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Informing Water Policies with a Residential Water Demand Function: The Case of Serbia

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Abstract

We provide the first estimate of a household water demand function in Serbia. The econometric model is estimated on a panel dataset made of the 25 Serbian districts (oblasts) covering years 2009 to 2012. Our estimates reveal a price elasticity of the Serbian household water demand varying between -0.2 and -0.9, depending on the model considered. We also demonstrate how the household water demand function can inform water policies in a prospective context. Using our estimates, we explore some possible future patterns of regional household water consumption in Serbia.

JEL Classification: C33, Q21, Q25

Keywords: Residential Water Demand, Price Elasticity, Water Policy, Serbia

1. Introduction

Serbia is considered as a moderately water-poor country (Todic and Vukasovic, 2009). This has led the European Environmental Agency to qualify water resources in Serbia as being insufficient.[5] The water availability issue is worsened by an unequal distribution of resources over space, as well as by differences in water quality across the Serbian territory. The most populated lowland regions have limited water resources[6], while high quality water resources are mostly located along the country's perimeter. As a result, 84% of available water in Serbia originates outside the territory (Kaštelan-Macan et al., 2007).

These considerations on low water availability call for an efficient management of water resources in Serbia. As a result, substantial legislative

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[5] In Serbia, the water available represents 1,600 m3 per person per year whereas it is usually considered that a country has enough water if the domestic flow is greater than 3,000 m3 per capita annually.

[6] Lowland regions have a domestic water flow much lower than the average, in some cases less than 500 m3 per person per year

efforts have been undertaken by Serbia for securing water resources and developing water protection in the last decade. The Law on Environment Protection passed in 2004[7] and the Law on Waters adopted in 2010[8] constitute two examples of legal frameworks passed in this field. Despite these noticeable efforts, Serbia still faces some difficulties to achieve compliance with the main pollution control requirements specified in European Directives (Republic of Serbia, 2011). This noncompliance also results in failures to achieve the environmental objectives of the Water Framework Directive.[9] The same document recognizes nevertheless a reasonable level of compliance with the requirements of the Drinking Water Directive in most areas, although some serious problems of arsenic contamination have been noticed in some parts of Vojvodina.

An efficient management of water resources requires a good understanding of water demands for all users (Renzetti, 2002). Demand-side water management has become now a crucial activity of water sector regulation in most of the countries.[10] More generally, water demand modelling has been shown to be a valid approach to examine the sensitivity of water consumption to weather and climate (Balling and Cubaque, 2009), or to understand how consumers may react, in the short-term or in the long-run, to changes in water pricing (Martínez-Espiñeira, 2007). It has also been used to compute consumer's welfare changes for different types of water management policies (Garcia and Reynaud, 2004).

Surprisingly, and to our best knowledge, no estimate of the residential water demand function in Serbia has been published.[11] Our current work aims at filling this gap by providing the first estimate of the residential water demand function in Serbia. Providing some estimates of the price elasticity for the residential water demand in Serbia is relevant for a policy perspective. Indeed, one may expect in the future an increase in water prices in Serbia for several reasons. First, compared to similar countries, water prices in Serbia are quite low.[12] Second,

[7] Official Gazette of the Republic of Serbia, No. 135/2004.

[8] Official Gazette of the Republic of Serbia, No. 30/2010.

[9] The National Environmental Approximation Strategy for the Republic of Serbia reports that, of the 2.5 million households, only 1.3 million are connected to public sewerage. On the 365 million m3 of waste water discharged in 2009, only 51 million m3 were treated (mostly only to primary standards). See Republic of Serbia (2011) for further references.

[10] In their recent analysis of the water sector in UK, Parker and Wilby (2013) stress how water management policies have moved away from a purely supply-side perspective toward a greater emphasis on demand-side options. The UK water companies are for instance required to forecast water demands and they are encouraged to provide specific forecasts of domestic customer's demand (Defra, 2011).

[11] More generally speaking, we have not been able to find an estimate of the residential water demand for any of the Balkan countries, at the exception of Greece.

[12] According to the National Environmental Approximation Strategy for the Republic of Serbia, the average water tariff is Serbia was estimated at € 0.41 per m3 in 2011. This

according to the National Environmental Approximation Strategy for the Republic of Serbia, massive investments are expected to be realized by water utilities since much of the water supply and wastewater infrastructures have not been well maintained over the last decades (Topalović et al., 2012). Third, still according to the same report, many public utility companies do not achieve cost recovery for the water services they provide, partly as a result of the relatively low tariffs they charge and partly because of lower than optimal scales of operation.[13] Our estimates of the Serbian residential water demand may then be used to assess how households will adjust their water consumption following the expected water price increases. Welfare implications could also be derived and used by public authorities in a cost/benefit perspective.

