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Basics of Water Pricing and Necessity to Model Municipal Water Pricing

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Abstract

The paper presents a brief overview of water pricing changes in the last two decades in Poland and impacts to demand and water price levels. Moreover, a model is proposed relating water price to water sales, production, average cost resumed in a relationship between current and previous period prices. This model results in a price convergence situation where the equilibrium price depends on the above mentioned parameters. Consequences for the water supply system of lower demand are presented.

Keywords: *Water utility, water consumption, water meter*

1. Introduction. Basics of water pricing

Establishing a reasonable price for water is very important both to water utility companies and consumers. To achieve rational use of water, prices should be based on the real cost of supply which means that they include the operation, maintenance and capital costs (Bagieński et al. 1996, Bylka 1994, Roman, 1995). Water production requires large capital investments and has serious health implications for the community.

The first objective of a water utility pricing scheme is to generate revenues covering costs. An efficient pricing rate must also realize two other functions, i.e. cost allocation between consumers and incentive generation for efficient use of water, which is a public good.

Prices are derived from an accounting system that emphasizes historical rather than economic costs and they are based on unit costs. In general, the price of water is set in such a way that the expected revenues from water sales should cover the forecasted expenses (Krauser, 1992). This is very close to average-cost pricing. Moreover, the accounting observed cost might not correspond to the true economic cost. This, for example, is the case when a single operator manages water services for different local communities.

Applying these criteria to determine the best rate structure is a complex challenge. First, some of the criteria may be in direct conflict and require making tradeoffs among each other. The balance between revenue stability and price efficiency is an example of such a tradeoff. Moreover, as water services require high capital investments, numerous expenses constitute fixed costs, which are independent of the quantity of water consumed. This makes cost allocation among consumers more difficult to achieve.

The broadest criticism of the unit cost price scheme is directed at the objective, which underlies the entire process of rate-setting (Garcia et al, 2004). There is little recognition of the role played by prices to signal resource scarcity. Consumer demands are viewed as exogenously determined and, as a result, there is no attempt to maximize the surplus from consumption through a choice of appropriate prices. Furthermore, since consumer demand is exogenous, no attempt is made to measure the market's valuation of water.

2. Specific situation of water sector in Poland as previous communist country

During centrally planned economy, decisions concerning the water / sewerage sector fell to the discretion of state enterprises. Since 1990, local authorities are responsible for water supplies, and accessibility to water supply networks and sewerage networks. These tasks are carried out through municipal companies. In the period from 1990 to

2005 year, 152.000 km of water supply lines and 56.00 km of sewerage lines were constructed. In 2005, 86,1% of Poles were connected to water supply system (94,9% of city residents and 84,5% of rural residents). The figure for sewerage networks was 59,1% (72,1% of city residents and 17,9% of rural residents). Over the last 15 years there was a significant development of the water / sewerage networks in comparison to the period before the transformation, when the sector was underinvested (figure 2).

Water resources are very unevenly distributed in Poland. They amount annually to about 1600 m^3 per inhabitant. This is similar to Egypt. Due to the uneven distribution of resources and their seasonal variability, the number of water deficit areas is increasing.

Accession to the EU imposed on Poland the requirement of further investments in the water and sewerage network, especially in the expansion of the sewerage network, modernization and construction of sewage treatment plants. These investments are significant, considering that the entire territory of Poland was acknowledged as an area sensitive to the eutrophication, and according to Directive 91/271/EEC: all urban areas with a REU equal or greater than 15.000 must have treatment plants in operation that ensure enhanced removal of nitrogen and phosphorous compounds. Urban areas with an REU less than 15.000 should possess sewage treatments plants ensuring complete biological treatment. Investments defined in the Accession Treaty are due to end in 2015. In the period 2003-2015 planned investments include construction of 21.000 km of sewerage network, 259 new sewage treatment plants and the reconstruction or modernization if 904 existing treatment plants. The necessary investment outlays

Figure 2. Length of water and sewerage networks in Poland (Source Central Statistical Office)

were estimated at 35,4 billion PLN (Ministry of Environment, 2003). The implementation of the European Directive on Urban Wastewater5 implies higher wastewater charges to cope with new investment and operation costs. Similarly, the implementation of the revised Directive on Drinking Water that sets more stringent limits for lead concentration in drinking water will entail significant investments and increases in prices. As a consequence, all the actors involved in water management in Poland will face a substantial raise in investment costs, which needs to be balanced by a growth in financial resources.

