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Water Tariffs as a Determinant for Water Consumption – The Analysis Across Polish Cities

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Abstract: This paper presents an empirical verification of the demand price elasticity for piped water in major cities in Poland – it was the main goal of the research. The information concerning the demand reaction to price changes is substantial for sustainable urban water demand. Any prediction of possible adaptation to global climate change also requires detailed information about consumer behaviour related to water consumption. This study was conducted on panel data consisting of approx. 100 largest Polish cities over the period of 5 years: 2010-2014. It was the second analysis in Poland and the first conducted on individual data from Polish agglomerations, instead of aggregated data for the whole country. Such detailed level of disaggregation has also some disadvantages – due to the lack of income data for each city – the income elasticity was skipped in the model. Finally the results were in the same range as figures obtained in other EU countries..

Keywords: water consumption, water demand price elasticity

JEL codes, C54, D12, E39, H40, H44, Q25, Q53

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1. Introduction

There is a serious pressure across Europe on the increase of efficiency of natural resource consumption, including water resources. Such pressure is not in all regions justified by the scarcity of water resources however, the predicted effects of the global climate change point at a growing role of water savings. The demand management seems to be more efficient than increase of the supply, especially in countries with well-developed water infrastructure. The aim of this paper is

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to estimate the demand price elasticity for water services in Poland. The previous attempt of such an analysis was undertaken more than 10 years ago. During such a long transition period serious changes have occurred in Poland on both, the water supply infrastructure and consumer behaviour. Therefore, it seems to be reasonable to conduct a next verification of the present possibilities of demand management. Furthermore, the systematic drop in water consumption per capita seems to be not linear and some minimum existence level seems to be approaching. Therefore, verifying the demand reaction to the price changes using new data (2010-2014) provides a new view on demand elasticity in Poland. The general conception of the study is based on the regression model describing changes in water consumption as a function of changes in expenditure for water services - depending on the water tariffs. The paper consists of a short review of existing studies, a review of water consumption and water prices at macro level (the whole country), Next the sources of data for the research sample are described. The sample consists of the approx. 100 biggest Polish cities – for such a panel the prices and consumption per capita are available and published by Central Statistical Office. The discrepancies between tariffs, prices, expenditures are presented in the next part as in introduction to the detail description of the modelling. The final part consists of results, their discussion and interpretation.

2. Review of the literature

The history of estimation of the demand price elasticity exceeds 60 years (the first study dates back to 1951 - see Baumann et al. 1998), however majority of the last researches focus on the issue how to better fit the models to complex increasing block pricing structures. Usually the additional flat charge (if existed) was skipped in the modelling. Such an approach correspond with the most popular water pricing structure (Hewitt and Hanemann 1995; OECD 1999) but has limited application to the Polish standards where only single volumetric tariff exists, with or without flat charge. The review skips also the majority of projects realised in the USA, due to different determinants of water consumptions (single houses with gardens – very sensitive on weather changes, presence of swimming pools etc.). The above reasons led to somehow subjective choice of the literature focusing on European research only. One of the most complex review of the existing studies was done by Dalhuisen et al (2003). The authors gathered 50 studies including 268 estimations of the price elasticity and 149 income elasticity, however only 6 research cases

were related to the European countries. The discrepancies between obtained results are highlighted by the authors and explained as an effect of different set of variables, different set of understanding the term “price” (marginal vs average) and different econometric models (dynamic, static). During the last decade the number of studies has seriously increased, however, the majority based on regional US data. It’s worth mentioning that the first assessment for Polish circumstances was done by Bartczak et al (2009) with similar result -0,22 for price elasticity. The observations comes from 39 cities in the period 2001-2005. The European research was conducted by Grafon et al (2011) – the comparative study of 10 OECD countries includes 6 European data-sets. The aggregate value of demand price elasticity was estimated at -0,43. One of the higher value (-0,70) was obtained for Romania by Cimos et al (2012) using long term series 2002-2010. The increase of water prices in the mentioned period was similar to Polish conditions. One of the last available study is the research done by Hortová and Křištoftek (2014) for the Czech Republic, with quite similar result; -0,22.