The remainder of this article is organized as follows. Section 2 exposes the material and the methods, and we provide an estimate of the Serbian residential water demand in Section 3. Policy implications are discussed in Section 4.

2. Material and methods

2.1. The water demand function approach

The water demand function approach relies on standard neoclassical economic assumptions. The utility of a representative consumer is maximised under a budget constraint and given prices of commodities. Thus the demand for a commodity depends on consumer's income, on price of all commodities, as well as on consumer preferences. Assuming weak separability of water with respect to other goods, the Marshallian demand in water can be written as:

$$y = y^*(p, I, Z) \quad (1)$$

where y is the water consumption either per capita or per household, p and I denote the unit water price (representing both water supply and the sewage treatment services) and the representative household income, respectively. Z is a vector of exogenous variables assumed to influence water consumption (i.e climate, household characteristics).

Here, we are especially interested in providing empirical evidence on the relationship between water price and household water consumption, as well as the relationship between household income and household water consumption.

price includes water supply, waste water collection (sewerage) and, in some limited cases, waste water treatment. Comparable figures in neighboring countries (although with generally higher rates of waste water treatment) are € 0.90 in Bulgaria, € 1.15 in Croatia, € 2.40 In Hungary and € 0.55 in Romania.

[13] Ensuring tariff setting according to the cost recovery principle is mentioned by World Bank (2015) as one of the three main challenges of the water and wastewater sector.

A simple way to measure these relationships is to compute the *price elasticity* of the water demand:

$$\varepsilon_p = \frac{\partial y^*(\cdot)}{\partial p} \times \frac{p}{y^*} \tag{2}$$

which measures the percentage change in household water use in response to a 1% change in price (all other things being equal, i.e. holding all the other determinants of demand, such as income, constant) and the *income elasticity* of the water demand:

$$\varepsilon_I = \frac{\partial y^*(\cdot)}{\partial I} \times \frac{I}{y^*} \tag{3}$$

which gives the percentage change in household water use in response to a 1% change in household income.

2.2. Data

In Serbia, local governments are responsible for water and wastewater service provision through 152 public utility companies (World Bank, 2015). These utility companies are founded by municipalities but remain state-owned. Water prices are proposed by public utility companies but they must be approved by the municipal assembly. Water tariffs are typically revised yearly. At national level, the Ministry of Finance is responsible for final control of tariff revision (in accordance with the general price policy). Most of the utility companies charge water with two-part tariffs (one fixed charge and one marginal price). Tariff setting in Serbia has often been dominated by political and social considerations rather than public utility company operation, maintenance, and investment needs (UTVSI, 2007). As a result the price of water barely covers operating and maintenance costs (World Bank, 2015).

The water sector is concentrated with 7 regional public utilities (including Belgrade waterworks) providing services to 31% of the population. Since there exists no consolidated database on household water use and price at the municipality-level for Serbia, we have worked at a more aggregated level. Our estimation of the residential water demand in Serbia is based on data at the district-level (oblast). For the 25 districts in Serbia, we have then collected data allowing to compute the average household annual water consumption per capita, the average unit water price paid by households and some average characteristics of households and districts supposed to be potential determinants of the residential water consumption.[14] These data have been collected on an annual basis from year 2009 to 2012.

Our main source of information on household water consumption is the reports *EcoBulletins* published each year by the Statistical Office of the Republic of Serbia. This publication provides each year at the district level the volume of water distributed by the public water network to residential water users. By personal communication with the Statistical Office of the Republic of Serbia we have also been able to get, per district and per year, the number of persons connected to the public water supply. This has allowed us to compute for each year and each district the water consumption per connected capita, see Table 1.

Substantial variations in water consumption per capita across districts can be observed, for instance from 28.18 m3 per capita in the Toplička district to 91.50 m3 in the Nišavska district, in 2012. Some differentiated temporal patterns emerge. Over the period 2009-2012, residential water consumption per capita has decreased by 3.9% in Serbia (unweighted average). The decrease is very substantial in the Zlatiborska or Pirotska districts (-20.4% and -17.2%, respectively). On the contrary, the Toplička and the Pčinjska districts have experienced a high increase of the water consumption per capita (+28.1% and +20.1%, respectively).

Finding reliable data on residential water prices at the most disaggregated level is a challenging task in any country. For Serbia, we rely on the publication *Municipalities and Regions of the Republic of Serbia* edited from 2010 to 2013 by the Statistical Office of the Republic of Serbia. We use the price paid by households for the water service (in euros per m3) provided for 15 Serbian municipalities from 2009 to 2012. The following table gives some basic statistics related to the residential water price for the 15 municipalities we have considered.

