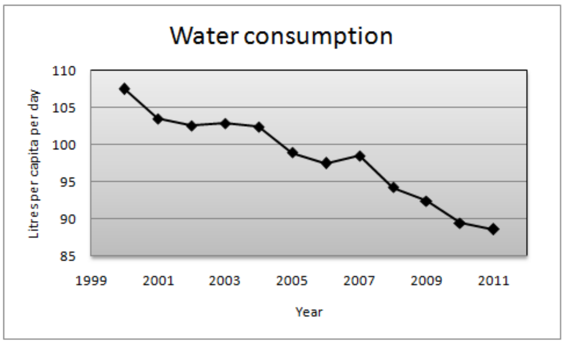
As a member of the EU, the Czech Republic needs to meet the Directives issued by the Council of the EU. The Directives concern with the quality of drinking water, wastewater treatment plants and the expansion of water networks (*Vodovody* *a kanalizace ČR 2000*, 2000). Constructions of new and reconstructions of old wastewater treatment plants and water networks are associated with huge costs. They are partly financed from the national budget and the EU funds. The rest of the costs is borne by producers and they usually finance them through loans. To be able to repay them, water price is steadily augmented.

The progress of water price for the Czech Republic for period 2000 to 2011 is depicted in Figure 3.1(a). The bottom solid line represents average water price per year without VAT and the upper dashed line stands for average water price including the reduced rate VAT [1]. In Figure 3.1(b) household water consumption is presented as the amount of water consumed per person per day from 2000 to 2011. The opposite trends can be seen in these two figures. We observe an augmentation trend in the left part indicating a continuous growth of water price regardless the reduced rate VAT is included or not. A descending trend can be found in the right part indicating a predominant decrease of water consumed.

Figure 3.1: Water price and consumption in the Czech Republic



(a) Average water price per year



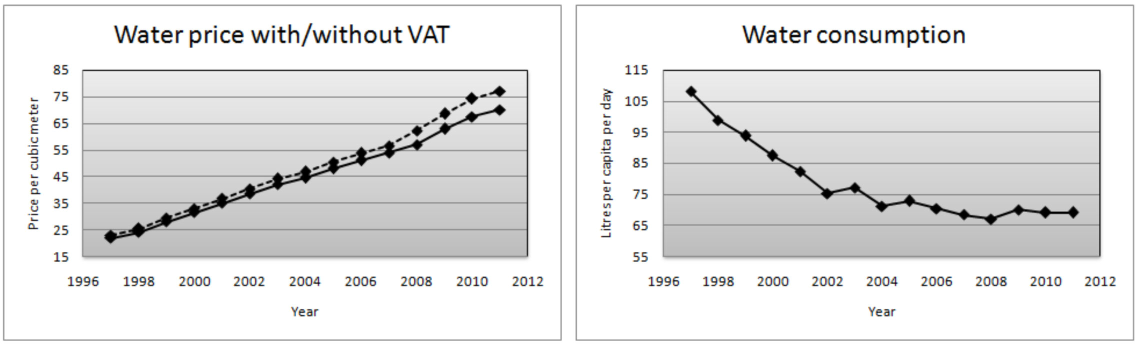
(b) Average daily water consumption per person

In Kladno, people can freely decide about their electricity and gas providers. Unfortunately, there is no choice to select water provider since there is only one to choose from. In Kladno, there is the same trend as elsewhere in the Czech Republic. The price paid for 1m^3 of water is steadily increasing. Figure 3.2(a) shows the progress of water price people paid in Kladno from 1997 to 2011. The bottom solid line displays water price per year without VAT and the upper dashed line depicts

[1] Average price needs to be considered as the total price differs across water providers.

water price including the reduced rate VAT. Average water consumption per person per day from 1997 to 2011 can be found in Figure 3.2(b). The opposite trends can be again recognized in these two parts.

Figure 3.2: Water price and consumption in Kladno



(a) Water price per year

(b) Average daily water consumption per person

The primary objective of the thesis is to find the short and long-run price elasticities of water demand. Elasticity represents the percentage change in the quantity demanded caused by the percentage change in price and is defined by equation (Schotter, 2008):

$$e_d = \frac{\triangle Q\%}{\triangle p\%} = \frac{\frac{\triangle Q}{Q}}{\frac{\triangle p}{p}} = \frac{\triangle Q}{\triangle p} \cdot \frac{p}{Q} \tag{3.1}$$

where △Q is change in the quantity demanded, △p is change in price, Q and p are the original quantity demanded and original price, respectively.

Moreover, according to the economic theory water is normal goods. This consequently means that if water price increases, consumption decreases. The first part of the multiplicative term of equation (3.1) is thus negative. The second part is always positive as neither price nor quantity can take negative values. The elasticity can acquire only values less than zero and three cases are possible to occur:

- when $e_d > -1$ we say that the demand is inelastic
- when $e_d = -1$ we say that the demand is unitary elastic
- when $e_d < -1$ we say that the demand is elastic

We expect water demand to be inelastic with respect to price and so 1% change in water price induces less than 1% change in water consumption, in the opposite direction. This arises from the impossibility to substitute water with another commodity. The price elasticity of water demand is also assumed to be higher in the long-run than in the short-run, both in absolute values. This theoretical framework can be easily explained. People can have deep-rooted habits and therefore need time to adjust their behaviour when a change in water price occurs. They are more able to react and adapt in the long-run rather than in the short-run (about one-year period).

To acquire the price elasticities econometrically, a constant elasticity model is employed. The model of this sort has the following form:

$$\log y = \beta_0 + \beta_1 \log x_1 + \beta_2 x_2 \tag{3.2}$$

where β_0 is the intercept and β_1 is the estimated elasticity of x_1 with respect to y. A bit caution should be made in explaining β_2 as this stands for the semi-elasticity. The interpretation of β_2 is as follows: $\%\Delta y = (100\beta_2)\Delta x$ (Wooldridge, 2009). Therefore, we can see that the coefficients on the independent variables expressed in the logarithmic form can be directly presented as elasticities. The coefficient interpretation of the econometric model thus corresponds to the economic interpretation of the elasticity captured in equation (3.1).

4 Czech Republic

In this section we study water consumption and water price in the regions of the Czech Republic from 2000 to 2011. We investigate both the short and long-run price elasticities of water demand and identify them to be inelastic. The effect of other variables such as income and weather is also examined.

4.1 Data and methodology

To estimate both the short and long-run price elasticities of water demand, the econometric model relating water consumption to water price and a set of other explanatory variables is employed. This subsection is devoted to the data description, variable specification and model specification.

