Institute of Economic Studies, Faculty of Social Sciences
Charles University in Prague

Price Elasticity of Household Water Demand in the Czech Republic

Jana Hortová
Ladislav Krištoufek

IES Working Paper: 38/2014

Institute of Economic Studies,
Faculty of Social Sciences,
Charles University in Prague

[UK FSV – IES]

Opletalova 26
CZ-110 00, Prague
E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Institut ekonomických studií
Fakulta sociálních věd
Univerzita Karlova v Praze

Opletalova 26
110 00 Praha 1

E-mail : ies@fsv.cuni.cz
http://ies.fsv.cuni.cz

Bibliographic information:
Hortová J., Krištoufek L. (2014). "Price Elasticity of Household Water Demand in the Czech Republic" IES Working Paper 38/2014. IES FSV. Charles University.

Price Elasticity of Household Water Demand in the Czech Republic

Jana Hortová[a]
Ladislav Krištoufek[a,b]

[a]Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Smetanovo nábreží 6, 111 01 Prague 1, Czech Republic

[b]Institute of Information Theory and Automation, Academy of Sciences of the Czech Republic, Pod Vodárenskou Věží 4, 182 02, Prague, Czech Republic
E-mail: kristouf@utia.cas.cz

December 2014

Abstract:

In the Czech Republic, water prices have been steadily increasing while water consumption has been decreasing during the last decades. 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. In the paper, we examine the short and long-run price elasticities of water demand in the Czech Republic between years 2000 and 2011. We find that the water demand is inelastic (lower than one) with respect to water price regardless of the time period and the income elasticity is on the edge of statistical significance. Our inferences are in line with previous findings.

Keywords: water consumption, price elasticity, income elasticity
JEL: C54, Q25, Q53

1. Introduction

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

According to economic theory, consumers are viewed as rational agents and water is supposed to be a normal good – an increased price is followed by a decreasing consumption and vice versa. There are other factors affecting water demand besides the prices – personal income, temperature, precipitation, household size and age composition of the population. These are discussed in the Literature review section in more detail.

Although the vast majority of the literature is based on a static approach, we believe that the past consumption can affect the future consumption and therefore, we employ a dynamic approach to control for such persistence in consumption. In our investigation, we use regional data on household water consumption in the Czech Republic for a period between 2000 and 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 endogenity that can be potentially presented in the model and perform tests to decide about the most appropriate technique to estimate the water demand model.

The results suggest that the 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 – the short-run price elasticity is estimated to be -0.20 while the long-run price elasticity is -0.54. The conclusions and estimated values are consistent with findings of other studies dealing with different regions. The paper is structured as follows. Section 2 provides a review of the relevant literature. In Section 3, we briefly describe the water market in the Czech Republic. Section 4 presents the dataset and the utilized methodology. Section 5 provides the results and their discussion. Section 6 concludes.

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 the 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. We present a brief summary of the relevant studies, mainly focusing on the literature studying the European countries. To the best of our knowledge, no similar study has been devoted entirely to the Czech Republic.

The evidence of diversities of the studies is surveyed by Arbues et al (2003). The authors report that the most commonly used variables consist of 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 of the 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 and Nosvelli (2007) propose to apply a dynamic framework since they assume it can characterize the household behavior much better. The sampling period ranges between 1998 and 2001, and the panel consists of 102 Italian municipalities. By applying the generalized method of moments (GMM) on the log-log specification of the model, the authors find the short-term and long-term elasticity to be -0.27 and -0.47, respectively. Water demand is thus found to be less elastic in the short-run than in the long-run.

The aforementioned diversities are observed by Worthington and Hoffman (2008) who bring another investigation of literature relating to water demand published predominantly since 1980. More than a half of the analyzed studies is devoted to the USA, a quarter to Europe and the rest to Australia. The authors present that the most frequently used independent variables include price, income, weather, seasonal factors, household composition and other factors (such as campaigns for water conservation). In the same way as Arbues et al (2003), Worthington and Hoffman (2008) find 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 for Poland between 2001 and 2005. A panel of municipal districts with more than 50,000 inhabitants is used in the study. Based on a static random effect model, the authors report the price elasticity of -0.22 and the income elasticity of 0.12. Residential water demand in Germany is explored by Schleich and Hillenbrand (2009) using the cross-sectional data set. Using various model specifications, the price elasticity of around -0.25 and the income elasticity around 0.25 are reported. Worthington et al (2009) study residential water demand in Queensland, Australia from 1994 to 2004 finding only a weak elasticity of approximately -0.1.