[14] A highly debated issue in the water demand modelling literature is the appropriate aggregation level (namely the choice between working with household-level data or at more aggregated levels such as municipality or region levels). The suitability of aggregated data for estimating a residential water demand has been challenged for a long time but the meta-analysis literature is not fully conclusive on this issue. Espey et al. (1997) and Dalhuisen et al. (2003) did not find any statistically significant difference between elasticities derived from the household level and aggregated level studies. These finding have been challenged by Gardner (2010) who indicates that price and income elasticity estimates generated using aggregated data are more elastic than those from household-level data. On the contrary, Sebri (2014) concludes that studies using aggregated data produce less elastic estimates than those using household-level data. It then seems that no systematic bias can then be attributed to using aggregated data for estimating a residential water demand function.

Table 1: Household water consumption (in m3 per connected capita per year)

Region	District	2009	2010	2011	2012	Δ (%)
Belgrade	Grad Beograd	85.06	80.41	86.66	83.22	-2.16
Vojvodina	Južnobački	42.51	36.28	37.76	36.32	-14.56
	Južnobanatski	52.32	54.41	46.97	57.96	10.78
	Severnobački	43.06	40.77	38.56	39.06	-9.29
	Severnobanatski	50.22	44.47	49.35	50.82	1.19
	Srednjobanatski	48.24	49.63	52.05	53.04	9.95
	Sremski	50.64	47.99	52.4	55.52	9.64
	Zapadnobački	48.78	47.7	53.74	51.69	5.97
South and east Serbia	Nišavski	99.52	100.12	98.72	91.5	-8.06
	Pčinjski	51.04	62.39	59.71	61.28	20.06
	Borski	64.34	62.4	67.21	60.27	-6.33
	Braničevski	51.25	46.19	39.52	41.97	-18.11
	Jablanički	50.5	43.61	41.46	38.35	-24.06
	Pirotski	68.32	61.92	60.41	56.57	-17.20
	Podunavski	54.23	53.27	49.75	50.31	-7.23
	Toplički	22	24.07	27.37	28.18	28.09
	Zaječarski	43.56	41.39	39.55	37.93	-12.92
Sumadija and west Serbia	Kolubarski	58.8	55.31	44.55	43.97	-25.22
	Mačvanski	53.7	48.82	51.98	50.53	-5.90
	Moravički	51.19	49.07	46.58	47.64	-6.93
	Pomoravski	48.19	51.37	42.67	49.38	2.47
	Rasinski	48.35	49.5	49.92	49.2	1.76
	Raški	52.82	50.35	52.47	49.2	-6.85
	Šumadijski	49.83	49.36	47.35	48.78	-2.11
	Zlatiborski	70.21	60.98	58.58	55.87	-20.42
Total		54.35	52.47	51.81	51.54	-5.16

Δ*: Change between 2009 and 2012.*

Source: Author's computation.

Table 2: Unit price paid by households for the water and wastewater services (in € per m3)

Municipality	2009	2010	2011	2012	Δ(%)
Beograd	0.371	0.378	0.394	0.408	9.95
Valjevo	0.270	0.287	0.320	0.327	20.98
Zaječer	0.288	0.377	0.414	0.425	47.5
Kragujevac	0.267	0.283	0.311	0.362	35.88
Kraljevo	0.295	0.382	0.397	0.472	59.78
Leskovac	0.215	0.278	0.398	0.504	134.56
Niš	0.244	0.309	0.379	0.407	66.46
Smederevo	0.240	0.313	0.396	0.437	82.03
Užice	0.260	0.327	0.378	0.431	65.29
Šabac	0.224	0.244	0.274	0.297	32.76
Novi Sad	0.237	0.394	0.578	0.589	148.52
Zrenjanin	0.176	0.218	0.297	0.297	68.86
Pančevo	0.240	0.326	0.423	0.546	127.58
Sremska Mitrovica	0.228	0.270	0.297	0.312	36.91
Subotica	0.328	0.390	0.447	0.470	43.33
Total	0.259	0.318	0.380	0.419	65.36

Δ*: Change between 2009 and 2012.*

Source: Author's computation.

As it can be seen in Table 2, the unit water price significantly varies across municipalities, for instance from €0.297 per m3 in Šabac to €0.589 per m3 in Novi Sad in 2012. In 2012, the price of drinking water and wastewater remains very low at €0.419 per cubic metre, representing approximately 1% of the average household budget. The temporal evolution also differs across municipalities. Whereas the water price has increased only by 10% from 2009 to 2012 in Beograd, it has more than doubled in the municipalities of Leskovac, Novi Sad and Pančevo. Despite the water price increase, the low price of water barely covers operating and maintenance costs (World Bank, 2015). Cross-financing between domestic and other sectors and subsidizing from the municipality budget remain commonplace.