4.1.1 Data description and variable specification

The data set consists of annual region's water consumption, water price, income, temperature, rain and the proportion of the population aged more than 65 years during 2000 - 2011.

Every year the Ministry of Agriculture of the Czech Republic publishes yearbooks that include all important information regarding the water-supply and sewage systems. Data on household water consumption and the number of people connected to the water-supply and sewage systems are obtained from the yearbooks *Vodovody a kanalizace ČR* (2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011) for each region from 2000 to 2011. Annual region's water and sewage tariffs are provided by the Czech Statistical Office. Data on income and age composition of the population are partially acquired from the publications *Kraje České republiky* (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009), *Věkové složení obyvatelstva ČR v roce 2001* (2003), *Porovnání krajů - vybrané ukazatele 1995-2000* (2001) issued by the Czech Statistical Office and the rest of the data are taken from their website (Český statistický úřad, 2013a), (Český statistický úřad, 2013b). Data corresponding to weather, annual average region's temperature and rain are obtained from the Czech Hydrometeorological Institute on their website (Český hydrometeorologický úřad, 2008a), (Český hydrometeorologický úřad, 2008b).

The description of the dependent and independent variables that enter the water demand equation can be found below.

1. **Consumption**

   The dependent variable is annual water consumption per person in each region measured in m^3. It is obtained by dividing overall region water consumption by the number of people that are supplied with water in this region.

2. **Lagged consumption**

   The past consumption can influence the consumption in the future. Musolesi & Nosvelli (2007) suggested looking at the dynamic form equation rather than to the static one. To obtain equation of the dynamic form, the lagged consumption is added as the independent variable to the model. Moreover, this modification enables to study both the short and long-run price elasticities.

3. **Price**

   The crucial independent variable is water price. It has already been said in the previous section that the total charged price is the sum of water and sewage tariffs and added reduced rate VAT. This total charged price is deflated using annual CPI (Český statistický úřad, 2013c) for water. The variable price is thus expressed in real terms. As already stated, negative relation between water price and water consumption is assumed.

4. **Income**

   Another important independent variable is the average monthly gross wage of employees in each region, in CZK. Even though the consumption is definitely positively related to the income, we do not presume a large effect in magnitude. Together with higher wage people can afford higher water bills but starting from some threshold they do not increase the consumption any more.

5. **Temperature**

   The average temperature, in °C, per year recorded in each region is expected to be positively related to water consumption. Since houses with gardens and swimming pools are included in our data set, the higher the temperature, the higher the garden watering and topping-up of swimming pools.

6. **Rain**

   A great deal of previous studies confirm that the total amount of region's precipitation per year, measured in millimeters, influences water consumption. Rain is supposed to be negatively related to water consumption as water gardening need not to be done during rainy days.

7. **Senior**

   Senior is the last independent variable employed in the model. It stands for the proportion of the region's population aged more than 65 years and is thus expressed in %. It is commonly known that older people extensively save money and therefore we assume lower consumption with a high proportion of older people.

The sampling period is from 2000 to 2011 and in the Czech Republic there are 14 regions. This results in 168 observations. Table 4.1 provides the summary statistics. The maximum amount of water, 52.31 m^3 per capita per year, was consumed in 2000 by people living in Capital Prague Region. The minimum amount of water consumed, 21.49 m^3 per capita per year, was determined in Vysočina Region 2001. During the observed period, the highest price was detected in Ústí nad Labem Region 2011. Its real value 1.02 corresponds to 79.42 CZK. On the other hand, in 2000 people living in Moravia-Silesian Region paid the lowest price 28.92 CZK, which is equal to 0.37 in real terms. The highest income was 30 842 CZK and was determined in Capital Prague Region 2010. The lowest income 11 346 CZK was in Vysočina Region during 2000. The average annual maximum temperature is 10.3°C, recorded in South Moravian Region 2000, and the average annual minimum temperature is 5.8°C, recorded in Karlovy Vary Region 2010. The lowest total amount of precipitation per year 391mm was founded in Ústí nad Labem Region in 2003, conversely the highest total amount of precipitation per year 1 163mm was detected in Moravia-Silesian Region 2010. According to the summary statistics, on average a seventh of the population is aged more than 65 years.

Table 4.1: Summary statistics for the Czech Republic

Variable	Mean	Standard Deviation	Minimum	Maximum
Consumption	31.82	5.55	21.49	52.31
Lagged consumption	32.04	5.66	21.49	52.31
Real price	0.60	0.14	0.37	1.02
Income	17 981.23	3 926.01	11 346.00	30 842.00
Temperature	8.30	0.80	5.80	10.30
Rain	729.96	143.57	391.00	1163.00
Senior	14.48	1.17	12.00	17.20

4.1.2 Region disparities

It is well-known that each region has more or less different characteristics such as population features (number of people, age structure), geographical features (area, mountainousness), climatic features (temperature, precipitation) and population distribution (proportions of people living in houses and in flats). Water consumption per person per year should be lower in regions where greater percentage of people lives in houses compared to flats. These people often have their own drilled wells. Even though water from wells does not always satisfy the hygiene standards to be used for drinking or even personal sanitation, they still have advantage to use it for water gardening or washing a car. We also assume lower water prices and incomes in pooper regions and higher water prices and incomes in richer regions. For each region, Table 4.2 surveys the averages (Avg) and standard deviations (SD) of each variable. The variable price is not deflated by CPI for water. It is thus expressed in nominal rather than in real terms. It can be seen that there are huge disparities across the regions. As it is later evident, these disparities only support using panel data techniques for estimation of the price elasticities.