Arbues et al (2010) examine how household responses to changes in water prices differ among different household sizes. With a use of a panel of Spain households, the period from 1996 to 1998 is examined. The authors conclude 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 changes in water price.

Grafton et al (2011) enrich the literature by a cross-country survey. The household level dataset on ten OECD countries is used in this study. Apart from the Czech Republic, Australia, Canada, France, Italy, South Korea, Mexico, the Netherlands, Norway and Sweden are analyzed. As a main finding, the authors conclude that volumetric water prices to be the most efficient way of decreasing water consumption. For our purposes, the more relevant findings of the study are the price elasticity of -0.43 and the income elasticity of 0.11.

Ciomos et al (2012) investigate the effect of increasing water price on residential water consumption in Romania for the period between 2002 and 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 resources 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, which is substantially higher than the values found in the other reviewed studies.

Rinaudo et al (2012) carry out an empirical study related 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 resulting price elasticity is equal to -0.18 and the income elasticity is found to be 0.42. Beside the price elasticity, the authors bring an additional contribution to the already existing literature by creating a model which is able to simulate changes in water consumption under various price alternatives.

Cyprus is another country where the authorities need to regulate water consumption through water pricing to avoid future water scarcity. Polycarpou and Zachariadis (2013) econometrically assess the price elasticity of water demand using quarterly household level data on three districts. For the period between 2001 and 2009, they find the price elasticity to range between -0.25 and -0.45. The income elasticity is also in line with the previous findings and it takes values between 0.53 and 0.75.

In our study, we focus on the water market of the Czech Republic between 2000 and 2011 using a regional panel. In the line with the reviewed literature, we focus on the price and income elasticities while controlling for income, temperature, rain and age structure of the consumers.

3. Water market in the Czech Republic

Like in other countries, water prices charged by individual water producers differ considerably in the Czech Republic as well. Besides a spatial distribution of consumers and a degree of utilization of water and sewage capacity, the main reasons for such disparities are formed by the amount of rent and of depreciation, overhead costs, labor costs, and construction and reconstruction costs. The types of pricing schedules vary substantially across countries. In the Czech Republic, consumers are subject to a fixed volumetric charging. It means they pay the same price per each unit of water consumed. Water companies charge 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 plus the value added tax (VAT). The total price does not increase only due to the growth of water and sewage tariffs but also due to a rather frequent adjustments in the VAT levels. The reduced rate VAT has been changed four times since the Czech Republic was established in 1993. It had been equal to 5% until 2007, then it almost doubled to 9% in 2008 and 2009, it increased to 10% between 2010 and 2011, then up to 14% in 2012 and eventually to 15% in 2013.

As a member state 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. 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 1. 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. 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 the two figures. We observe an augmentation trend indicating a continuous growth of water price regardless the reduced rate VAT is included or not.

Our primary objective is the analysis of 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)

$$e_d = \frac{\triangle Q\%}{\triangle p\%} = \frac{\frac{\triangle Q}{Q}}{\frac{\triangle p}{p}} = \frac{\triangle Q}{\triangle p} \cdot \frac{p}{Q} \approx \frac{\partial Q}{\partial p} \cdot \frac{p}{Q} = \frac{\partial \log Q}{\partial \log p} \tag{1}$$

where $\triangle Q$ is a change in the quantity demanded, $\triangle p$ is a change in price, Q and p are the original quantity demanded and the original price, respectively. Elasticities are standardly estimated through a log-log specification of a regression model as hinted on the right-hand side of Eq. 1 and specified later in the text.