Since the household water demand is to be estimated at the district-level, we need to pass from municipal-level water prices toward the district-level prices. The unit water price for a given district has been assumed to be equal to the price of the municipality located in this district and presented in the previous table. For the 10 districts for which no municipal price is observed, we have used the average price for the region in which the district is located.

The district-level database has been complemented by some additional data to be introduced as potential determinants of the water consumption per capita. First average characteristics of the population (income, age, household size) have been obtained from the publication *Municipalities and Regions of the Republic of Serbia* edited from 2010 to 2013 by the Statistical Office of the Republic of Serbia. Second, some meteorological data have been extracted from the JRC climate database. Grid data (5km×5km) on rainfalls, temperatures and evapotranspiration have been aggregated at the district-level over the period 2009 to 2012.

3. Results of the empirical analysis

3.1. Estimating the residential water demand function

To estimate Equation 1, a wide variety of functional forms have been applied in the water demand literature, including linear forms, semi or double logarithm forms and more complex forms such as the Stone-Geary specification (Gaudin et al., 2001). The existing literature is however not very informative concerning the specification which should be preferred. Since the double-log model is the most common specification in the residential water demand literature, we have adopted this model in order to facilitate comparison to other studies. Furthermore, the specification implies that coefficient estimates are also elasticity estimates. With a double-log specification, the residential water demand function writes:

$$\ln(y_{it}) = \alpha \ln(p_{it}) + \beta \ln(I_{it}) + \gamma \ln(Z_{it})' + \varepsilon_{it} \tag{4}$$

where $i=\{1,..,I\}$ indexes districts, $t=\{1,..,T\}$ represents years and ε_{it} is the usual random term. In Equation 4 the coefficients α and β can be directly interpreted as the price and the income elasticities of the water demand. Two panel data estimators may be used namely the fixed effects model and the random effects (or error components) model. We propose to use these two estimators and to conduct some specification tests (Hausman test) to decide which is the most appropriate to our data.

In our case, a specific estimation issue arises due to the use of the average water price as an explanatory variable. Stated simply, the average price a consumer faces depends on his level of consumption but this level of consumption is also affected by the average price. This simultaneity violates standard assumptions regarding independence of the error term from explanatory variables.[15] OLS are in such case inconsistent and a specific estimation procedure is required. This simultaneity problem can be addressed by using instrumental variables (IV) techniques.

3.2. Estimation of the household water demand

In Table 3, we report our estimates of the household water demand function for Serbia using Ordinary Least Squares (OLS), Generalized Least Squares (GLS) and Generalized Least Squares with instrumental variables for the water price (GLSIV). The instrumental variables must satisfy two requirements. They must be correlated with the endogenous variable (water price) and be uncorrelated with the error term of the water demand equation. We have included four instruments. The first is the share of water supplied to the households. The second is the share of households connected to the water supply network. The third instrument is the household network density (number of household connected per km of network length). The fourth instrument gives the percentage of water lost in the distribution network. In addition, a dummy variable for the district of Belgrade has been included, due to its highly particular socio-economic characteristics.[16]

[15] The main reason for this problem of endogeneity is related to the fact that we have included as an explanatory variable of the water consumption the "average price paid by households for the water and wastewater service" which is typically computed by dividing the water bill of an average household by his water consumption. This implies an endogeneity problem since the water consumption appears both in the left and in the right hand-side terms of the water demand equation. For Germany, Schleich and Hillenbrand (2009) discusses another potential reason related to the cost-pricing mechanism usually used by water services which may result in endogenous price of water. In the German water sector, reported prices do not usually balance supply and demand. Instead, prices are set to approximately cover costs. In this case, an increase in water demand results in lower prices because the fixed cost components are distributed among higher consumption levels. Thus, water prices may have to be treated as endogenous.

[16] The estimated instrumental equation of the water price is available from the authors upon request.

Table 3: Estimation of the household water demand

	OLS	GLS	GLSIV
ln Water price (€ per m3)	-0.428***	-0.176**	-0.869**
	(0.14)	(0.08)	(0.37)
ln Household income (€ per capita)	0.567***	0.158	0.977**
	(0.11)	(0.16)	(0.46)
ln Age	0.687	0.067	1.520
	(0.65)	(0.96)	(1.46)
ln Household size	1.152**	-0.056	1.546
	(0.49)	(0.87)	(1.32)
ln Days without rainfall in summer	-0.039	-0.021	0.063
	(0.23)	(0.12)	(0.17)
Constant	-4.069	2.539	-11.176
	(3.20)	(4.20)	(8.91)
R-squared or pseudo R-squared	0.227	0.158	0.210
N. of obs.	100	100	100

*Note: The dependent variable is the logarithm of the household annual water consumption per capita at district-level from 2009 to 2012. ***, **, * for significant at 10%, 5% and 1% respectively. See Appendix A. for a description of each variable.*

Before commenting on the empirical results, some preliminary specification tests must be conducted. First, the parameter estimates for the four additional instrument variables in the first stage exhibit the expected signs. Second, the F-statistic for the partial R2 of the first stage exceeds the threshold for inference based on the IV estimator to be reliable. Lastly, the Hausman test statistic suggests that the assumption of exogeneity is rejected. Thus, we have evidence that results from the OLS and the IV procedures are different, i.e. that water price is endogenous.