Table 4.2: Summary statistics for regions

Region		Consum	Price	Income	Temp	Rain	Senior
Capital Prague R.	Avg	46.03	48.61	24 651.75	9.00	609.17	15.87
	SD	4.60	11.46	4 968.48	0.58	105.87	0.26
Central Bohemia	Avg	26.72	48.28	19 235.17	8.97	609.17	14.64
	SD	1.14	10.14	3 616.11	0.57	105.87	1.03
South Bohemia R.	Avg	30.01	49.39	17 225.67	7.83	741.42	14.31
	SD	1.10	8.56	3 213.76	0.57	132.92	0.59
Plzeň Region	Avg	29.37	41.29	18 273.42	8.03	727.33	14.93
	SD	1.79	8.74	3 525.67	0.57	129.06	0.60
Karlovy Vary R.	Avg	36.45	50.46	16 532.08	7.21	792.42	13.42
	SD	3.96	11.60	3 025.30	0.64	121.00	1.53
Ústí nad Labem R.	Avg	34.66	52.78	17 695.08	8.62	668.08	13.02
	SD	4.47	15.44	3 367.60	0.60	124.45	0.98
Liberec Region	Avg	31.22	51.46	17 538.08	7.83	912.00	13.45
	SD	2.29	15.17	3 422.24	0.55	136.90	0.67
Hradec Králové R.	Avg	30.07	46.54	17 074.25	8.17	770.17	15.01
	SD	1.16	10.28	3 343.13	0.60	105.24	0.52
Pardubice Region	Avg	30.43	46.56	16 813.17	8.33	722.50	14.94
	SD	1.15	11.01	3 244.30	0.61	96.38	0.97
Vysočina Region	Avg	26.74	43.79	16 924.50	7.93	705.42	14.74
	SD	2.52	7.15	3 533.51	0.58	101.83	0.83
South Moravia R.	Avg	32.38	49.28	17 882.33	9.40	577.75	15.09
	SD	0.87	8.16	3 818.61	0.62	100.35	0.74
Olomouc Region	Avg	28.21	44.23	16 757.67	8.22	739.50	14.64
	SD	1.20	9.51	3 372.90	0.63	95.99	1.04
Zlín Region	Avg	26.92	45.13	16 951.00	8.63	795.75	14.83
	SD	0.60	12.30	3 157.38	0.64	119.10	0.89
Moravia-Silesian R.	Avg	36.25	39.35	18 183.08	8.13	848.83	13.87
	SD	1.38	10.64	3 338.91	0.63	136.17	1.50

4.1.3 Model and estimation

Our data set incorporates data for each region from 2000 to 2011, as noticed above. The data set has therefore both cross-sectional and time series dimensions. There are two possible ways of dealing with the data. We can treat them as the pooled cross sections or the panel data. When the pooled cross sections are used, then the individual heterogeneity is not accounted for resulting in biased estimates. On the other hand, regions can be viewed as heterogenous using the panel data approach (Baltagi, 2005). Above we concluded that there exist differences across regions. The panel data approach is therefore used and later supported by statistical tests. Furthermore, the panel data set is balanced as there is no missing year for any cross-section.

The log-log model we want to estimate has the following form:

$$\begin{aligned}\log(consum_{it}) = \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) + \\ + \beta_3 \log(income_{it}) + \beta_4 temp_{it} + \beta_5 rain_{it} + \beta_6 senior_{it} + a_i + u_{it}\end{aligned} \tag{4.1}$$

where i ($i = 1, 2, \ldots, 14$) denotes the ith region, t ($t = 2, 3, \ldots, 12$) denotes the tth year. $consum_{it}$ is annual water consumption per person in the ith region in time t, $consum_{i,t-1}$ is the lagged consumption in the ith region, $price_{it}$ is the real price of water in the ith region in time t, $income_{it}$ is the average monthly gross wage of the employees in the ith region in time t, $temp_{it}$ is the average annual temperature in the ith region in time t, $rain_{it}$ is the amount of annul precipitation in the ith region in time t and $senior_{it}$ is the proportion of the population aged more than 65 years in the ith region in time t. The composite error $\nu_{it} = a_i + u_{it}$ comprises the unobserved effect (unobserved heterogeneity) a_i and the idiosyncratic error u_{it}. Both the unobserved effect and idiosyncratic error represent unobserved factors that affect the dependent variable. While the latter one captures factors that change in time, the former one stands for time-invariant factors. By this time-invariant factors we mean cross-sectional factors that are specific to each region. Moreover, $a_i \sim \text{iid}(0, \sigma_a^2)$ and $u_{it} \sim \text{iid}(0, \sigma_u^2)$ are independent of each other and among themselves (Baltagi, 2005).

According to Musolesi & Nosvelli (2007) the coefficient on price represents the short-run price elasticity of water demand and the long-run price elasticity can be computed from the subsequent formula:

$$\varepsilon_p = \frac{\beta_2}{1-\beta_1} \tag{4.2}$$

where β_2 is the coefficient on price and β_1 is the coefficient on the lagged consumption. Therefore, if the effect of the lagged consumption is positive (and below unity), the long-run price elasticity is higher than the short-run price elasticity.

We have already noticed that the pooled cross-section should not be preferred to the panel data as there is strong evidence of regional dissimilarities. By using the pooled OLS, the resulted estimates would be biased and inconsistent. When dealing with the panel data set, the fixed effect or random effect can be used to estimate the log-log model (4.1). In the fixed effect estimation we suppose that the region specific factors are fixed parameters and not random. By the nature of the estimation technique, the non-randomness implies that the unobserved factors are eliminated under the fixed effect even though the model still accounts for them. Moreover, under the fixed effect the intercept is excluded from the model and any correlation between the unobserved effect and the independent variable is allowed. In the random effect estimation we have to take into account that the unobserved effect is uncorrelated with independent variables (Wooldridge, 2009).

Nevertheless, we can test econometrically whether the pooled OLS, fixed effect or random effect should be used to estimate model (4.1). According to Park (2010), it is suggested to perform the Wald test and the Breusch - Pagan Lagrangian multiplier test and based on the results of these tests decide about the estimation technique (see Table A.1 in Appendix A). Since the region specific factors seem to be fixed parameters rather than random ones, we assume to prefer the fixed effect to both the random effect and pooled OLS.

When Wald test is carried out, the OLS is used to estimate model (4.1) with added dummy variables for all but one region, where Capital Prague Region is the base group. For clarity, we estimate the model of the form:

$$\log(consum_{it}) = \sum_{i=1}^{13} \delta_i \cdot region_i + \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) +$$
$$+ \beta_3 \log(income_{it}) + \beta_4 temp_{it} + \beta_5 rain_{it} + \beta_6 senior_{it} + a_i + u_{it} \quad (4.3)$$

where $region_i$ represents the region dummy variables. It is equal to one for observations that belong to the ith region and zero otherwise. The joint significance of region dummy variables is subsequently tested for. Therefore, the null and alternative hypothesis are:

$$\begin{aligned} \mathrm{H_0} &: \delta_1 = 0, \delta_2 = 0, \ldots, \delta_{13} = 0 \\ \mathrm{H_A} &: \mathrm{H_0} \text{ is not true} \end{aligned} \quad (4.4)$$

The existence of heterogeneity is tested through the Breusch - Pagan LM test. The null and alternative hypothesis of this test are:

$$\begin{aligned} \mathrm{H_0} &: \mathrm{Var}(a_i) = 0 \\ \mathrm{H_A} &: \mathrm{Var}(a_i) \neq 0 \end{aligned} \quad (4.5)$$

Before we proceed to the empirical results, one important comment is needed. Apart from the lagged consumption, all remaining independent variables are certainly exogenous as these are not correlated with the composite error. There is also no doubt that the dependent variable is a function of the unobserved effect. From equation (4.1) directly follows that also the lagged dependent variable is a function of the unobserved effect. This fact implies that including the lagged consumption together with the unobserved effect in the model can be source of endogeneity[2] (Baltagi, 2005). Nevertheless, the endogeneity is not a problem if the unobserved heterogeneity is not presented in the model. As we already remarked, if the fixed effect is used to estimate model (4.1), then the unobserved factors are eliminated from the model. Therefore, if the fixed effect appears to be appropriate, we do not have to be concerned with the endogeneity problem. Otherwise, further treatments need to be done.