According to economic theory, water is a normal good, i.e. if water price increases, consumption decreases. The first part of the multiplicative term of equation (1) is thus expected to be negative. The second part is always positive as neither price nor quantity can take negative values. The elasticity is thus expected to acquire only negative values, and three cases are possible to occur – demand is inelastic ($-1 < e_d < 0$), unitary elastic ($e_d = -1$) and elastic ($e_d < -1$). We expect water demand to be inelastic with respect to price so that 1% change in water price induces less than 1% change in water consumption, in the opposite direction. This arises from a rather complicated substitutions of 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 behavior when a change in water price occurs. They are also more easily able

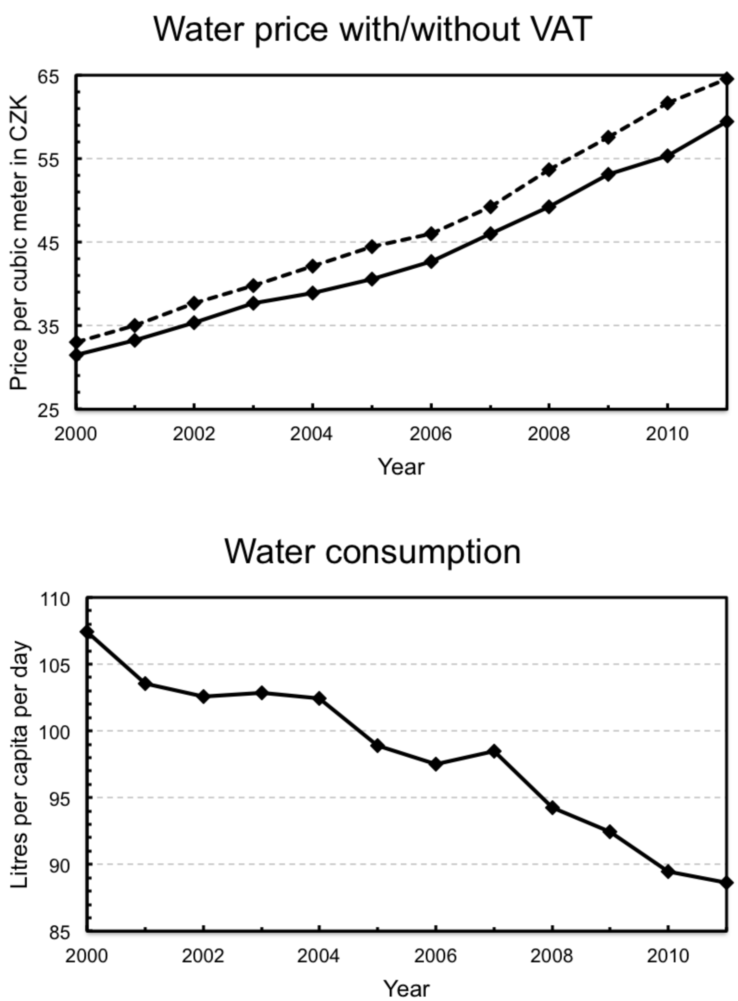

Figure 1: **Water price and water consumption in time.** Evolution of water price with and without VAT (top) and water consumption (bottom) is shown for years 2000-2011.

to react and adapt in the long-run rather than in the short-run.

4. 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. 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. The dataset is collected from the Ministry of Agriculture of the Czech Republic, the Czech Statistical Office and the Czech Hydrometeorological Institute. The description of the dependent and independent variables that enter the water demand equation is presented below.

1. **Consumption**
   The dependent variable is an 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**
   Water consumption is assumed to be at least somehow persistent. To avoid spurious results due to strong dependence of consumption series, the lagged consumption is included. Moreover, Musolesi and Nosvelli (2007) suggest utilizing the dynamic form of the equation rather than the static one. For this purpose, the lagged consumption is added as an additional independent variable. This way, we are able to study both the short and long-run price elasticities.
3. **Price**
   Water price is the crucial independent variable. It has been already mentioned that the total charged price is the sum of water, sewage tariffs and added reduced rate VAT. This total charged price is deflated using the annual CPI (consumer price index) so that the price is expressed in real terms. In the remainder of the text, a reference to price means a reference to the real price unless stated otherwise. As already stated, negative relation between water price and water consumption is expected.
4. **Income**
   Average monthly gross wage of employees in each region, measured in the Czech korunas (CZK), is another important independent variable. Even though the consumption is definitely positively related to the income, we do not presume a large effect in magnitude. Together with a higher wage, people can afford higher water bills but starting from a certain threshold, they do not increase the consumption any more.