Before 1990, due to low prices which were subsidized by the State, there was a very high and unjustified water consumption in Poland. In 1992, the Ministry of Housing, Construction and Development come to a decision that each apartment in an apartment building should be metered.[1] Currently, metering is almost universal and water demand has dropped since 1992 by about 50%, to almost 112 liters per person per day in 2003. Other data show that water consumption has decreased in Polish cities from 200 l/person/day in 1990 to 141,7 l/person/day in 1999 (Kloss-Trębaczkiewicz et al, 2000).

1 As of January 1, 1992, the Ministry of Construction and Spatial Planning requires that water meters be installed in all new buildings. (Business News From Poland, 15 March 1990, "Water and water supply system in Poland - promoting investments"). In mid-to-late 1990s, meter installation in existing buildings was widespread, partly under pressure from consumer organizations and the national government.

Consumption of water still decreases and is below 100 litres per capita and day in 2007. This is not very high consumption. Water consumption varies greatly among countries due to differences in economic development. The average municipal use in the United States is about 150 gal (568 l) per person per day, though the rate can be higher than 350 gal (1324 l) in some locations. This includes home use for bathing, waste disposal, and gardening, as well as institutional and commercial usage. The Dutch use 100 litres of water per person per day to drink, wash, shower and flush the toilet, according to research by Twente University. Per capita (per person) water usage in Asia is only 22 gal (85 l) per day, and just 12 gal (47 l) in Africa. According to the World Health Organization (WHO) of the United Nations, people have a minimum water requirement of about 5 gal (20 l) per person per day. This is the minimum amount needed for physiological rehydration, cooking, washing, and other subsistence requirements[1].

Demand for water is still unstable, decreasing by about 2% per year. In 1990, metering had a very limited range and payments were based on norms. For a typical apartment, the norm was 7,5 m^3 per person per