[2] "By endogeneity we mean the correlation of the right-hand side regressors and the disturbances" (Baltagi, 2005, p. 113).

4.2 Empirical results

The estimated coefficients of model (4.1) differ considerably when using the pooled OLS, the fixed effect and random effect. Moreover, the majority of independent variables turn up to be insignificant. Just three independent variables are individually statistically significant under the fixed effect estimation, and under the random effect estimation and the pooled OLS estimation even two of them (see Table A.2, Table A.3 and Table A.4 in Appendix A). Therefore, the variable temperature is dropped away and the model is reestimated. For clarity, the model is of the form:

$$\begin{aligned}\log(consum_{it}) = \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) + \\ + \beta_3 \log(income_{it}) + \beta_4 rain_{it} + \beta_5 senior_{it} + a_i + u_{it}\end{aligned} \tag{4.6}$$

where the model's conditions and definitions of each variable are exactly the same as in the original model.

The estimates from this modified model are still different under the pooled OLS, the fixed effect and random effect although the results are now somehow better compared to model (4.1). The outcomes of all estimation techniques are not presented here but are available upon request. The aforementioned tests are exploited in order to decide econometrically about the most appropriate estimation technique.

To perform the Wald test, the region dummy variables are added to model (4.6) as the temperature has been excluded from model (4.1). After the OLS is employed, the joint significance of region dummy variables is tested for. The resulted p-value is equal to 0.0027 implying that the region dummy variables are jointly statistically significant at even 1% significance level. We also need to test for heterogeneity by performing the Breusch-Pagan LM test which yields p-value equal to 0.3861. It follows from this that we fail to reject the null hypothesis. Based on these findings we conclude the fixed effect to be the most appropriate for estimating model (4.6) (see Table A.1 in Appendix A). Furthermore, the unobserved heterogeneity is eliminated under the fixed effect by the nature of the estimation technique. It consequently means that we do not need to be concerned with the endogeneity problem as the unobserved heterogeneity is not presented in the model.

Table 4.3: Fixed effect estimation

Variable	Coefficient	Standard Error	Coefficient	Standard Error
$\log(consum_{t-1})$	0.62421	0.05786	10.79	0.000***
$\log(price)$	-0.20336	0.05139	-3.96	0.000***
$\log(income)$	0.10346	0.04945	2.09	0.038**
rain	-0.00004	0.00002	-1.77	0.079*
senior	0.00887	0.00582	1.53	0.130

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

4.2.1 Interpretation of fixed effect results

As shown in Table 4.3 all coefficients have expected signs. The coefficient on the lagged consumption is highly significant and therefore confirms that the past influences the present. Its magnitude is in line with Musolesi & Nosvelli (2007) findings.

According to the coefficient on price, the short-run price elasticity is -0.20. The long-run price elasticity turns to be -0.54, based on formula (4.2). This indicates that 1% increase in water price results in 0.20% decrease in short-run water consumption but in the long-run the same price change causes water consumption to decrease by 0.54%. We can see that water demand is inelastic both in the short and long-run period. Moreover, the long-run price elasticity is more than twice as high as the short-run, both in absolute values. This corresponds to what we expected and also to what other researchers demonstrated (Worthington & Hoffman, 2008).

The positive significant coefficient on income indicates 0.10% increase in consumption caused by 1% increase in income. This relatively small magnitude is consistent with what one would anticipate. There is no need to double water consumption if person's income is doubled. Moreover, the finding is in line with Bartczak *et al.* (2009) conclusion.

As it can be seen, given 100mm change in rain leads to 0.4% change in water consumption in the opposite direction. Even though it is statistically significant, it is out of practical significance. The last independent variable is insignificant suggesting that in the Czech Republic seniors do not have extensive effect on water demand.

5 Kladno

The interests of this section are the short and long-run price elasticities of water demand across different household sizes in Kladno. Based on our previous findings we except the short and long-run elasticities of water demand of all household sizes to be less than zero. These elasticities are also assumed to differ across different household sizes as already shown for Spanish households by Arbués *et al.* (2010).

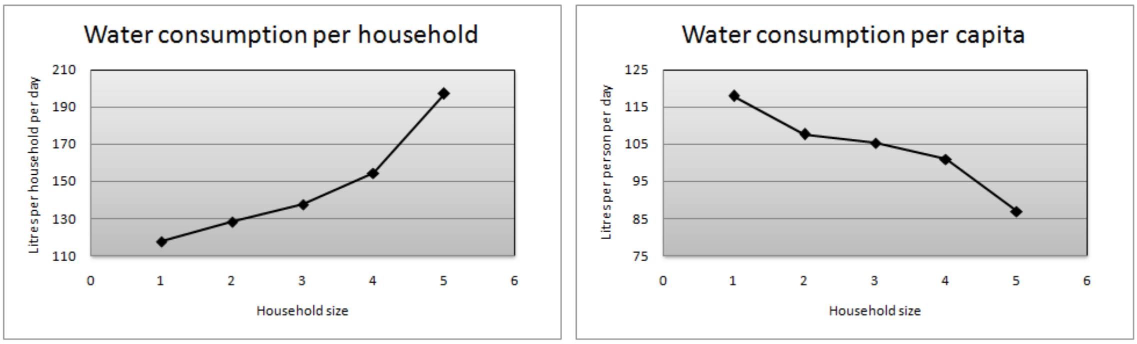
Moreover, we suppose smaller price elasticities for households with more members. Household chores need to be done regardless of the household size. On the one hand, more family members bring more clothes and dishes to be washed. On the other hand, washing machines and dishwashers are not full when running in case of 1 or 2 family members. When $1m^3$ of water becomes more expensive, smaller households can make their household chores more efficient. They run the washing machines and dishwashers less often but more filled compared to the larger families which cannot fill the already overfull dishwasher.

Before we proceed to the analysis, we have a closer look on the relationship between the household size and water consumption. It is obvious that families with more members pay higher bills for their water consumption compared to smaller families. The relationship between the household size and daily household water consumption in litres is depicted in Figure 5.1(a). On the other hand, these larger families have advantage of the economics of scale and the consumption per capita is hence lower. In Figure 5.1(b) the relationship between the household size and daily water consumption per capita in litres can be found. These two figures display the opposite trends of the overall household consumption and the consumption per capita. We can see that with more family members the overall consumption is higher while the consumption per capita is lower.