3. Water consumption and prices for water services in Poland

The final amount of water provided (invoiced water) depends in a long term on a number of factors:

- consumption of water per capita (decreasing),
- demographic changes (drop in total number of inhabitants),
- number of people connected to piped water (increasing),
- indirectly the development of sewerage systems has also a serious impact on unit water.

The results of the above listed factors is presented in Table 1.

Table 1. Dynamic of water consumption in Poland

Water consumption	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Poland, total all sectors	hm ³	9348,5	9073,7	9146,5	9482,9	9370	9281	10160,8	9742	9084,7	9150,2	9203,3	9568	9247,1	10106	10243,7
Poland, municipal sector only	hm ³	1753,8	1671,3	1626,6	1657	1599,8	1587,4	1603,9	1573,4	1580,5	1544,1	1541,1	1544,7	1539,1	1521,8	1537,0

Source: Environment. Central Statistical Office. Consecutive yearbooks from 2001-2015

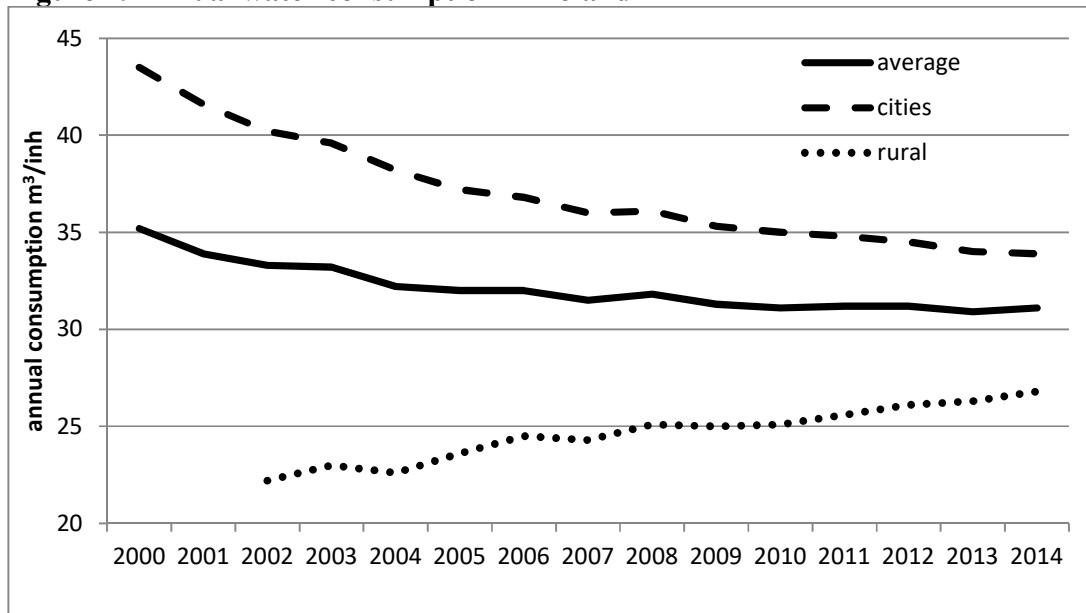
Between 2000 and 2014 the amount of water provided to households dropped by 12% in spite of the increase of people connected to the network by 5,4% and the increase of people connected to the sewerage by 16,3%. The changes in per capita consumption are shown in Table 2 and Figure 1. The disaggregation into population living in cities and rural areas is more appropriate for the purpose of this research, which is based on data from urban consumption.