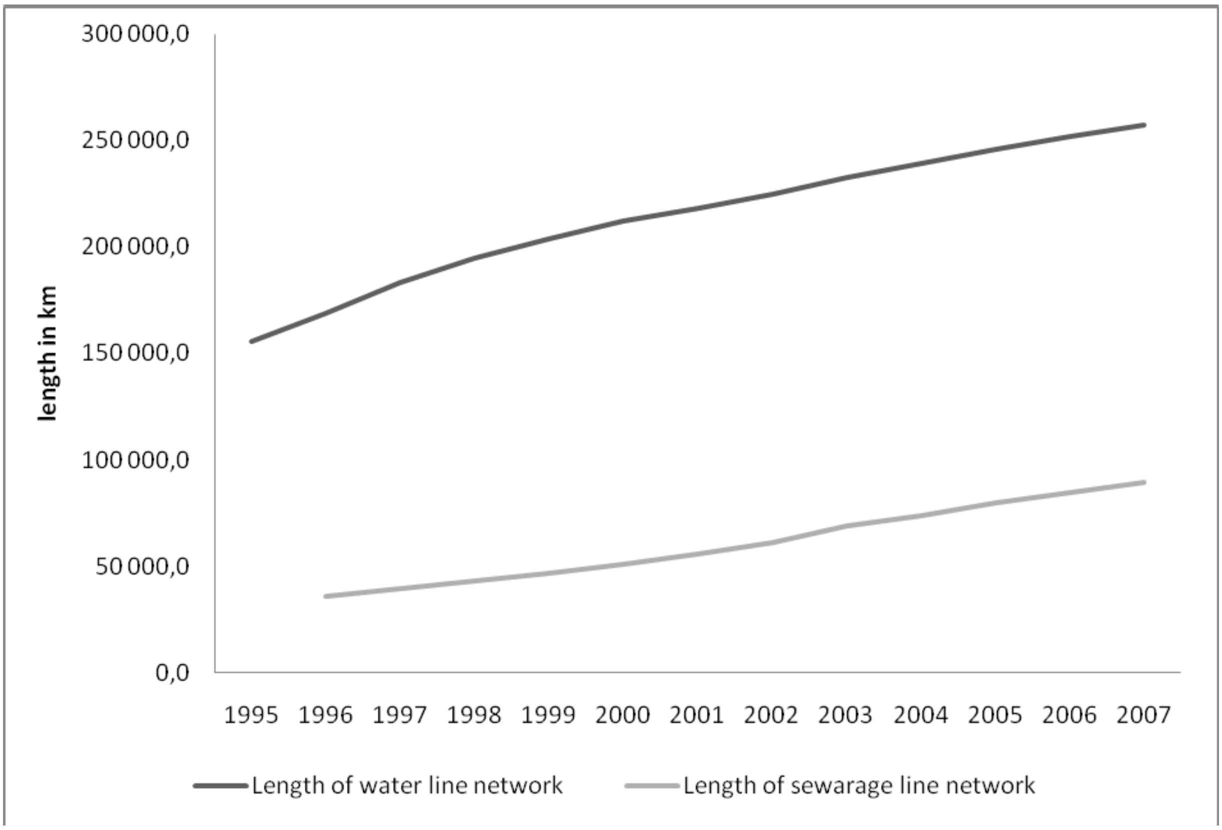


Figure 1. Consumption of water from water supply systems in litres per capita in Polish households per day (Central Statistical Office, Poland)

month (240 liters per person per day). The decline in individual demand for water is surely tied to the increase in prices for water use and sewage discharge brought about by system changes and the start of significant investments during this period in the water /sewerage sector. From 1995 to 2004 prices for supplying cold water in the municipal sector increased nearly fourfold (GUS, 2005).

Prices increased faster than the decline in individual water use. While in 1997 disbursements for cold water and sewage discharge comprised 0,9% of disposable income per person, in 2005 this share had nearly

1 http://science.jrank.org/pages/7304/Water-Conservation-Water-consumption.html - Water Conservation - Water Consumption

doubled and equaled 1,75%. In consequence of tariff increases and meter installation, average household consumption decreased throughout the country. In effect of metering and higher prices, in just 1995, the average household consumption decreased by 15%. It is worthy to observe that in the two previous years it decreased by less than 5% (Motte, 2005). This resulted in financial losses for some of the water utility companies and was the most dramatic annual decrease in the period of 1992-2003, during which there was a total decline of 52%. No one expected such a rapid **decrease** in demand from metering – which led to decreased revenue. This meant that the unit price increased and the share of fixed costs went up. For example, in order to compensate the losses of Saur Neptun Gdańsk SA, a joint-venture water utility company operating in Gdańsk, prices were increased by several percent to compensate losses associated with this “exceptional circumstance”.

A model of water prices illustrating the concept with special reference to municipal water supply is discussed in the paper. This paper proposes a method for assessing the impact of economic incentives such as charges on water consumption, for instance. This novel method is supported by case study of Poland. Following the end of the Second World War, domestic consumers in Poland normally paid a small percentage of the cost of drinking water while the rest was paid by the state in the form of subsidies.

In the paper, the work hypothesis is presented. The decrease of water consumption leads to lower sale and production of water. It leads to higher average water cost, due to higher percentage of fixed costs in the water treatment cost. Therefore, higher price had to be introduced. This led again, to a significant decrease of water consumption and not fully utilised capacity of existing plants. Whether the observed falling trend of water consumption can be stopped and when it might happen has been unknown until now. One of the reasons of lower consumption was installation of water meters after 1990 and more realistic charges. They reached a significant proportion of the household’s average income. In fact, knowledge on the impact of price changes on water demand is insufficient. Moreover, there is no satisfactory model to explain the existing phenomenon.

After an introduction, methodology is presented in which various elements influencing water pricing are examined, i.e. production, sale and consumption of water. Next, a case study of Polish waterworks is given with the explanation why a decrease in household water consumption leads to a significant increase of municipal water prices. Finally, some consequences of declining water consumption, like a decrease in wastewater discharged to treatment plants are examined. Some conclusions and hints for correct price systems aiming at more sustainable consumption are given.

3. Concept and Implementation

3.1 Overview

Crowley et al. (1994) remark that since a price increase tends to decrease demand, it must consequently decrease the sale of water. They proposed a polynomial relationship between consumption of water and its price. This relationship will be applied to the present relationship between the volume of water being sold and the price of water. Such a mathematical formula was chosen for a number of reasons. First, the graphical representation of this relationship is a convex curve, which does not cross either vertical or horizontal axe. Second, it is in agreement with the economic theory, according to which, as the price of water increases, its consumption falls. Since y is proportional to the inverse of x, hence a_2 must be negative. When a_2 equals zero, changes of prices have almost no effect on demand.

$$y_t = a_1 x_t^{a_2} , \quad (1)$$

where:
y_t - sale of water in period t
x_t - price per unit of consumption in period t,
a_1 - constant,
a_2 - a coefficient which measures the elasticity of demand.

