A07/1

111/2001

Raport Badawczy

Research Report

RB/05/2001

Modeling Sustainable Water Prices

Paweł Bartoszczuk

Instytut Badań Systemowych
Polska Akademia Nauk

Systems Research Institute
Polish Academy of Sciences

POLSKA AKADEMIA NAUK

Instytut Badań Systemowych

ul. Newelska 6

01-447 Warszawa

tel.: (+48) (22) 8373578

fax: (+48) (22) 8372772

Pracę zgłosił: prof. dr hab. Zbigniew Nahorski

Warszawa 2001

INSTYTUT BADAŃ SYSTEMOWYCH PAN

PRACOWNIA MODELOWANIA KOMPUTEROWEGO
I IDENTYFIKACJI

A 7 - 05/2001

Paweł BARTOSZCZUK

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Zadanie badawcze:

Modele matematyczne w ochronie środowiska i zdrowia
- kierownik: prof.dr hab.inż. Zbigniew NAHORSKI

Podzadanie:

Modelowanie wybranych wpływów procesów technicznych i biologicznych na środowisko naturalne

WARSZAWA , grudzień 2001

Chapter

Modeling Sustainable Water Prices

Pawel Bartoszczuk

1.Introduction

Establishing a rational price for water is very important both for the waterworks and consumers. The price should be based on the cost of supply to reach more reasonable use of water. Paper, after reviewing main issues connected with sustainable development and water pricing, proposes a method assessing the impact of economic incentives, like charges on water consumption. This method is applied to specific conditions of countries in Central Europe. Following the end of Second World War, domestic consumers in countries of that area, normally paid small percent of the cost of drinking water, while the rest was paid by state in the form of subsidies.

After 1990 water charges suddenly have increased and reached significant proportion of the household's average income, what resulted in significant decrease of water consumption and not fully utilised capacity of existing plants. One of decisive factors of decrease of water consumption was installation of meters. Until now, it is not known if the observed decreasing trend of water consumption will be stopped and when it will happen. In fact, little is known on the impact of price changes on water demand. Moreover, there is no satisfactory model to explain existing phenomenon. In the paper, basic principals for setting water prices will be presented: providing incentive for efficient use of water, distribute the cost equitably, considering social issues and keep the tariff rate structure rather simple to be easily implemented. Finally, conclusions and hints for correct price systems aiming at more sustainable consumption will be given.

Sustainable development.

Many cultures in the past have recognized the need of harmony between the environment, society and economy without expressing it as sustainability. No agreed definition of sustainable development has emerged, but up most this concept refers to the description given in the report Our Common Future (known as the Brundtland Report), that identifies this term with activity which meet present needs without compromising the ability of future generations to meet their future needs (WCED, 1987; Greiner, 1999).

Peet, cited by Somlody (1994) adds correctly, that the definition of Brundtlant is too general, but until nowadays nothing better was proposed. According to him sustainability is rather ethical guiding principle. Many sustainable programs, including European Community program summarize rather general guidelines. Others indicate that despite growing concern about environmental issues there is a wide gap between awareness and action (Grainer, 1999). Without a state intervention, and incentives like prices, sustainable development is unlikely. For such development stable economic is important precondition, but difficult to reach by most developing countries.

Ring et al. (1999) claims that sustainable development does not present fixed state, but rather process of change towards a more environmentally sound and socially equitable way of life. Helm (2000) argues, that sustainability is a recognition that without intervention the global environment will not be able to provide a reasonable standard of living for future generations. Nevertheless, delivering all goals of sustainable development like economic development, a better environment, a concern for the poor simultaneously is probably beyond the capabilities of policy makers (Atkinson, 2000). Some opponents to sustainable development say that its cost is large and propose rather weak sustainability. A world characterized by weak sustainability suggest that social cost should be add to private costs of produced goods. Ecologists and ecological economists take a rather different approach: strong sustainability. Pearce et al. all citied by Atkinson op. cit. (2000) claims very few supporters of strong sustainability support the idea that all natural assets must be preserved for all cost.

Sutainable development of water resources.

To recognize what "sustainable consumption of water" means is extremely difficult task. There is not really a global or unified strategy on how to handle the variety of water problems existing in the world. This is probably one reason why the Brundtlandt report and conference of United Nations in 1992 overlooked the water issue (Somlody, 1995). According to OECD (1998), water consumption "should meet basic needs for water servicing without jeopardizing the ability of future generations to meet their water needs and while protecting the water need of the environment".