Table 2. Changes in water consumption per capita in Poland, m³/inh/y

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
average	35,2	33,9	33,3	33,2	32,2	32	32	31,5	31,8	31,3	31,1	31,2	31,2	30,9	31,1
cities	43,5	41,6	40,2	39,6	38,2	37,2	36,8	36,0	36,1	35,3	35,0	34,8	34,5	34,0	33,9
rural	-	-	22,2	23,0	22,6	23,6	24,5	24,3	25,1	25,0	25,1	25,6	26,1	26,3	26,8

Sources: Environment. Central Statistical Office. Consecutive yearbooks from 2001-2015

Figure 1. Annual water consumption in Poland

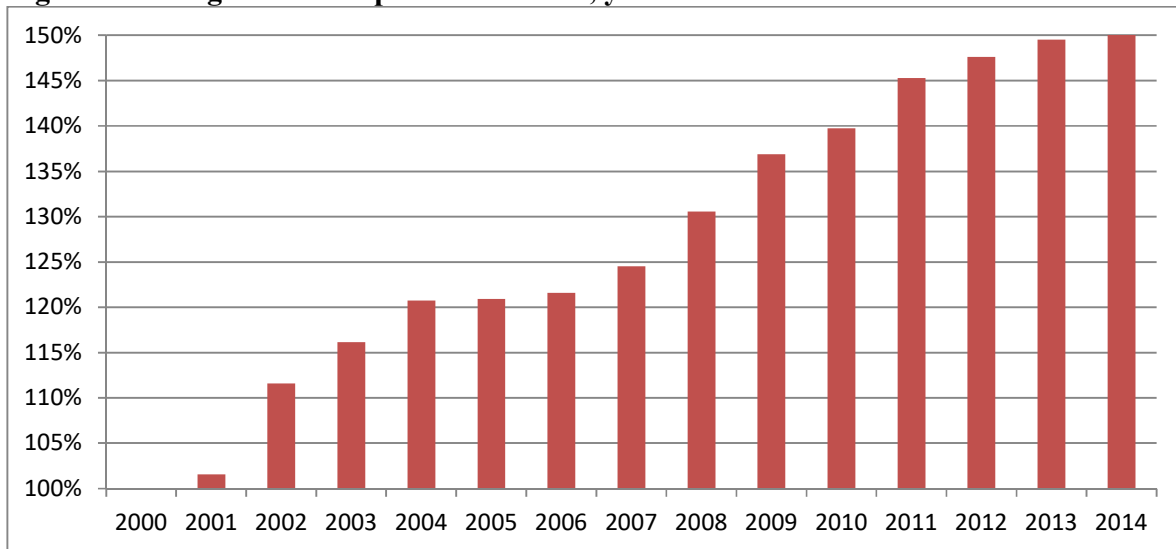


Sources: Environment. Central Statistical Office. Consecutive yearbooks from 2001-2015

Figure 1 justifies also the methodological approach adopted – instead of highly aggregated data for the whole country – only the urban population was analysed. The data for the whole country or administrative regions (NUTS-2) would enable supplementation of the model by the income factor however, the aggregation of urban and rural population cumulates the opposite trends and skips the real changes that are only visible on disaggregated data. Similar discrepancies between rural and urban population exist also in the analysis of the available income; the average for the whole Poland is 1340 PLN/month/per capita while for rural and urban populations the figures are 1067 PLN and 1516 PLN respectively (GUS 2015a).

The average of water prices in Poland suggest a permanent increase of the tariffs, however, the proper estimation of the trend should be made using constant prices. Such a comparison is shown at Figure 2. The dynamics estimated based on the constant price changes show the rise (in comparison to 2000) of 153% (what is equivalent to the factor*2,5). During the research period (2010-2014) the prices have increased by approx. 15%.

Figure 2. Changes of water prices in Poland, year 2000 = 100%



Source: Own comparison based on public database: <http://www.cena-wody.pl>, data from Chamber of Water Operators and Regional Water Authorities

4. Database

The calculation was conducted on the sample consisting of the largest cities in Poland. The sample includes the cities responsible for 67% of the total municipal water consumption in Poland. Such data about per capita consumption in household sector are published year by year by Central Statistical Office (GUS, 2015b). The information describing the annual water consumption provided by GUS was compiled with water tariffs per each city. The individual tariffs per 1000 major water operators in Poland are published in an open data base www.ceny-wody.pl. The GUS database consists of approx. 109 cities where processing and the time series have started in 2010 till 2014. As a result, 400 price changes with associated demand changes were taken into consideration. The basic description of the sample is presented in Table 3.