This means that, as the price of water increases, its consumption decreases in an asymptotic way, and the reverse is also true. A big inelasticity of demand in households occurs when coefficient a_2 is between –1 and 0. When a_2 =-1, then y is proportional to $1/x_t$ (reverse of x_t), small changes of x_t causes almost proportionate changes in y_t. Low a_2 value indicates a high degree of inelasticity. Several cases of water price increase had shown a decrease in consumption. When a_2 equals –0.2, a 29 per cent price increase is required to reduce demand by 5 percent (Crowley, 1994). In a number of developed countries - Israel, Canada, United States, Australia and Great Britain - empirical analysis has shown that the price elasticity of demand for water in households is between -0.3 and -0.7. Most studies record price elasticity around zero, but some found price elasticity below –1.5 (Dalhuisen J et al (no date), Dalhuisen J, 2005).
The next relationship described is the relationship between water production and the sale of water (3). By production we understand water abstraction and treatment, by sale – the amount of water delivered to the end-users. Not all water is sold to the latter. During delivery there is some leakage and some water is used for technological purposes. The problem associated with leakage is related to the quality of water transported and not only to the state of the water supply network. Losses of water in the distribution network can reach high percentages of the initial volume. The average cost of water production is inversely proportional to the volume of water production (4) and water price is related to the average cost of water production (5).

3.2 Case study

Parameters for formulas (2)-(5) were obtained from data collected in the 1990s in 30 water supply utility companies in Polish towns. Obtaining data on the cost of water treatment was quite a difficult task because such data are not collected by the Statistical Office, nor any other organisation. They were obtained from conducted surveys. Other data were available in statistics. Each of the analyzed towns was inhabited by more than 20.000 inhabitants and the volume of water sold annually varied from 1 mln m^3 to 184 mln m^3 in Warsaw, the largest city. In total, the average volume of water sold was 30 mln m^3. It is assumed that, in the long run, relations between variables of the model are constant.

$$y_t = 78.829 x_t^{-0.59} \qquad (2)$$

$$p_t = 1.133 y_t + 1.884 \qquad (3)$$

$$k_t = 699.3 p_t^{-1.2412} \qquad (4)$$

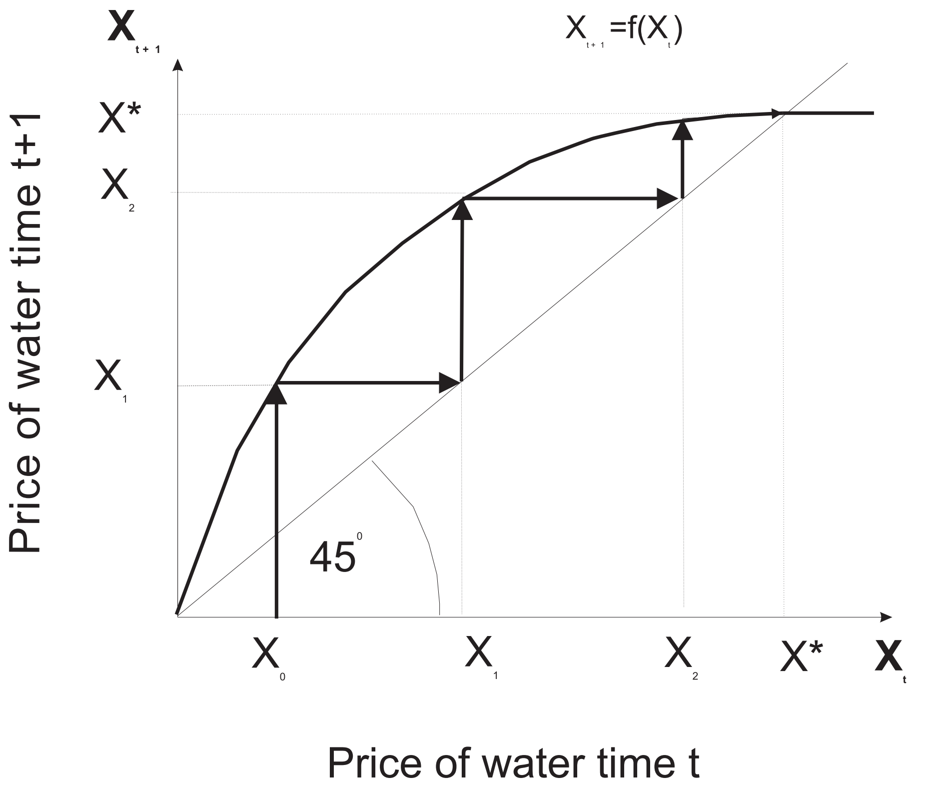
$$x_{t+1} = 1.599 k_t^{0.70} \qquad (5)$$