The levels of the (adjusted) R2 suggest that all the models explain a relatively small share of the variability in the water consumption per capita across districts. This low explanatory power of the estimated models may be due to the limited number of variables introduced in the demand function. Another way to assess the validity of the model is to compare the water consumption predicted by the demand function to the observed water consumption. For most of the districts the model performs quite well, with a mean absolute percentage error representing 18.64%.

It should be noticed that in addition to variables presented in Table 3, we have also considered other potential determinants of household water consumption. In particular, to capture the fact that Serbian districts may differ in terms of their rural/urban environment, we have introduced the population density. The econometric estimates with this additional variable are qualitatively very similar to the ones presented in Table 3. Serbian districts also differ according to their housing characteristics, and in particular according to the proportion of individual houses and multi-family housings.[17] Not having accounted for these differences may have resulted in a biased estimate of the Serbian water demand function especially because water consumption in individual and multi-family housings is not always metered in the same way: It is well-known that households may react differently to water pricing if their water consumption is individually metered or not (Agthe and Billings, 2002). In Serbia, individual houses are typically equipped with individual meters and the bill is then based on individual water consumption. Although some multi-family housings are also equipped with individual meters (one meter for each apartment) there are still a lot of cases where there is only one meter for the whole multi-family housing (one meter for several apartments). In this case, the multi-family housing water bill is allocated across apartments based on the number of persons that live in each flat or based on the area of each flat - both water bill allocation mechanisms are actually used. Although the information on metering could be highly relevant for our study, this type of data is not collected by the *Statistical Services of Serbia*. Our second-best strategy has then been to find a variable in order to proxy the proportion of households equipped with individual meters. Since it is likely that the proportion of individual meters will be higher in rural areas were people tend to live more in individual houses, we have used as a proxy the "percentage of land in each district devoted to agricultural activities". This variable is available in each district and each year in the annual reports *Municipalities of Serbia* published by the Statistical Office of Serbia. We have re-estimated our demand models by including the percentage of land in each district devoted to agricultural activities (in logarithm) as an additional explanatory variable. The main parameters of interest remain unchanged (in particular the price elasticity) which means that our estimated Serbian residential water demand function is not affected by an omitted variable bias (due to differences in water metering conditions across districts).

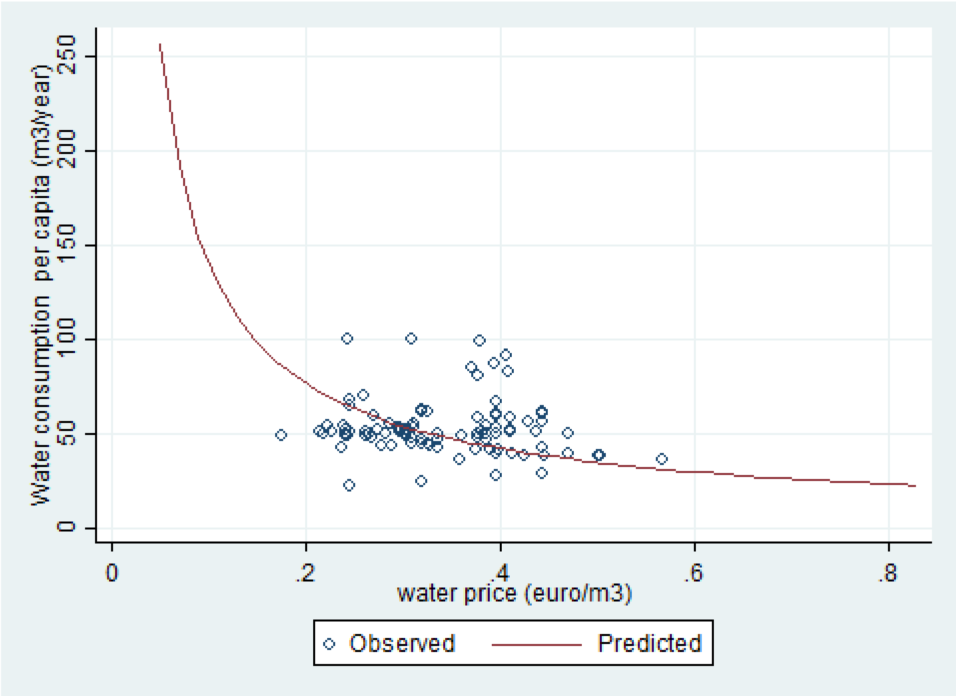
3.3. The determinants of household water demand in Serbia