5. **Temperature**
   Average annual temperature, measured in the degrees of Celsius ($^\circ C$), 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 does not need to be done during rainy days.
7. **Senior**
   Seniors form the last potentially influential factor employed in the model and the variable stands for the proportion of the region's population aged more than 65 years and is thus expressed in percentages. It is commonly known that older people extensively save money and therefore, lower consumption with a high proportion of older people is presumed.

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

4.2. Region disparities

It is standardly believed that each region has different characteristics such as population features (number of people, age structure), geographical features (area, mountains), 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 a 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,

Table 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

they still can be used for a water gardening or a car-washing. We also assume lower water prices and incomes in pooper regions and higher water prices and incomes in richer regions. For each region, Table 2 surveys the averages (Avg) and standard deviations (SD) of each variable. The price is not deflated by CPI here and it is thus expressed in nominal terms for better informational value. It can be seen that there are huge disparities across the regions. As it is evident later, these disparities only support using panel data techniques for estimation of the price elasticities and the fixed effects estimation specifically.

4.3. Model specification and estimation

The model of interest can be written in the log-log specification with a panel structure as

$$\begin{aligned}\log(consum_{it}) = \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) + \\ + \beta_3 \log(income_{it}) + \beta_4 temp_{it} + \beta_5 rain_{it} + \beta_6 senior_{it} + a_i + u_{it}\end{aligned} \tag{2}$$

where i ($i = 1, 2, \ldots, 14$) denotes the ith region, t ($t = 2, 3, \ldots, 12$) denotes the tth year. $consum_{it}$ is an 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 a real price of water in the ith region in time t, $income_{it}$ is an average monthly gross wage of the employees in the ith region in time t, $temp_{it}$ is an average annual temperature in the ith region in time t, $rain_{it}$ is an amount of annul precipitation in the ith region in time t and $senior_{it}$ is a 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 of an unobserved effect (unobserved heterogeneity) a_i and an idiosyncratic error u_{it}. Both the unobserved effect and idiosyncratic errors represent unobserved factors that affect the dependent variable. While the latter one captures factors that change in time, the former one stands for the time-invariant factors. By these 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 both mutually and serially independent (Baltagi, 2005).

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

Table 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
Pilsen 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
Usti 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 Kralove 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
Vysocina 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
Zlin 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

from the formula

$$\varepsilon_p = \frac{\beta_2}{1-\beta_1}, \tag{3}$$

where β_2 is the coefficient on the 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 indicated that the pooled cross-section should not be preferred to the panel data as there is a 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 approaches can be used to estimate the log-log model. 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 approach, 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 assume that the unobserved effect is uncorrelated with the independent variables (Wooldridge, 2009).

In any case, we can test econometrically whether the pooled OLS, fixed effect or random effect approach should be utilized to estimate the model in Eq. 2. We perform the Wald test and the Breusch-Pagan LM test to decide between the pooled and the panel approach. Since the region specific factors seem to be fixed parameters rather than random ones, we expect 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 in Eq. 2 with added dummy variables for all but one region (Capital Prague Region is used as a base group). For clarity, we estimate the model of the form

$$\begin{aligned} \log(consum_{it}) = \sum_{i=1}^{13} \delta_i \cdot region_i + \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) + \\ + \beta_3 \log(income_{it}) + \beta_4 temp_{it} + \beta_5 rain_{it} + \beta_6 senior_{it} + a_i + u_{it} \end{aligned} \tag{4}$$

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

$$\begin{aligned} \mathrm{H_0} &: \delta_1 = 0, \delta_2 = 0, \ldots, \delta_{13} = 0 \\ \mathrm{H_A} &: \mathrm{H_0} \text{ is not true} \end{aligned} \tag{5}$$

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

$$\begin{aligned} \mathrm{H_0} &: \mathrm{Var}(a_i) = 0 \\ \mathrm{H_A} &: \mathrm{Var}(a_i) \neq 0 \end{aligned} \tag{6}$$

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. It directly follows from Eq. 2 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 a source of endogenity. Note that endogenity is not a problem if the unobserved heterogeneity is not presented in the model. As we have already mentioned, if the fixed effect is used to estimate the model, the unobserved factors are eliminated from the model. Therefore, if the fixed effect appears to be appropriate, the endogenity is not an issue in this specific case. As it turns out, the fixed effects model prevails.