Although water resources are renewable, water systems can be so degraded, that they are potentially lost, and ecosystem can be dependent on a minimum quantity and quality of water to threshold beneath which they are damaged.

For many countries the availability of water is main determinant of economic growth, industrial structure and national trade. Water is limited valuable resource (freshwater resources form less than 1% of the total water in globe from which 85% of use is for irrigation) essential to life, which behaves rather differently than other elements of the biosphere. Since the beginning of this century, global water withdrawals have increased by over 6 times, while world population only doubled in the same period. Seckler from Water Resource Institute (1996) put the number of people living in water scarcity country as 13-20% of the global population by 2050.

As water becomes rare good, the need to control the deterioration of water quality is translated into demanding legislation. Countries state the purposes and objectives of their water policies in water legislation. Various systems of water regulations and laws are varied among different countries. For example, Canadian Water Act encourages optimum use of water resources for the benefit of people. Law of Germany requires the water will be managed in a manner that serves the common interest, benefiting individual users, while preventing avoidable harmful impacts. All these statements stress that the water management forms one of the biggest challenges of the coming decades. Therefore, suppliers and regulators, using charges for uses, metering and educating by increasing the awareness of users about water conservation, must reduce its demand toward more sustainable level (EEA, 2000).

The most of water in Europe is consumed by industry, not like in other continents, for agriculture (Cowan, 2000). According to European Environment Agency (2000), 38 percents of water in Europe is abstracted for public water supply, 30 percents for agriculture-mainly irrigation and the rest for industry and power. The largest group of customers of the public water utilities are households and small businesses (Gorczyca, 1998). Households' consumption of water was increasing until in 1990s in many countries. The then existing prognoses, which were made with supposition that price is very low, assumed the further increase of consumption due to a forecast higher demand (Somlody op cit., 1994). Increasing trend of consumption was inverted with the application of more market charges, depended more on cost of water supply. A number of industrial enterprises also decreased water consumption and it was clear that the existing waterworks have excessive capacity. The current use of water in Central Europe is on the average European level, and much lower than it was forecasted in the past (table 1).

For example, average consumption of water in Polish households calculated on 1 inhabitant was 136 litres per capita using water network in 1999 year (GUS, 2000). In Western countries, e.g. in Austria and Italy the use of water is higher than 200 litres per capita and day. In Japan and Canada a value of this indicator is higher than 250 litres per capita a day, in the USA is even more as 380 litres/capita and day.

Table 1 Consumption of water in some European countries

	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Poland	214	210	203	203	195	183	169	158	150	142	136
Czech Republic	165	173	161	159	137	129					
Hungary	153	181	153	138	127	120	115	112	105	108	
Germany	145		144		136	132	132	128	129		
Great Britain				140	142	144	153	148	149		
Bulgaria		217									
France		157									

Source: EEA, 1999, GUS, 2000, OECD, 1999,.

Charging for water

Currently, water is overconsumed worldwide and wasted in large part because consumers do not receive appropriate signals about value of this resource (OECD, 1998). The literature emphasizes a big concern on improving pricing signals in order to move towards sustainable consumption. A reform of pricing regimes and tariffs systems is important, not only for the incentives this would bring to commercial and residential consumers to rationalize their consumption, but also for proper revenues of water company. Although it is largely accepted that water has an economic value in all competing uses, and should be treated as economic good, the amount of money paid for water does not only reflect environmental cost of water, but even economic cost (OECD, 1999.). There is lots of concern about how much, if anything, low-income consumers should pay for this basic commodity (Constance, 1999). Proponents of low prices are arguing, that impact of economic instruments applied to public water supply on health together with the affordability of water to poorer consumers needs to be considered. Additionally, there are technical complications how to set charge that would best reflect water value (Gonzales et al., 1998).

A tariff is a system of procedures and elements, which determines a customer total water bill. Any part of that bill can be called a charge, measured in money per time or money units alone. And any units can be called a rate, usually measured in money/volume units. Further in the text, the rate will be called price. Most tariffs are a combination of elements dependent on consumption or other factors. A connection charge is put on a customer who joins the public water supply systems. A fixed charge is equal for each customer or depends also on some other factors (volume of water meters and geographic location or customer group). If a metering system is in place, the following elements occur: a volumetric rate, block charge, or minimum charge. A volumetric rate, which when multiplied by the volume of water consumed in a charging period, gives rise to volumetric charge for that period.