5.1 Data and methodology

To analyze the water demand equation for flats in Kladno, we need to specify the econometric model. This subsection is therefore devoted to the data description, variable specification and model specification.

Figure 5.1: Water consumption and household size



(a) Water consumption per household

(b) Water consumption per capita

5.1.1 Data description and variable specification

We use the household level data for period 1997 - 2011 for people living in flats in Kladno. The data are acquired from SUNNY Kladno s.r.o. This company keeps the administration of blocks of flats and it is able to provide data on various household characteristics. The most important one includes annual household consumption of cold and hot water, the price of water (including VAT), the number of household members, the area of the flat. The full data set is available upon request.

Before we continue to the variable specification, one comment relating to water price needs pointing out. In the household level data we have the advantage that we can include the price of hot water. To get $1m^3$ of hot water, one needs to pay heating up water in addition to water and sewage tariffs. Water price is thus pretty different due to high disparities in the price for heating up water. It is not a goal of the thesis to discuss the dissimilarities of various heating options. It is sufficient to know that it depends on whether electricity, gas or water vapor is used for heating up water. We are also not obliged to calculate the total price for each household as they are included directly in the data set received from SUNNY Kladno s.r.o.

The description of the dependent and independent variables that enter the water demand equation can be found below.

1. **Consumption**

   The dependent variable is water consumption per capita per year, in m^3. Household annual consumptions of cold and hot water are added up and divided by the number of household members.

2. **Proxy for lagged consumption**

   As we have already stressed, the past consumption influences the future consumption. To make the model dynamic, the lagged consumption needs to be included as the independent variable. As it is commented later, we deal with the pooled cross section rather than the panel data set. This indicates that we do not know past water consumption for any household. The proxy is therefore used to capture the effect of the past consumption on the future consumption. The average consumption of households with the same size in the previous year is computed and employed as the proxy for the lagged consumption for this household size.

3. **Price**

   The crucial independent variable is water price. As mentioned above, water price is the sum of the price paid for cold and hot water and differs substantially across households. SUNNY Kladno s.r.o. devotes the total price (including VAT) each household pays for 1m^3 of water in each year. The total price can rise simply due to inflation and therefore needs to be expressed in real terms. To deflate the total price, we use the CPI for water (Český statistický úřad, 2013c). We again expect negative correlation between water price and water consumption.

4. **Household size**

   To be able to compare the responses to changes in water price among households with different sizes, five dummy variables related to the household size are introduced.

$$D1 = \begin{cases} 1 & \text{if household has less than 1.5 members} \\ 0 & \text{otherwise} \end{cases}$$

$$D2 = \begin{cases} 1 & \text{if household has } \langle 1.5; 2.5) \text{ members} \\ 0 & \text{otherwise} \end{cases}$$

$$D3 = \begin{cases} 1 & \text{if household has } \langle 2.5; 3.5) \text{ members} \\ 0 & \text{otherwise} \end{cases}$$

$$D4 = \begin{cases} 1 & \text{if household has } \langle 3.5;\, 4.5) \text{ members} \\ 0 & \text{otherwise} \end{cases}$$

$$D5 = \begin{cases} 1 & \text{if household has more than or equal to 4.5 members} \\ 0 & \text{otherwise} \end{cases}$$

For brevity, we use simplified notation for each household size. We employ households with 1, 2, 3, 4, 5 and more members instead of households with less than 1.5 members, ⟨1.5; 2.5) members, ⟨2.5; 3.5) members, ⟨3.5; 4.5) members and households with more than or equal to 4.5 members, respectively.

5. **Area**

   This independent variable is the size of the dwelling, in m^2. We suppose that the size of the dwelling is positively related to water consumption.

6. **Year**

   Other variables such as the annual wage of each household could enter the model. Unfortunately, since these data are not accessible, the variable year is included in the model to capture the heterogeneity across years.

The total number of observations is 21 011. As shown in Table 5.1 there is an enormous difference in annual water consumption per person. On the one hand, the lowest one is 13.14 m^3. On the other hand, the highest one is 72.00 m^3. A similar imbalance is observable in case of the size of the dwelling. While one household lives on 120.54 m^2, another household has only 27.30 m^2.

5.1.2 Model

We have already stated that our data set consists of the household level data from 1997 to 2011. Even though the data set has again both the cross-sectional and time series dimensions, the same households were not followed in sampling the data. This results in the pooled cross section (Wooldridge, 2009). The log-log functional form

Table 5.1: Summary statistics for Kladno

Variable	Mean	Standard Deviation	Min	Max
Consumption	39.49	22.42	13.14	72.00
Proxy for lagged consumption	39.64	5.31	29.21	50.82
Real price	3.49	1.92	1.63	37.69
Area	58.77	14.75	27.30	120.54
Year	2004.44	4.05	1997	2011

is applied and the model is assumed to be of the type:

$$\begin{aligned}\log(consum_i) = \delta_0 + \alpha_0 \log(lagged_i) + \alpha_1 \log(lagged_i) \cdot D1 + \alpha_2 \log(lagged_i) \cdot D2 + \\ + \alpha_3 \log(lagged_i) \cdot D3 + \alpha_4 \log(lagged_i) \cdot D4 + \beta_0 \log(price_i) + \\ + \beta_1 \log(price_i) \cdot D1 + \beta_2 \log(price_i) \cdot D2 + \beta_3 \log(price_i) \cdot D3 + \\ + \beta_4 \log(price_i) \cdot D4 + \delta_1 area_i + \delta_2 year_i + u_i \end{aligned} \quad (5.1)$$

where i denotes the ith household and u_i is the error term representing the unobserved factors that affect the dependent variable (Wooldridge, 2009). $consum_i$ is water consumption per capita per year in the ith household, $lagged_i$ is the proxy for the lagged consumption for the ith household, $price_i$ is the real price of water for the ith household, $area_i$ is the size of the dwelling for the ith household, D1, D2, D3 and D4 are the dummy variables representing households with 1, 2, 3 and 4 members, respectively. To avoid the dummy variable trap, all dummy variables related to the household size apart from D5 (the base group) are incorporated in the model. The interactions of the dummy variables with other independent variables allow to determine the differences between that group and the base group.