Table 3. Basic description of the sample

	Base year 2010	Sample	Sample as % of total value
Urban population (thousands inhabitants)	23264,4	14802,4	63,6%
Total water consumption in cities (hm ³ /y)	819,5	554,1	67,6%

Source: Own elaboration based on GUS, 2015b and data base www.ceny-wody.pl.

The sample consists of the largest cities in Poland. It means that smaller cities are skipped in the analysis. Such an approach increases in fact the credibility of final results. This can be explained and justified by differences in the ratio of inhabitants connected to the sewerage that exist between large and small cities. The reviewed sample of cities (63,6% of total urban population in Poland) produces 87,5% of wastewater. It means that in small cities there is a serious sub-population connected to piped water but not connected to sewerage. For such a sub-population a demand reaction to the water price increase is different than it is for the population connected to both piped water and sewerage. Therefore, the sample used for estimation seems to be homogenous. In the next steps some data was excluded due to the lack of some information and some was skipped due to the reasons described in methodological section. Finally the sample consists of 258 observations.

5. Methodology

The household tariffs include the effect of subsidies (if existing) provided by the municipalities. It means that the prices calculated by the water providers can be reduced if the municipality decides to subsidise such an activity (water provision). Because the demand depends on the final price/prices the subventions have to be included in the calculation.

The prices adopted for the purposes of the demand price elasticity estimation are gross (VAT included), for the same reason. The real cost of water purchased by a household consists of a volumetric price (a single tariff; block tariffs do not exist in Poland, however, such a solution is not illegal) plus flat charges (if exist). For the calculation of the real price the following formula was applied:

$$P_1 = Te_1/Bw \qquad \text{Equation 1}$$

Where

P_1 – real price

Te_1 - Total expenditure₁ = sum of flat payments₁ + quantity of billed water * price of water

Bw – quantity of billed water

Because the demand reaction is induced by a total water bill, the second approach includes also payments for sewage. There are valid arguments to incorporate the expenditure related to sewage collection and treatment in the calculation:

- a) The payment for sewage is calculated as the amount of billed water multiplied by the price for sewage + fixed costs (if exist)
- b) There is no single case in the sample of separate operators providing services (separately water provision and wastewater collection). Therefore for typical consumer there is one “water bill” including not clear and obvious incremental costs. Furthermore the common name for such a bill is “a bill for water” instead of “a bill for water provision and wastewater collection and treatment”.
- c) There is quite general understanding that the total value of the bill depends on the amount of water consumed.

Therefore the second approach assumes that:

$$P_2 = Te_2/Bw$$

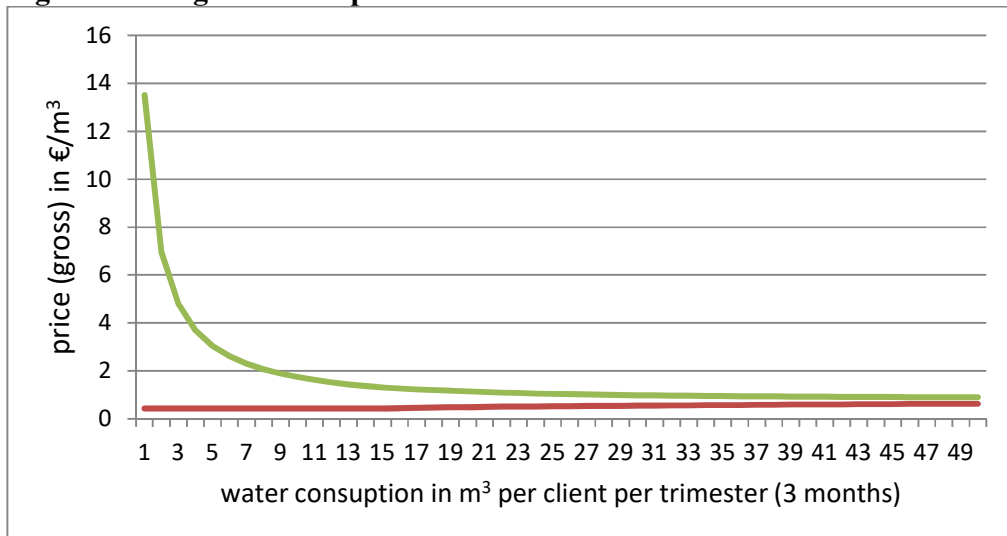
Equation 2

Where:

Te_2 - total expenditure₂ = sum of flat payments + quantity of billed water * (price of water + price of wastewater)
 Bw – quantity of billed water

A simple solution described above was not applied in the reviewed literature. The authors focus rather on the discussion related to econometric models especially in the case of increasing block tariffs. The difference between using rough data that exclude the influence of flat payments and the proper recalculation of the prices into marginal prices is shown on Figure 3. Presented recalculation was made for 8 block tariffs supplemented by flat payment. This is a case study from Skiathos (Greece). The difference between the price extracted from block tariffs (almost linear) and the function including flat payment (hyperbolic) is really serious.

Figure 3. Marginal water prices in Skiathos



Source: Own calculations based on working papers prepared for the EWATUS project.

Between 2010 and 2011 the reduced VAT rate increased from 7% to 8%. This has led to an increase in the expenditures for water services for all households even if the providers had not raised their net prices.

The result of water price rise – the demand reduction is smoothed by an opposite trend – an increase of water consumption being a result of a connection to the sewerage system¹. In big cities the sewerage connection ratio is high but still below 100% however, continuously increasing². Unfortunately, the detailed data city by city and year by year is not available. Lack of such information seems to be crucial for this investigations. During the data processing, 90 (out of 400) data sets for cities in Poland were quite difficult to explain: rising water prices caused increase of water consumption. Such situation is only explicable in the case of serious extension of the sewerage system when the subpopulation served so far only by piped water is now connected also to an extended sewerage. This 90 data sets were extracted from the database.

¹ The price of septic tanks service is approx. 6 times higher than the price of collection the wastewater using sewerage. Therefore, following the connection to the sewerage (which is usually paid by a water provider), households experience a serious drop in the expenditures.

² According to the information of Polish Chamber of Water Providers the connection ratio reach 89,3% in 2014 it was more by 3 percentage points in comparison to the base year 2010.

6. Modelling approach

The modelling process starts from the fundamental equation describing the demand price elasticity. Elasticity represents the percentage change in the quantity demanded caused by the percentage change in price and is defined by the equation (Schotter, 2008):

$$E_p = \frac{\frac{dQ}{Q}}{\frac{dP}{P}} \quad \text{Equation 3}$$

Where:

Q – quantity of water consumed (m³/y, per capita)

P – real price of water (or water+wastewater in the second approach)

The simple regression model has the following form:

$$dQ/Q = E_p * dP/P \quad \text{Equation 4}$$

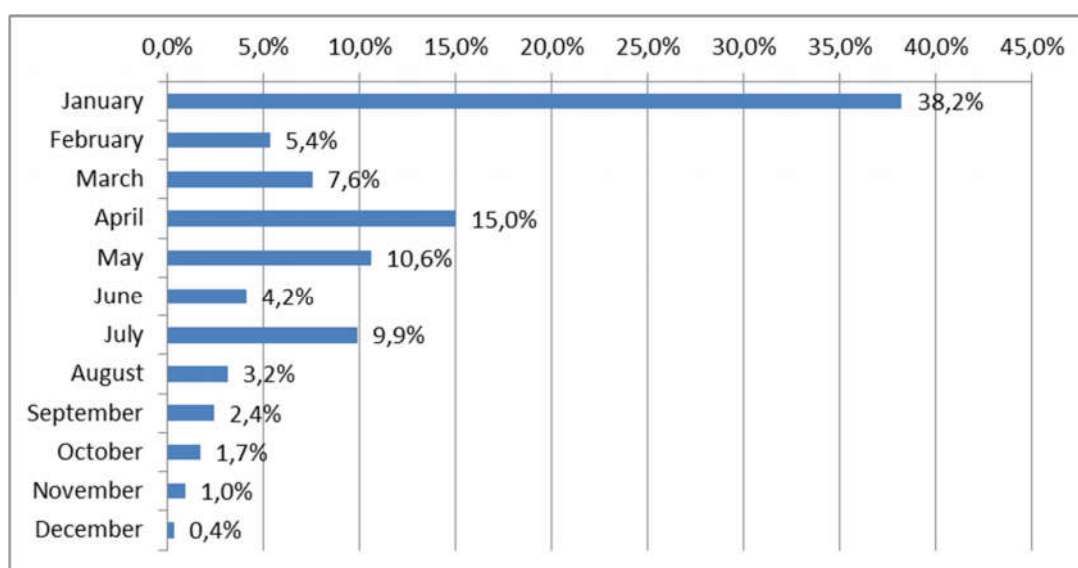
Going into the details two variants were taken into consideration. The first one based on the understanding of dQ and dP as a difference between values in year “i” and “i+1” (short term elasticity), the second assuming that the dQ = Q₂₀₁₀ – Q₂₀₁₄ (beginning and end of calculation period). Per analogy dP = P₂₀₁₀ – P₂₀₁₄. The connotation of both variants are presented by the next two formulas:

$$E_p = \frac{\frac{Q_i - Q_{i+1}}{Q_i}}{\frac{P_i - P_{i+1}}{P_i}} \quad \text{Equation 5}$$

$$E_p = \frac{\frac{Q_{2010} - Q_{2014}}{Q_{2010}}}{\frac{P_{2010} - P_{2014}}{P_{2010}}} \quad \text{Equation 6}$$

The second variant limits the sample to approx. 100 observations however, such an approach has some justification: not all cities change the tariffs at January 1st (see Figure 4), which means that the incentives from higher prices in many cases will start later than in January. On the other hand the consumption of water is reported annually, which means that the influence of price increase (drop in annual water consumption) is underestimated. Therefore the 5 years period seems to be more relevant for such an estimation because the longer period smooths the demand reaction.

Figure 4. Months of the changes of tariffs for water and wastewater services in Poland



Source: Own calculation using open database of water prices: <http://www.cena-wody.pl>.

Because high number of different assumptions would make such calculation less transparent the next table presents all scenarios taken under consideration with the distinction between the assumptions discussed above.

Table 4. Review of the scenarios

	Year by year changes	Long term changes between 2010 and 2014
Changes of real price of water	Scenario 1 (S1)	Scenario 2 (S2)
Changes of real price of water and wastewater	Scenario 3 (S3)	Scenario 4 (S4)

Source: Author's own elaboration

7. Results

The final output - price demand elasticity factor for cities in Poland was quite similar to the previous calculation results concerning Poland and some European investigations. More detailed analysis indicates however that the average value is quite controversial. The basic statistic for the above specified scenarios are presented in Table 5 and Table 6.

Table 5. Results of estimation

Scenario	Coefficient	<i>t Stat</i>	p-Value	St dev
S1	-0,21887581	-2,64331	0,008637114	0,082804
S2	-0,22688363	-4,80979	0,000006	0,047171
S3	-0,12658236	-7,05505	0,00000000001	0,017942
S4	-0,16783087	-10,9785	4,85664E-18	0,015287

Source: Own calculation.