According to the criterion of economic efficiency, the volumetric charge components of the pricing structure could cover any cost that vary with demand on a system (short and long term) or peak demands made on system, while the fixed element should be left to cover only costs that do not vary with consumption or cannot be accommodated in the variable element. The variable part of tariff gives consumers incentives to use water efficiently, and the fixed part allows covering overhead expenses by water works. For the metered customers charge for water can be influenced by the ratio between standing and variable charge. Based on the actual cost to the water supplier the standing charge should be more than 80 percent (EEA, op cit. p. 80) of the total charge with the remainder as variable charge, since the fixed assets are prevailing. In practice percentage of volume related charge is higher, even more than 75 per cent. This system is an incentive to save water and is attractive to low water users. The huge variation of the fixed element of pricing schemes between sectors and countries reflects the varying objectives of countries for their pricing schemes. Different volumetric rates are frequently attached to different blocks. If rates rise or fall consequently as more water is consumed, the schedules are referred to an increasing or decreasing-block tariffs. A block charges are defined by lower and upper volumes of consumption per charging level. In general two-parts, rising or declining block are widespread (EEA, 1999).

Charges are generally not related to the true cost of water and not the same for different categories of consumers. Water charges are varying according to the capital and social cost of operating of water supply, (OECD, 1999). Tariff structure is generally fixed at municipal level and can vary widely within a country.

Tariffs can include a basic allowance (charged at zero or very low rate) to allow for equity concerns. It specifies certain minimum volumes of the service that should be paid whether or not that amount has been consumed. Sometimes the quantity of water to which the lowest price is applied is so large that few users face the higher charges associated with larger consumption levels. This policy diminishes the impact of pricing on consumption patterns. According to (OECD, 1999), the presence of minimum charges or a significant fixed element in tariff decrease the conservation message and lowers the potential strength of the signal to decrease consumption. The flat fee tariffs decrease the strength of the tariff at all (table 1).

Social equity considerations figure more prominently in several countries today. The strong tradition of low tariffs for households and increasing block rates is present in Spain, Italy and Greece, US and Belgium. In previous years social tariffs were also present in countries in Central Europe, like Hungary and Poland.

Rising block tariffs exist in Italy, Portugal and Spain. In Spain there is a large diversity of tariff structures, with most increasing block tariffs. It is observed that there are countries without fixed charge (non-volumetric) shares of average waters like Austria, Czech Republic, Hungary and Poland and also country with high percentage of fixed part of tariff, reaching 49 percent of fixed parts in prices, like Japan (OECD, 1999). However there are high service fees in France - as high as 90 % of water bills. They give the scope to introduce tariff schedule with very low volumetric rates. From the other side, most recent evidence suggests that the fixed elements in households' bills are on average only 15 % of total bill (Conso cited by OECD).

Strong discussion of a possible shift towards simplistic volumetric prices takes place in many other countries. Such policy undoubtfuly can lead to sustainable consumption of water.

Table 1
Categories of prices applied in many OECD countries.

Category	Countries Included	Conservation signal	No. of countries
"Cutting Edge" Conservation Pricing	Korea	Very Strong	1
Conservation or Social Pricing	Belgium, Greece, Japan, Italy, Mexico, Spain, Portugal, Turkey	Stronger	8
Price times Quantity Volumetric	Czech Rep., Hungary, Poland	Stronger	3
Traditional Volumetric	Austria, Denmark, Finland, France, Germany, Netherlands, Sweden, Switzerland	Normal	8
Mixed Volumetric	Australia, Luxembourg, US	Weak	3
Mixed (general)	Canada	Weak	1
Predominantly Flat Fee	Iceland, New Zealand, Norway, UK	None	4
Domestic Water Charges in general taxation	Ireland	None	1

Source: adapted from (OECD, Household water Pricing…, 1999, p. 24)

Although Germany applies only traditional volumetric system, its prices are set to recover the full cost of supply. From the other side, water in US and Canada is perceived as very cheap, because of the previous subsidies and slow recognition of emerging environmental problems. Only one-fourth of the US utilities have switched out from decreasing –block schedules to increasing-block ones.

Water prices have increased significantly in OECD countries in last period. According some American data cited by Dinar and Subramanian (1998), the increase of prices in last years in many countries was bigger than the rate of inflation. For example residential water prices has increased almost 10 percents above the inflation rate. About 37 percents of the utilities charged the fixed prices, 22 percents used rising block increases and, and 38 percents used declining prices. The rest 3 percents used a mixture of schemes.

Water prices in different countries in Europe vary from 53 euro per year per family in Rome to 287 euro per year in Brussels and 350 Euro in Germany. The calculations were made for family living in a house using 200 cubic meters of water per year (EEA, 1999). In Central Europe they vary from 20 Euro to 59 Euro (EEA, 2000; Strosser, 2001). In relation to GDP per capita the annual expenditures for water varies from 0.2 percent of the household's income in Oslo to 3.5 percent in Bucharest, close to affordable level which equals 5 percent, according World Bank.