As remarked previously, applying the log-log functional form makes the explanation easier. The coefficients on the independent variables expressed in the logarithmic form can be directly interpreted as elasticities. However, we need to be cautious as multiplicative forms are presented in the model. Only β_0 represents the short-run price elasticity of household with more than 5 members. The coefficients β_1, β_2, β_3 and β_4 are the differences in the short-run price elasticities between the households with 1, 2, 3 and 4 members and the base group, respectively. The short-run price elasticities of households with 1, 2, 3 and 4 members are $(\beta_0 + \beta_1)$, $(\beta_0 + \beta_2)$, $(\beta_0 + \beta_3)$ and $(\beta_0 + \beta_4)$, respectively. In a similar way the coefficients on the lagged consumptions (α_0, α_1, α_2, α_3 and α_4) can be explained. The coefficients δ_1, δ_2 denote the semi-elasticities of the consumption with respect to the size of the dwelling and year, respectively.

To calculate the long-run price elasticity, we again exploit Musolesi & Nosvelli (2007) method. For each household size the long-run price elasticity can be calculated according to the formula:

$$\varepsilon_p = \frac{\beta_p}{1 - \alpha_c} \tag{5.2}$$

where in case of the base group β_p is the coefficient on the price and α_c is the coefficient on the proxy for the lagged consumption.

In case of other household sizes β_p is the sum of β_0 and the coefficient on the multiplicative form of the price and the corresponding dummy variable. Likewise, α_c is the sum of α_0 and the coefficient on the multiplicative form of the proxy for the lagged consumption and the corresponding dummy variable (see Table B.1 in Appendix B).

When estimating model 5.1 the assumptions of no perfect collinearity, normality of residuals and homoskedasticity are necessary to test for. Although the coefficient estimates would remain unbiased and consistent in case of failing any of the assumption, the standard errors and the usual statistical inference would be invalid (Wooldridge, 2009).

To test for no perfect collinearity, the correlation matrix is exploited. The Jarque-Bera test is employed to test for the normality of residuals where the null and alternative hypothesis are:

$$\begin{aligned} \mathrm{H_0} &: \text{normal distribution} \\ \mathrm{H_A} &: \text{non-normal distribution} \end{aligned} \tag{5.3}$$

To test for homoskedasticity the White test is performed. The null hypothesis and the alternative hypothesis are:

$$\begin{aligned} \mathrm{H_0} &: \mathrm{Var}(u_{it}) = \sigma^2 \\ \mathrm{H_A} &: \mathrm{Var}(u_{it}) \neq \sigma^2 \end{aligned} \tag{5.4}$$

If we fail to reject the null hypothesis, then the heteroskedasticity is not a problem. On the other hand, if the null hypothesis is rejected, then the heteroskedasticity is present. If the latter is the case, the standard errors are replaced with the heteroskedasticity-robust standard errors (or robust standard errors) that are valid in presence of the heteroskedasticity and thus make the usual statistical inference valid.

5.2 Empirical results

The estimated coefficients of model (5.1) are presented in Table 5.2. The White test for the heteroskedasticity yields p-value equal to 0.0000 resulting in rejection of the null hypothesis. Based on the former explanation the heteroskedasticity is present. For this reason, instead of the usual standard errors their robust counterparts are reported. Due to the high number of observations, the robust standard errors are reliable.

After testing for no perfect collinearity, the correlation between some variables reaches up to 0.8. Nevertheless, it is beyond the scope of the thesis to treat it. Moreover, since we are interested in the short and long-run price elasticities across different household sizes, no other model specification is supposable. When testing for normality of residuals, the Jarque-Bera test suggests the rejection of the null hypothesis. Nonetheless, when looking at the histogram (see Figure B.1 in Appendix B) we observe that it is very close to normal distribution. Given 21 011 observations, we conclude that neither correlation nor non-normality cause problems to the model's inferences.

As shown in Table 5.2, coefficients on the price, multiplicative forms of the price and dummy variable, area and year have all expected signs. The price is highly statistically significant as shown by the reported p-value. Its coefficient suggests that 1% increase in water price results in 0.33% decrease in short-run water

Table 5.2: Pooled OLS estimation

Variable	Coefficient	Robust Standard Error	t statistic	p-value
log(*lagged*)	-0.0450	0.0768	-0.59	0.558
log(*lagged*)·D1	0.2247	0.0167	13.44	0.000***
log(*lagged*)·D2	0.1056	0.0150	7.03	0.000***
log(*lagged*)·D3	0.0600	0.0146	4.12	0.000***
log(*lagged*)·D4	0.0268	0.0159	1.68	0.092*
log(*price*)	-0.3297	0.0391	-8.42	0.000***
log(*price*)·D1	-0.3353	0.0452	-7.41	0.000***
log(*price*)·D2	-0.1553	0.0445	-3.49	0.000***
log(*price*)·D3	-0.0691	0.0434	-1.59	0.111
log(*price*)·D4	-0.0459	0.0484	-0.95	0.343
area	0.0040	0.0002	19.85	0.000***
year	-0.0034	0.0008	-4.14	0.000***
constant	10.5210	1.8191	5.78	0.000***

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

consumption for households with more than 5 members. Given the same price change, the households with 1 member are predicted to decrease their consumption by $(-0.33 - 0.34) = -0.67\%$ in the short-run. According to the expression (5.2), the computed long-run price elasticity of households with more than 5 members is -0.32%. When there is only 1 member, the long-run price elasticity appears to be -0.81%. The short and long-run price elasticities of other household sizes can be obtained in the same manner (more details are provided later on). It can also be seen that the proxy for the lagged consumption is individually insignificant at even 10% significance level. It implies that for the base group the difference between the short and long-run price elasticities is not statistically significant.

Both the area and the year are individually statistically significant at even 1% significant level. The coefficient on variable area suggests that given 1m^2 increase in the size of the dwelling results in 0.40% increase in water consumption. The coefficient on the variable year proposes that due to changes in the wage etc. the consumption decreases in time.

5.2.1 Short-run and long-run price elasticity estimates

We have already briefly discussed the short and long-run price elasticities of households with 1 and 5 members. For clarity, Table 5.3 provides the short-run price elasticities, the proxy for the lagged consumptions and the computed long-run price elasticities for each household size. As this table indicates, in case of the household level data water demand is inelastic for all household sizes in both the short and long-run. This corresponds to our previous findings and expectations.

Table 5.3: Price elasticities across different household sizes

Household size	Short-run elasticity	Proxy for lagged consumption	Long-run elasticity
1	-0.665	0.180	-0.811
2	-0.485	0.061	-0.516
3	-0.399	0.015	-0.405
4	-0.376	-0.018	-0.369
5 and more	-0.330	-0.045	-0.315

Two interesting ascertainment can be noticed in Table 5.3. Firstly, the lower the household size, the higher the price elasticity (although all of them are lower than 0). This detection confirms our initial assumption and it is consistent with Arbués *et al.* (2010) conclusion. Secondly, two notable shifts in the short-run and long-run price elasticities are observable. They arise when household size changes from 1 to 2 members and from 2 to 3 members.