Where
y_t : sales of water as a function of price,
x_t : price for the 1 m^3 of water in the *t* period,
p_t : water production (amount of treated water),
k_t : an average cost of water production,
x_{t+1} :-price for the 1 m^3 of water in the *t*+1 period,

By elimination of variables: sale of water, production of water and average cost from model equations (2)-(5) the recurrent relation was obtained by the following equation:

$$x_{t+1} = 3.1808 x_t^{0.4806}, \qquad (6)$$

Let us consider the numeral x_0 belonging to the domain of function $f(x)$, that is, by assumption, water price in a current year (set on the basis of average cost of water production). By substituting this price to equation (6), we obtain price in "1" period $f(x_0) = x_1$, and similarly we get price in the period "2" $f(x_1) = x_2$, higher than price x_1[1] . Then, for period $t=2$ we receive price in the next period $f(x_2) = x_3$ (water consumption is simultaneously declining), sale of water, and similarly until the price equals x^*. The sequence $x_{t+1}=f(x_t)$ is convergent to that price and its boundary is the value x^* (figure 3). This means that the price increase process will stop at this point [2].



Convergence of the sequence does not depend on the choice of the starting point x_0. By substituting for x_0 any number from the interval $(0,+\infty)$, another sequence of successive approximations could be obtained, always convergent to the boundary x^*. When $x_0 < x^*$, then the successive approximations form an increasing sequence (if $f(x)$ is ascending), so the values of this sequence are increasing till the value of a x^*

Calculations were made on a simple spreadsheet. For example, as the initial price, a price in one of the towns set at 1.29 euro/m^3 was used. The recurrent process (5) with this initial price is convergent to the price x^*=2.45 euro/m^3, which is an abscissa of the point, in which the line $x_{t+1}=x_t$ cross the curve $f(x)$(Figure 1). The number x^* is a boundary of sequence, (10). For this price, the sale of 21 million m^3 of

1 Process (5) is an increasing process

water per year was obtained, identical to two Polish towns: Gorzow (130.000 inhabitants and Kalisz (110.000 inhabitants). From the above calculations it is clear that a decrease in water sale causes a significant increase in the water price, which again causes decrease of water consumption.

4. Conclusions and outlook

The end-results of the simulation show that it is possible that the water price increases will come to an end. It is not clear, however, if this will be the case. Predicting future residential water consumption in Poland, similarly to other Figure 3. Convergence of water price increase. The curved line denote function $x_{t+1} = f(x_t)$, and straight line is 45 degree line post-communist countries, like Slovak Republic, is a difficult issue as they are currently experiencing important structural changes. More work are required to more deeply address the issues I have developed in this chapter. In particular, an analysis of the links between water consumption and income level would yield interesting insights. But such a work requires micro data, that are currently not available in Poland. Effective metering of water consumption reduces water use but only if it is coupled with an incentive-oriented pricing structure such as a decreasing block rate. There are both positive and negative consequences of a water consumption decrease. First of all, smaller quantity of a rare environmental resource is consumed. Second, an increased cost of water supply and wastewater treatment is not welcomed by the end-users (Motte, 2005, Roman, 1995). The biggest threat to water supply is secondary water pollution. Reduction in water flow velocity and prolonged water standing in pipes constitute the negative technical aspect of water consumption declines. This, in consequence, leads to sludge sedimentation and pipe clogging and requires secondary disinfection in pipe–ends. This results in intensified pipe exploitation and pollution (Bogdanowicz et al, 2001).

Decreased water consumption also leads to reduction of sewage discharged into wastewater treatment plants (Suligowski, 2000). This induces higher concentration of impurities in sewage when the load of impurities is constant. Such a situation can cause serious exploitation problems for wastewater treatment plants and can require changes in the biological part of the existing plant. Due to insufficient financial resources for expensive technology changes the environment may become polluted inadequately treated wastewaters. Therefore, a paradox may arise that a pro-environmental decrease of water consumption may even generate pollution by insufficiently treated wastewaters.

On the other hand, a decrease in the volume of water and wastewater can lead to a new situation in which both new water supply companies and new wastewater treatment plants can be smaller and cheaper in construction and operations. To assess further consequences of the decrease of water consumption, particularly with respect to the cost of wastewater treatment, further studies are required

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