In Table 3 we report our estimation of the household water demand function for Serbia. Depending upon the specification considered, we obtain a price elasticity varying between -0.17 and -0.87, which is a level in line with the existing literature for similar countries. For comparison, the average price elasticity in the studies surveyed in the meta-analysis by Dalhuisen, Florax, de Groot, and Nijkamp (2003) is -0.41 with a standard deviation of 0.86. In the more recent meta-analysis conducted by Sebri (2014), price elasticity estimates

[17] This point has been stressed by one of the reviewer of the paper we would like to thank.

range from -3.054 to -0.002 with a mean of -0.365. In Figure 1 we have represented the household water demand for Serbia (at the mean sample for all explanatory variables, at the exception of the price).

Figure 1: A graphical representation of the household water demand in Serbia



We provide some evidence that water is a normal good for Serbia with an income elasticity varying between 0.16 and 0.98. The household water use tends to increase with household income, but less than proportionally. The explanation is quite simple. A high level of income is associated with high living standards, which could imply a higher quantity of water-consuming appliances and a higher probability of the presence of high-water demanding outdoor uses such as lawn gardens and swimming pools. Our results regarding income elasticities are consistent with the previous literature showing that domestic water consumption is positively correlated with income (Arbues et al, 2003).

We find a positive (but not significant) relationship between average age of the population and water consumption per capita. This is consistent with the existing literature. For Germany, Schleich and Hillenbrand (2009) finds that if the average age increases by one year, water consumption per person increases by about 1.8 litre per day. One may elaborate on what drives this result. Water use may increase with age because retired people spend more time at home and gardening, because children use less water for washing and hygiene than adults, or because health reasons may force older people to use the bathroom more frequently.

Household size is only significant in the OLS model, with a positive impact on water consumption per capita. Although presenting an expected negative sign with the IV estimator, the coefficient for the number of days without rainfall in summer is not statistically different from zero. Climate conditions do not seem to play a major role in impacting on household water consumption in Serbia.

3.4. Informing water policies

A first result which may be useful from a water policy perspective is the fact that the price elasticity appears to be significant. This implies that one may expect adjustments in the water consumption per capita in case of price changes. In particular, increasing the water price by 10% will result in a reduction of the household water consumption between 1.8% and 8.7%. It is then demonstrated that water price may play a role towards signaling water scarcity or water cost to households in Serbia. One should stress that the price elasticity we have estimated should be considered as a short-term price elasticity. In the long-term, one may expect a higher reduction of the water consumption. Indeed, it is usually found that the long-term price elasticity of the household water demand is higher (in absolute value) than the short-term price elasticity, see Martínez-Espiñeira (2007) or Nauges and Thomas (2000). There are two main reasons explaining this result. First, if the share of water expenses in household budget increases, it is likely that consumers will keep a closer eye on their water consumption. Second, since in the short run household durable equipments (i.e. sanitary equipment) cannot be easily replaced, this creates persistence over time in water consumption. Household's ability to invest in low-water consuming equipments (i.e. dual-flush toilets) is however much higher in the long run which translates into a less inelastic household water demand function in the long term.

We now demonstrate how the household water demand function can inform water policies in a prospective context. We propose to conduct a scenario analysis to explore what could be the future patterns of household water consumption in the different districts of Serbia. We explore changes in consumption per capita, but also changes in water consumption aggregated at the district-level. This allows us to disentangle changes in water consumption resulting from a modification of households' habits or characteristics (change in per capita water consumption) from those resulting from demographic change.

To conduct this simulation exercise, we need some population projections for Serbia at the most disaggregated level. We use the medium-term (2011-2041) population projections of municipalities/cities provided by the Statistical Office of the Republic of Serbia, for the period 2011-2041.[18] We consider here the medium fertility variant.

[18] The population projections at the municipality level for 2041 are available in the publication Population projections of the Republic of Serbia – Data by municipalities and cities 2011-2041 edited by the Statistical Office of the Republic of Serbia in 2014.