The first conclusion is that the elasticity is higher for prices that aggregate water and wastewater. Such a result is quite surprising because the water bills in Poland are quite complex and the majority of households do not distinguish between incremental costs. The next remark is related to the long and short term elasticity – in case of water prices only - there is no difference between such elasticities, the difference in case of aggregate prices of water and wastewater is also not crucial.

Table 6. Basic statistics for demand price elasticity index in analysed scenarios

Scenario	S1	S2	S3	S4
Average	-0,71009	-0,41929	-0,4112	-0,21994
Standard error	0,182655	0,093067	0,043257	0,019646
Median	-0,1829	-0,20597	-0,21518	-0,18345
St. dev.	3,37788	0,873049	0,694804	0,182193
Curtosis	69,6471	34,00226	43,06336	4,050832
Skewness	-7,85496	-5,60218	-5,70975	-1,86157
Range	42,20073	6,404534	6,715752	0,923285
Min.	-36,7143	-6,42	-6,71575	-0,93926
Max.	5,486445	-0,01547	0	-0,01597
N	342	88	258	86

Source: Own calculation

The details of the calculation are presented on the following four pictures. These pictures give us a clear visualisation of how far are the single values from the median and what is the credibility of such a generalisation.

Figure 5. Demand price elasticity index - scenario S1

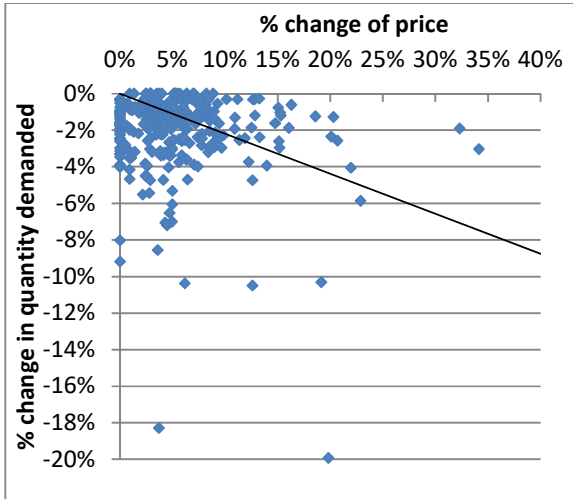


Figure 6. Demand price elasticity index - scenario S2

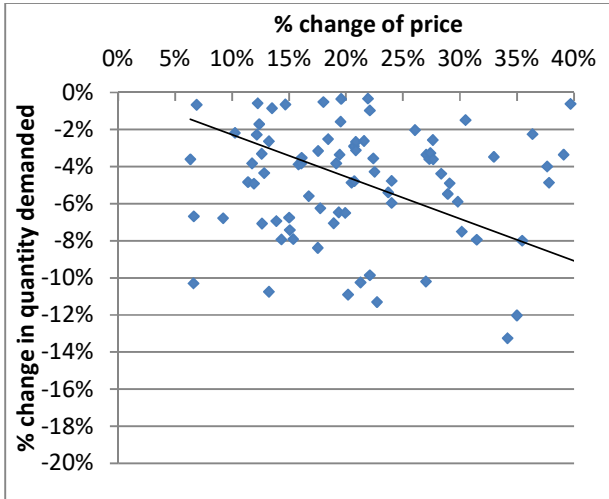


Figure 7. Demand price elasticity index - scenario S3

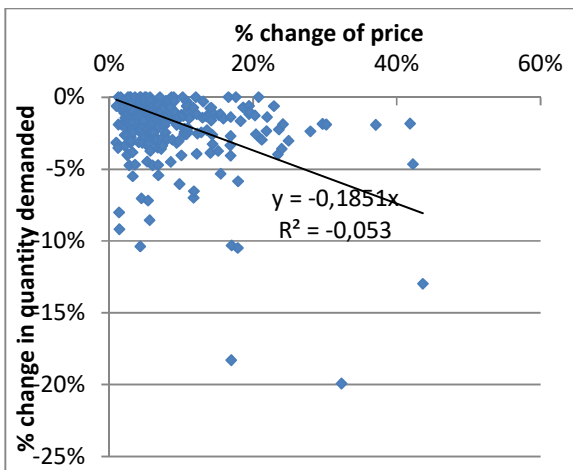
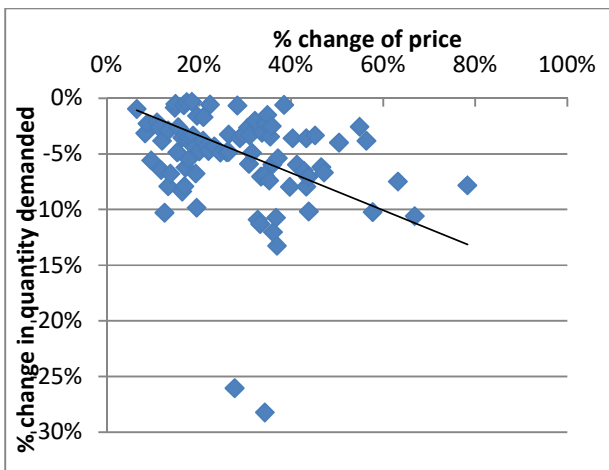


Figure 8. Demand price elasticity index - scenario S4



Source: Own calculation.

8. Discussion

The methodological approach promised improvement of the credibility of calculation due to:

- longer data series,
- extension of the intervals (from one year to 5 years period),
- implementation of additional factors (changes in fixed prices +volumetric prices, prices of wastewater).

In fact, the results are quite similar - independent on the additional variables. Furthermore, level of fitting of the demand elasticity function is very low. It means that there are more much serious factors influencing the water consumption than the price. It seems that the intensive sewerage investment programmes have to be included in the calculations. It is possible to collect data describing this process (increase of population connected to the