5. Results

The estimated coefficients of the model in Eq. 2 differ considerably when using the pooled OLS, the fixed effect and the random effect approaches. Moreover, majority of the independent variables turn out 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, we arrive at only two significant variables (see Tables 4-6 in the Appendix). Therefore, the variable *temp* is dropped away for an increased efficiency of the results and the model is re-estimated. For clarity, the model is of the form

$$\begin{aligned}\log(consum_{it}) = \beta_0 + \beta_1 \log(consum_{i,t-1}) + \beta_2 \log(price_{it}) + \\ + \beta_3 \log(income_{it}) + \beta_4 rain_{it} + \beta_5 senior_{it} + a_i + u_{it}\end{aligned} \tag{7}$$

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 somewhat better compared to the original model. 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 the model in Eq. 7. The joint significance of the regional dummy variables is tested for and the resulted p-value is equal to 0.0027 implying that the regional dummy variables are jointly statistically significant even at 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 so that we fail to reject the null hypothesis. Based on these findings, we conclude the fixed effect to be the most appropriate for the model estimation. 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 3: Fixed effect estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.6242	0.0579	10.79	$< 0.01^{***}$
$\log(price)$	-0.2034	0.0514	-3.96	$< 0.01^{***}$
$\log(income)$	0.1035	0.0495	2.09	0.038^{**}
$rain$	-0.0000	0.0000	-1.77	0.079^{*}
$senior$	0.0089	0.0058	1.53	0.130

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

Let us now turn to the results of the reduced fixed effects model. As shown in Table 3, all coefficients have the expected signs. The coefficient on the lagged consumption is highly significant and therefore confirms that water consumption is quite strongly persistent. Its magnitude is in line with the findings of Musolesi and Nosvelli (2007).

According to the coefficient on price, the short-run price elasticity is equal to -0.20. The long-run price elasticity turns out to be -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%. We can see that water demand is inelastic both in the short and long-run period, i.e. the estimated elasticities (their absolute values) are lower than one. Moreover, the long-run price elasticity is more than twice as high as the short-run one. This corresponds to what we have expected and also to what other researchers demonstrated (Worthington and Hoffman, 2008).

The positive significant coefficient on income indicates a 0.10% increase in consumption caused by an 1% increase in income. This relatively small magnitude is consistent with our expectations. The finding is in line with the conclusions reported by Bartczak et al (2009). As it can be seen, given a 100mm change in rain leads to a 0.4% change in water consumption in the opposite direction. Even though it is statistically significant, it is out of practical significance, which is in hand with the results of Slavikova et al (2013). The last independent variable is insignificant suggesting that in the Czech Republic, the seniors do not have extensive effect on the total water demand.

6. Conclusion

We have focused on the estimation of price and income elasticities in the water market in the Czech Republic. According to the fixed effect estimations of the model, the short-run price elasticity is estimated at -0.20 while the long-run price elasticity at -0.54. This indicates that a 1% increase in water price results in a 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 horizon 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). The elasticity of water demand with respect to income is estimated to be 0.10. While the estimated coefficient on rain is statistically significant, it is out of practical significance. The results fill the gap in the water demand elasticity literature which has not been studied the Czech market in a sufficient detail yet.