We consider two scenarios of change. In the first scenario, both water price and household income are assumed to increase at the same growth rate, 2.89% per year.[19] Using the population projections at the municipality level for Serbia, the average age of the population is expected to increase by 6.2% between 2010 and 2041, and the household size is assumed to decrease by 2% over the same period. Finally the number of dry days in summer are expected to increase by 5% between 2010 and 2041, a percentage in line with preliminary evidence of climate change in Serbia. The second scenario is similar to the first one, except that we assume a greater annual growth rate for the water price. As stressed by World Bank (2015), tariffs barely cover operation and maintenance costs of water services in Serbia. As a result, subsidies from the national budget are necessary to cover operation costs. In addition, investments represent less than 15% of sector costs, a level too low to fund the investments needed to maintain and expand both water and sanitation services (World Bank, 2015). As a result increasing water price to ensure cost recovery through tariffs has been a major recommendation of the report (World Bank, 2015). In the second scenario, the water price is expected to increase at an annual rate of 4% whereas we keep an annual growth rate equal to 2.89% for household income. This differential in annual growth rates is expected to mimic a stronger implementation of cost recovery for the water services through water pricing.

[19] This growth rate corresponds to the average annual growth rate for the GDP per capita of Serbia for the period 2010-2030 forecasted by the Economic Research Service of the US Department of Agriculture (source: ERS International Macroeconomic Data).

Table 4: Evolution of the per capita and aggregated water consumption from 2011 to 2041

District	Region	2011	Scenario 1 for 2041			Scenario 2 for 2041		
		*y*cap.	*y*cap.	ΔY	Δpop.	*y*cap.	ΔY	Δpop.
		m3	m3	%	%	m3	%	%
Grad Beograd	1	87.2	101.5	39.2	19.6	77.5	6.3	19.6
Borski	2	51.7	60.1	-24.5	-35.1	45.9	-42.4	-35.1
Branicevski	2	56.6	65.9	-4.6	-18.0	50.3	-27.1	-18.0
Jablanicki	2	42.9	49.9	-8.7	-21.5	38.1	-30.3	-21.5
Nisavski	2	47.5	55.2	-1.1	-15.0	42.2	-24.5	-15.0
Pcinjski	2	43.4	50.6	5.3	-9.5	38.6	-19.6	-9.5
Pirotski	2	48.5	56.5	-19.5	-30.9	43.1	-38.6	-30.9
Podunavski	2	58.1	67.6	-7.3	-20.4	51.6	-29.2	-20.4
Toplicki	2	29.4	34.3	-15.0	-27.0	26.2	-35.1	-27.0
Zajecarski	2	37.8	44.0	-22.5	-33.5	33.6	-40.9	-33.5
Kolubarski	3	59.8	69.6	-4.3	-17.8	53.1	-26.9	-17.8
Macvanski	3	50.9	59.3	0.4	-13.8	45.3	-23.3	-13.8
Moravicki	3	51.7	60.2	5.5	-9.4	45.9	-19.5	-9.4
Pomoravski	3	54.4	63.3	0.6	-13.6	48.3	-23.2	-13.6
Rasinski	3	45.6	53.1	-0.4	-14.4	40.5	-23.9	-14.4
Raski	3	36.6	42.6	23.6	6.2	32.5	-5.6	6.2
Sumadijski	3	56.6	65.8	12.1	-3.7	50.3	-14.4	-3.7
Zlatiborski	3	47.9	55.7	3.1	-11.4	42.6	-21.3	-11.4
Juznobacki	4	66.2	77.1	17.0	0.5	58.9	-10.6	0.5
Juznobanatski	4	52.4	61.0	1.8	-12.5	46.6	-22.2	-12.5
Severnobacki	4	42.8	49.8	2.1	-12.3	38.0	-22.0	-12.3
Severnobanatski	4	44.0	51.2	-7.7	-20.7	39.1	-29.5	-20.7
Srednjobanatski	4	63.5	73.9	-7.1	-20.2	56.4	-29.1	-20.2
Sremski	4	49.0	57.0	-2.9	-16.6	43.5	-25.8	-16.6
Zapadnobacki	4	45.6	53.1	-9.6	-22.4	40.6	-31.0	-22.4

ycap.: predicted water consumption per capita in 2011 or in 2041

ΔY.: *percentage change in aggregated water consumption (district-level) between 2011 and 2041*

Δpop.: percentage change in projected population at district-level between 2011 and 2041

Region: 1 (Belgrade), 2 (South and East Serbia), 3 (Sumadija and West Serbia), 4 (Vojvodina)

In Table 4 we present the result of the scenario analysis for the 25 districts in Serbia. Column 3 gives the water consumption predicted by the model for 2011, our baseline year. Then, columns 4-6 provide the predicted consumption per capita and the change in aggregated water consumption at the district level for the first scenario in 2041. Columns 7-8 give the same information, but for the second scenario. Even if this scenario analysis is largely exploratory, a few interesting results emerge from Table 4.