We can easily test the differences in the short-run price elasticities across different household sizes. The p-values on β_1, β_2, β_3 and β_4 show whether the differences between the households with 5 and more members (the base group) and households with 1, 2, 3 and 4 members are statistically significant. For $i = 1, 2, 3, 4$ the null hypothesis and the alternative hypothesis are:

$$\begin{aligned} \mathrm{H_0} &: \beta_i = 0 \\ \mathrm{H_A} &: \beta_i \neq 0 \end{aligned} \tag{5.5}$$

If we reject the null hypothesis, there is statistically significant difference between the base group and the given household size. According to Table 5.2 the short-run price elasticity of the base group is not statistically different from the short-run price elasticities of households with 3 and 4 members as shown by reported p-values.

To ascertain whether the short-run price elasticities between other household sizes are statistically different, we change the base group and reestimate model (5.1). The estimates of these models can be found in Appendix B (see Table B.2, Table B.3, Table B.4 and Table B.5). To sum up, households with 3, 4, 5 and more members do not have statistically different short-run price elasticities and thus their reactions are not statistically distinguishable. The remaining two household sizes, 1 and 2 members, appear to have statistically different short-run price elasticities from the others. It seems we are dealing with three types of household sizes consisting of 1 member, 2 members, 3 and more members.

Furthermore, by changing the base group we can easily test whether the differences between the short and long-run price elasticities for other household sizes are statistically significant. For households with 5 and more members the difference is insignificant as shown in Table 5.2. Besides households with 1 member, the differences between the short and long-run price elasticities for all other household sizes are insignificant (see Table B.2, Table B.3, Table B.4 and Table B.5 in Appendix B).

6 Conclusion

In this thesis we analyze the short and long-run price elasticities of water demand. We first focus on the Czech Republic and then concentrate on people living in flats in Kladno. In both cases we confirm that higher water price induces lower water consumption. Moreover, the outcomes suggest water demand is inelastic with respect to the price and the estimated values are consistent with findings of previous studies.

In Section 4 we investigate the short and long-run price elasticities of water demand in the Czech Republic using the log-log model specification. Employing annual region's data for period 2000 to 2011, we regress water consumption on the lagged consumption, price, income, rain and share of the population aged more than 65 years. The insignificant variable temperature is excluded from the model since when it is included, most of the other independent variables appear to be insignificant. The pooled OLS, the fixed effect or the random effect should be used for estimating the water demand equation. To compare these estimation techniques econometrically, the Wald test and the Breusch-Pagan LM test are performed. Based on the results of these tests we determine the fixed effect to be the most appropriate. Furthermore, we conclude that the endogeneity is not a problem.

According to the fixed effect estimations of the model, the short-run price elasticity appears to be -0.20 while the long-run price elasticity is -0.54. This indicates that 1% increase in water price results in 0.20% decrease in short-run water consumption but in the long-run the same price change causes water consumption to decrease by 0.54%. These results suggest that water demand is inelastic regardless of the time period but is more elastic in the long-run than in the short-run (the long-run price elasticity is more than twice as high as the short-run, both in absolute values). The elasticity of water demand with respect to income is 0.10. While the estimated coefficient on rain is statistically significant, it is out of practical significance. The last independent variable share of the population aged more than 65 years is insignificant.

In Section 5 we focus on household water consumption of people living in flats in Kladno from 1997 to 2011 using annual data. The price is multiplied with all except one size dummy variables. The same process is applied to the proxy for the lagged consumption. In the log-log model specification we regress water consumption per person on the proxy for the lagged consumption, multiplicative forms of the proxy for the lagged consumption, price, multiplicative forms of the price, the size of the dwelling and the year. Since the White test confirms the presence of the heteroskedasticity, usual standard errors are replaced with their robust counterparts. Even though the correlation between some variables reaches up to 0.8, it is beyond the scope of the thesis to treat it. Moreover, since we are interested in the short and long-run price elasticities across different household sizes, no other model specification is supposable. The residuals seem to be normally distributed. Given 21 011 observations, we conclude that neither correlation nor non-normality cause problems to the model's inferences.

Estimating the model by the pooled OLS yields interesting results. As household size increases the price elasticity decreases regardless of the time period. The short-run price elasticities vary in a range from -0.67 to -0.33 and the long-run price elasticities are in bounds from -0.81 to -0.32. We also change the base group to test the differences in the short-run price elasticities and conclude that it seems we are dealing with three types of household sizes consisting of 1 member, 2 members, 3 and more members.

To the best of our knowledge, no similar study has been devoted entirely to the Czech Republic. The thesis tries to add a little to this gap. Nevertheless, there are still many topics to focus on. For example, attractive findings could be brought by the study of the price elasticity of water demand of flats compared to houses in Kladno or in the Czech Republic. It can also be interesting to analyze how water-saving devices are extended in the Czech Republic and investigate their impact on water consumption.

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Appendix A

Table A.1: Fixed or random effect

Wald test	Breusch-Pagan LM test	Model
H_0 is not rejected	H_0 is not rejected	Pooled OLS
H_0 is rejected	H_0 is not rejected	Fixed effect model
H_0 is not rejected	H_0 is rejected	Random effect model
H_0 is rejected	H_0 is rejected	Fixed and random effect model[1]

Source: Park (2010)

Note: [1] choose one of the two depending on the result of the Hausman test

Table A.2: Fixed effect estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.63197	0.05848	10.81	0.000***
$\log(price)$	-0.19287	0.05262	-3.67	0.000***
$\log(income)$	0.09089	0.05127	1.77	0.079*
temp	0.00522	0.00558	0.94	0.351
rain	-0.00004	0.00003	-1.51	0.134
senior	0.00888	0.00582	1.53	0.129

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Table A.3: Random effect estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.89957	0.02229	40.36	0.000***
$\log(price)$	-0.05419	0.02362	-2.29	0.022**
$\log(income)$	0.00754	0.03205	0.24	0.814
temp	0.00666	0.00462	1.44	0.149
rain	-0.00003	0.00002	-1.16	0.244
senior	0.00091	0.00370	0.24	0.807
constant	0.18746	0.26732	0.70	0.483

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Table A.4: Pooled OLS estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.90075	0.02194	41.05	0.000***
$\log(price)$	-0.05376	0.02329	-2.31	0.022**
$\log(income)$	0.00736	0.03174	0.23	0.817
temp	0.00664	0.00459	1.45	0.150
rain	-0.00003	0.00002	-1.16	0.247
senior	0.00089	0.00367	0.24	0.809
constant	0.18570	0.26415	0.70	0.483