References

Arbues F, Garca-Valias MA, Martnez-Espineira R (2003) Estimation of residential water demand: a state-of-the-art review. Journal of Socio-Economics 32(1):81

Arbues F, Villanua I, Barberan R (2010) Household size and residential water demand: an empirical approach. Australian Journal of Agricultural & Resource Economics 54(1):61 – 80

Baltagi BH (2005) Econometric analysis of panel data, 3rd edn. J. Wiley & Sons. p. 302

Bartczak A, Kopanska A, Raczka J (2009) Residential water demand in a transition economy: evidence from Poland. Water Science & Technology: Water Supply 9(5):509 – 516

Ciomos VI, Ciataras DM, Ciomos AO (2012) Price elasticity of the residential water demand. Case-study: investment project in Cluj county, Romania . Transylvanian Review of Administrative Sciences 36:67 – 76

Grafton RQ, Ward MB, To H, Kompas T (2011) Determinants of residential water consumption: Evidence and analysis from a 10-country household survey. Water Resources Research 47(8)

Musolesi A, Nosvelli M (2007) Dynamics of residential water consumption in a panel of Italian municipalities. Applied Economics Letters 14(6):441 – 444

Polycarpou A, Zachariadis T (2013) An econometric analysis of residential water demand in Cyprus. Water Resources Management 27(1):309 – 317

Rinaudo JD, Neverre N, Montginoul M (2012) Simulating the impact of pricing policies on residential water demand: A southern France case study. Water Resources Management 26(7):2057 – 2068

Schleich J, Hillenbrand T (2009) Determinants of residential water demand in Germany. Ecological Economics 68(6):1756 – 1769

Schotter A (2008) Microeconomics: A Modern Approach, 1st edn. Addison-Wesley series in economics, South-Western Cengage Learning. p. 742

Slavikova L, Maly V, Rost M, Petruzela L, Vojacek O (2013) Impacts of climate variables on residential water consumption in the czech republic. Water Resources Management 27:365–379

Wooldridge JM (2009) Introductory econometrics: a modern approach, 4th edn. ISE - International Student Edition, South Western, Cengage Learning. p. 865

Worthington AC, Hoffman M (2008) An empirical survey of residential water demand modelling. Journal of Economic Surveys 22(5):842 – 871

Worthington AC, Higgs H, Hoffmann M (2009) Residential water demand modeling in Queensland, Australia: a comparative panel data approach. Water Policy 11(4):427 – 441

Appendix

Table 4: Fixed effect estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.6320	0.0585	10.81	$< 0.01^{***}$
$\log(price)$	-0.1929	0.0526	-3.67	$< 0.01^{***}$
$\log(income)$	0.0909	0.0513	1.77	0.079^{*}
temp	0.0052	0.0056	0.94	0.351
rain	-0.0000	0.0000	-1.51	0.134
senior	0.0089	0.0058	1.53	0.129

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

Table 5: Random effect estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.8996	0.0223	40.36	$< 0.01^{***}$
$\log(price)$	-0.0542	0.0236	-2.29	0.022^{**}
$\log(income)$	0.0075	0.0321	0.24	0.814
temp	0.0067	0.0046	1.44	0.149
rain	-0.0000	0.0000	-1.16	0.244
senior	0.0009	0.0037	0.24	0.807
constant	0.1875	0.2673	0.70	0.483

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

Table 6: Pooled OLS estimation

Variable	Coefficient	Standard Error	t statistic	p-value
$\log(consum_{t-1})$	0.9008	0.0219	41.05	$< 0.01^{***}$
$\log(price)$	-0.0538	0.0233	-2.31	0.022^{**}
$\log(income)$	0.0074	0.0317	0.23	0.817
temp	0.0066	0.0046	1.45	0.150
rain	-0.0000	0.0000	-1.16	0.247
senior	0.0009	0.0037	0.24	0.809
constant	0.1857	0.2642	0.70	0.483