First, the impacts of scenarios on water consumption per capita are quite different. In the first scenario, the water consumption per capita increases in all districts, in particular due to the strong income effect. In the second scenario, on the contrary, the water consumption per capita decreases significantly between 2010 and 2041. Households in Serbia react in that case to the higher increase in the water price by reducing their water consumption in order to limit as much as possible the effect on their water bill.

Second, it is clear that demographic change will play a major role in the future on the water sector of Serbia. Indeed, a very significant decrease in population is expected in all districts, at the exception of two of them (Grad Beograd and Raski). In the second scenario, the water price effect (which induces a decrease in the water consumption per capita) and the demographic trend (decrease in population per district) play in the same direction. Combining the diminishing population trend and the reduction in the water consumption per capita results in very significant reductions of the aggregated water consumption at the district level in 2041, at the exception of the Belgrade district. For the vast majority of districts this raises an issue of cost recovery through water pricing. The Belgrade district is quite specific in terms of demographic change since an increase of the population by more than 19% is expected between 2010 and 2041. At the aggregate level one may then expect (still under scenario 2) an increase in the water consumption for this district (+6.3%) despite the reduction of the per capita water consumption. Under scenario 2, the change in aggregated water consumption per district results from two contradictory effects. The first effect is the increase in the water consumption per capita. The second effect is related to the population decrease per district. As a result the change in aggregated water consumption per district is a priori ambiguous. As it can be seen in Table 4, some districts will experience an increase in the aggregated water consumption whereas, for other districts, an opposite result may hold. A deeper analysis of regional disparities is then required in this case.

The scenario analysis we have conducted is based on the assumption that there will be enough water resources for supplying the whole Serbian population. But it is important to remember first that Serbia is already considered as a moderately water-poor country (Todic and Vukasovic, 2009) and second that 84% of water in Serbia originates outside the territory (Kaštelan-Macan et al, 2007). Water availability in Serbia may then depend, at least partially, upon the water policies implemented in the upstream countries.

4. Conclusion

Demand-side water management has become a crucial activity of water sector regulation in most of the countries. Even if Serbia is considered as a moderately water-poor country, a good understanding of the main drivers of residential water consumption (including the water price) might be useful in this country. Indeed, since it is expected in the future an increase of water prices in Serbia[20] the way household will adjust their water consumption may inform water utility managers and more generally public authorities in charge of water sector regulation.

Surprisingly, and to our best knowledge, no estimate of the residential water demand function in Serbia has been published. Our current work aims at filling this gap by providing the first estimate of the residential water demand function in Serbia. We have estimated an econometric model using a panel dataset made of the 25 Serbian districts (oblast) covering years 2009 to 2012. Our estimates reveal a price elasticity of the Serbian residential water demand varying between -0.2 and -0.9, depending on the model considered. Facing a price increase by 10%, households in Serbia will react in the short-run by reducing their water consumption between 2% and 8%. This result has important policy implications. Indeed, pricing reforms are often cited as the first measure to be implemented in order to signal water scarcity and to encourage a *reasonable* use of water. The effectiveness of any pricing policy in engaging water consumption depends, however, on the price elasticity of consumption. The larger the price elasticity, the more effective these policies are at reducing water consumption. Our estimate of the residential water demand in Serbia allows decision-makers to simulate the impact of change in the water price on household water use per capita. To achieve more significant reductions of the household water consumption, public authorities should complement their price policies with non-price policies such as education or awareness campaigns.

We have also demonstrated how an estimated household water demand function, combined with population projections, can inform water policies in a prospective context. For a country like Serbia, population changes will have a major impact on household water consumption at district-level in the future. Although the results of our simulations should be considered with cautious, the combination of the diminishing population trend and the reduction of the per capita water consumption may result in very significant reductions of the household water consumption at the district level. For the vast majority of districts, this raises some issues related to cost recovery through water pricing that should be addressed by public authorities in charge of the water sector in Serbia.

[20] Many public utility companies do not achieve cost recovery for the water services, partly due to relatively low tariffs and partly because of a low scale of operation. As a result, water prices are quite low in Serbia, compared to similar countries (World Bank, 2015).

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Appendix A. Variables used for estimating the water demand function

Table A.1.: Definition of variables used for estimating the water demand function in Serbia

Variable	Definition	Mean	Std. Dev.
Water consumption (*y*)	Annual household water consumption (m3 per capita)	52.54	14.28
Water price (*p*)	Average price paid by households for the water and wastewater service (€ per m3)	0.39	0.08
Household income (*I*)	Annual salaries distributed to employees divided by population (€ per capita)	912.89	326.58
Age	Average age of the population (years)	2.93	0.20
Days without rainfall in summer	Number of days without rain from June to August (days)	18.1	3.47