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Appendix B

Table B.1: Coefficients β_p and α_c

Household size	β_p	α_c
1	$\beta_0 + \beta_1$	$\alpha_0 + \alpha_1$
2	$\beta_0 + \beta_2$	$\alpha_0 + \alpha_2$
3	$\beta_0 + \beta_3$	$\alpha_0 + \alpha_3$
4	$\beta_0 + \beta_4$	$\alpha_0 + \alpha_4$
5 and more	β_0	α_0

Figure B.1: Histogram

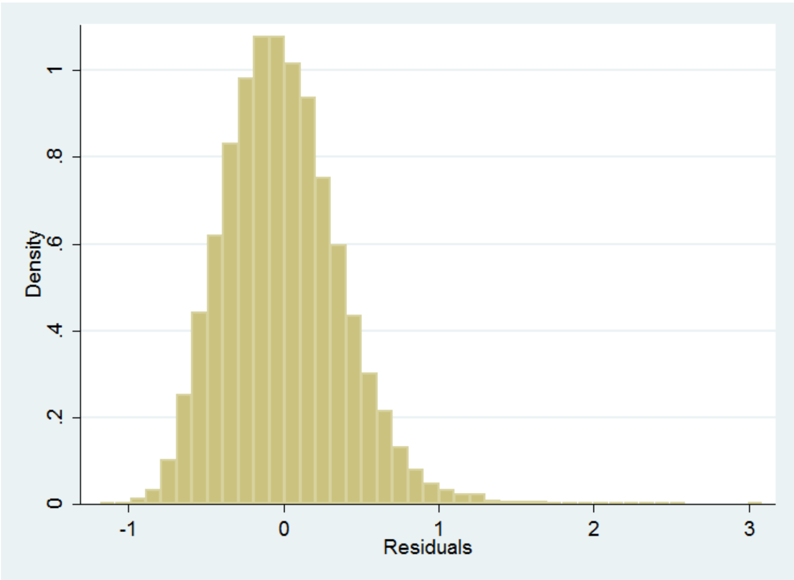

Table B.2: Pooled OLS estimation - D4 base group

Variable	Coefficient	Robust Standard Error	t statistic	p-value
$\log(lagged)$	-0.0183	0.0758	-0.24	0.810
$\log(lagged) \cdot$D1	0.1979	0.0132	14.94	0.000***
$\log(lagged) \cdot$D2	0.0788	0.0112	7.04	0.000***
$\log(lagged) \cdot$D3	0.0332	0.0106	3.14	0.002***
$\log(lagged) \cdot$D5	-0.0268	0.0159	-1.68	0.092*
$\log(price)$	-0.3756	0.0285	-13.17	0.000***
$\log(price) \cdot$D1	-0.2893	0.0364	-7.95	0.000***
$\log(price) \cdot$D2	-0.1094	0.0355	-3.08	0.002***
$\log(price) \cdot$D3	-0.0231	0.0341	-0.68	0.497
$\log(price) \cdot$D5	0.0459	0.0484	0.95	0.343
area	0.0040	0.0002	19.85	0.000***
year	-0.0034	0.0008	-4.14	0.000***
constant	10.5210	1.8191	5.78	0.000***

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Table B.3: Pooled OLS estimation - D3 base group

Variable	Coefficient	Robust Standard Error	t statistic	p-value
log(*lagged*)	0.0150	0.0748	0.20	0.841
log(*lagged*)·D1	0.1647	0.0111	14.82	0.000***
log(*lagged*)·D2	0.0456	0.0090	5.06	0.000***
log(*lagged*)·D4	-0.0332	0.0106	-3.14	0.002***
log(*lagged*)·D5	-0.0600	0.0146	-4.12	0.000***
log(*price*)	-0.3988	0.0187	-21.34	0.000***
log(*price*)·D1	-0.2662	0.0294	-9.05	0.000***
log(*price*)·D2	-0.0862	0.0282	-3.06	0.002***
log(*price*)·D4	0.0231	0.0341	0.68	0.497
log(*price*)·D5	0.0691	0.0434	1.59	0.111
area	0.0040	0.0002	19.85	0.000***
year	-0.0034	0.0008	-4.14	0.000***
constant	10.5210	1.8191	5.78	0.000***

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Table B.4: Pooled OLS estimation - D2 base group

Variable	Coefficient	Robust Standard Error	t statistic	p-value
log(*lagged*)	0.0605	0.0740	0.82	0.413
log(*lagged*)·D1	0.1191	0.0110	10.78	0.000***
log(*lagged*)·D3	-0.0456	0.0090	-5.06	0.000***
log(*lagged*)·D4	-0.0788	0.0112	-7.04	0.000***
log(*lagged*)·D5	-0.1056	0.0150	-7.03	0.000***
log(*price*)	-0.4850	0.0211	-22.97	0.000***
log(*price*)·D1	-0.1799	0.0308	-5.85	0.000***
log(*price*)·D3	0.0862	0.0282	3.06	0.002***
log(*price*)·D4	0.1094	0.0355	3.08	0.002***
log(*price*)·D5	0.1553	0.0445	3.49	0.000***
area	0.0040	0.0002	19.85	0.000***
year	-0.0034	0.0008	-4.14	0.000***
constant	10.5210	1.8191	5.78	0.000***

Note: *** significance at 1%, ** significance at 5%, * significance at 10%

Table B.5: Pooled OLS estimation - D1 base group

Variable	Coefficient	Robust Standard Error	t statistic	p-value
log(*lagged*)	0.1796	0.0693	2.59	0.010***
log(*lagged*)·D2	-0.1191	0.0110	-10.78	0.000***
log(*lagged*)·D3	-0.1647	0.0111	-14.82	0.000***
log(*lagged*)·D4	-0.1979	0.0132	-14.94	0.000***
log(*lagged*)·D5	-0.2247	0.0167	-13.44	0.000***
log(*price*)	-0.6650	0.0227	-29.35	0.000***
log(*price*)·D2	0.1799	0.0308	5.85	0.000***
log(*price*)·D3	0.2662	0.0294	9.05	0.000***
log(*price*)·D4	0.2893	0.0364	7.95	0.000***
log(*price*)·D5	0.3353	0.0452	7.41	0.000***
area	0.0040	0.0002	19.85	0.000***
year	-0.0034	0.0008	-4.14	0.000***
constant	10.5210	1.8191	5.78	0.000***

Note: *** significance at 1%, ** significance at 5%, * significance at 10%