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

IES Working Paper Series

2014

1. Diana Zigraiova, Petr Jakubik: *Systemic Event Prediction by Early Warning System*
2. Pavla Blahova, Karel Janda, Ladislav Kristoufek: *The Perspectives for Genetically Modified Cellulosic Ethanol in the Czech Republic*
3. Oxana Babecká Kucharčuková: *The impact of exchange rate volatility on trade: Evidence for the Czech Republic*
4. Oliver Polyák: *The Impact of Euro Adoption on Export Performance: Comparison of the Czech Republic and Slovakia*
5. Lucie Davidová, Vladimír Benáček: *Determinants of Austrian International Trade: Analysis Based on the Gravity Model*
6. Julie Chytilová, Václav Korbel: *Individual and Group Cheating Behavior: A Field Experiment with Adolescents*
7. Petr Janský: *Consumer Demand System Estimation and Value Added Tax Reforms in the Czech Republic*
8. Pavel Hait, Petr Janský: *Inflation Differentials among Czech Households*
9. Hana Džmuráňová, Petr Teplý: *Risk management of savings accounts*
10. Tomáš Fiala, Tomáš Havránek: *Ailing Mothers, Healthy Daughters? Contagion in the Central European Banking Sector*
11. Petra Andrlíková: *Is Barrier version of Merton model more realistic? Evidence from Europe*
12. Martin Pospíšil, Jiří Schwarz: *Bankruptcy, Investment, and Financial Constraints: Evidence from a Post-Transition Economy*
13. Matt Hunt, Goran Serdarević, Tom Ovington, Clive Kenny: *Evidence for a ladder of investment in Central and Eastern European countries*
14. Petra Andrlíková: *Bayesian default probability models*
15. Petra Buzková: *Has the Relationship Between Market and Model CDS Price Changed during the EMU Debt Crisis?*
16. Jakub Černý, Jiří Witzany: *Interest Rate Swap Credit Valuation Adjustment*
17. Martin Gregor: *Receiver's access fee for a single sender*
18. Pavel Ryska: *Deflation and Economic Growth in Long-Term Perspective*
19. Michal Paulus, Eva Michalíková, Vladimír Benáček: *German International Trade: Interpreting Export Flows According to the Gravity Model*
20. Michal Bauer, Nathan Fiala, Ian Levely: *Trusting Former Rebels: An Experimental Approach to Understanding Reintegration after Civil War*
21. Michal Skořepa: *Family Matters: Concurrent Capital Buffers in a Banking Group*
22. Martin Gregor: *Access Fees for Competing Lobbies*
23. Jozef Baruník, František Čech: *On the Modelling and Forecasting Multivariate Realized Volatility: Generalized Heterogeneous Autoregressivee (GHAR) Model*
24. Roman Horváth, Ayaz Zeynalov: *The Natural Resource Curse and Institutions in Post-Soviet Countries*
25. Petr Janský: *Impact of Excise Duties on Households in the Czech Republic*
26. Petr Jakubík, Thomas Reininger: *What Are the Key Determinants of Nonperforming Loans in CESEE?*

27. Jaromír Baxa, Tomáš Olešňaník: *Current Accounts in the Eurozone Countries: The Role of Euro, Fiscal Policies and Financial Developments*
28. Petr Polák: *The Productivity Paradox: A Meta-analysis*
29. Tomáš Havránek, Zuzana Iršová, Karel Janda, David Zilberman: *Selective Reporting and the Social Cost of Carbon*
30. Jozef Baruník, Tomáš Křehlík: *Coupling High-Frequency Data with Nonlinear Models in Multiple-Step-ahead Forecasting of Energy Markets' Volatility*
31. Lenka Šťastná, Jana Votápková: *Efficiency of Hospitals in the Czech Republic: Conditional Efficiency Approach*
32. Eva Michalíková, Michal Paulus: *Gravity Model Analysis: Robust Evidence from the Czech Republic and Corruption Matching*
33. Jozef Baruník, Lucie Kraicová: *Estimation of Long Memory in Volatility Using Wavelets*
34. Daniel Benčík: *Range-based Volatility Estimation and Forecasting*
35. Roman Horváth, Júlia Jonášová: *Central Banks'* Voting Records, Financial Crisis and Monetary Policy
36. Arshad Hayat: *FDI and Economic Growth: The Role of Natural Resources*
37. Božena Bobková: *On Estimation of Gravity Equation: A Cluster Analysis*
38. Jana Hortová, Ladislav Krištoufek: *Price elasticity of household water demand in the Czech Republic*

All papers can be downloaded at: http://ies.fsv.cuni.cz

Univerzita Karlova v Praze, Fakulta sociálních věd
Institut ekonomických studií [UK FSV – IES] Praha 1, Opletalova 26
E-mail : ies@fsv.cuni.cz http://ies.fsv.cuni.cz