sewerage). Unfortunately, data on another important factor, i.e. changes in the income level is not available across single cities in Poland. Such data are gathered only at the national and NUTS-2 level. Such aggregation does not fit to the data describing water and wastewater services. The rather low values confirm the Olmstead and Hanemann's conclusions (2005) – they found that households facing block prices are more sensitive to price increases than households facing constant unit prices.

9. Conclusion

The sensitivity of household's demand for water is much more complicated than simple reaction on the prices. This statement suggests the next gap: the favourite instrument of sustainable policy–demand management (instead of the supply increase) has quite limited applicability. The influence on the water demand requires much more sophisticated approach than increase of single volumetric price. This is the place for the introduction of multi block price systems. Also more detailed investigation of additional factors influencing consumers' behaviour is necessary. Presented research - like other mentioned in the paper - has relatively low level of the coefficient determination – this is an additional argument for future, more detailed research.

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Taryfy za wodę jako determinanty wielkości konsumpcji – analiza na podstawie miast w Polsce

Streszczenie

Artykuł prezentuje próbę empirycznej weryfikacji wskaźnika elastyczności cenowej popytu na wodę na bazie danych z dużych miast w Polsce. Informacje związane z reakcjami popytowymi odgrywają istotną rolę w procesie zrównoważonego zarządzania zaopatrzeniem w wodę. Metody dostosowania się do globalnych zmian klimatycznych również wymagają znajomości zachowań konsumentów w zakresie popytu na wodę. Badania wykorzystywały bazę złożoną z danych opisujących 100 największych miast w Polsce w okresie 2010-2014. Było to drugie badanie elastyczności cenowej popytu na wodę w Polsce a pierwsze oparte o dane z pojedynczych aglomeracji – zamiast danych zagregowanych dla całego kraju. Tak duży poziom szczegółowości kreował również pewne trudności – w skali poszczególnych miast brak jest danych o dochodach – stąd też pominięto zjawisko elastyczności dochodowej popytu na wodę. Otrzymane wyniki nie odbiegały znacząco od wcześniejszych badań realizowanych w krajach UE.

Słowa kluczowe: zużycie wody, elastyczność cenowa popytu na wodę