In Central and Eastern Europe water prices have risen sharply at a much higher rate than inflation since 1989. In Hungary there was large real price increases (18.7 percent per period 1986 –1996), mainly due to increasing restrictions on the use of central government subsidies in recent years and big increases in real charges. The results of analyses on influence of water price on consumption, conducted in Hungary, showed that a price increase might have a much greater impact in countries where the price of water had been kept on very low level in the previous period (EEA, 1999).

Domestic metering

According to Water Consumption and Sustainable Water Resources Management Proceedings, measuring the volume of used water is the only means to show the value of water to consumer (OECD, 1998). It creates strong incentives for consumers to use water more efficiently and is a precondition of proper application of tariffs policy. Immediate savings from introduction of metering are estimated to be about 20 percent of consumption OECD (1999). Research conducted in Great Britain shows that the use of water in metered households is 10 percent lower than in not metered ones (EEA, 1999). Decrease of water consumption in Poland after installation of water meters is estimated as 30 percent (Gorczyca, p.18, 1998).

The similar amounts were obtained in Hungary, although water meters are not installed everywhere (EEA, 1999). The other data shows the metered households in Canada use even 50 % less water than those that have no meters, even without price increase (Environment Waterworks Canada, 1997). Also Czech Republic experienced a reduction of consumption for about 18 percent in years 1992-97. Similar situation was observed in Luxemburg over the period 1990-94, where consumption has decreased for about 12 litres per capita, up to level 169 litres per capita and day, while water charges rose by 6 per cent.

Despite water scarcity, domestic metering is not very popular in OECD countries and even some European cities does not have meters. The water being supplied to individual apartment buildings is metered in nearly every OECD country, but not to all apartment blocks, where the most population of OECD live. The owner of block receives a volumetrically based water bill. These charges are recovered from tenants (or individual owners) by some criteria, like floor space, number of people in the household etc. The presence of a single master meter may have no effect on total demand (the owner allocate the increase in the aggregate bill, and each resident decides that the increase is not his fault, but pays the bill anyway.

The decision about whether to adopt a metering approach is based on perceptions about optimal pricing structure and after conducting analyses whether the cost of installing and administering water measures system are larger than the benefits anticipated in terms of reduced water consumption, induced infrastructure cost, and reduced variability in demand. There is also some risk associated with illegal connection, and that reduced water flows in water pipes may reduce the ability of those pipes to function as they were designed (OECD, 1999 op cit.).

Customers often opt for meters, because their measured charges will be lower than their previous charge based on the value of their houses, but installing a meter is very expensive option for them. Nonvolumetric charging systems promote subsidizing high water users by low users within apartment building. From the other side, putting the charges on a fairer basis inevitably has implications for charges paid by other customers, like big families or consumers remaining on a "traditional' rate.

It is true that metering can increase the environmental goals, like efficiency of water service and make households responsible for only their own consumption, but it may lead to increase of price that have impact on low-income consumers and is not socially accepted. Therefore a protection of the low-income consumers against excessive increase of water prices should be applied. One option in increasing common water metering is to select customers, and first install meters to people using large amounts of water.

Economic regulator OFWAT of privatized companies in England and Wales is opposed to universal domestic metering, but supports metering where water is scarce resource or is consumed in large amounts. The obligatory measured charging in those countries relies on the obligatory metering of: all new houses, water used for sprinkler gardening, and swimming pools. Anglian water expects to have 60% of households linked to volumetric charging early in the next decade. (Water charging in England and Wales, 1998). Currently about 3 % of households are switching to measured charges each year in England and Wales.

Theoretical basis of relations between water consumption, price and other parameters

Presented below method allows assessing the impact of observed in some countries increase of charges on drinking water consumption. To realise this goal, relations among factors influencing water prices: the average cost of water treatment in municipalities, production, and sale of water by the waterworks companies are needed.

Demand for a product, including water, generally reacts to a change in price. When the price goes up, consumption falls, as people conserve water to avoid higher bills. Leaks are repaired and water saving measures are introduced

It is difficult to assess the effect of water prices on consumption more globally, since insufficient information is available on prices charged locally in different countries and their effect on consumption. Until know, it is known that water demand for households is usually inelastic to a price. Elasticity of demand is a measure of how much demand changes in response to a change in price. When water meters are applied, the theoretical price-demand relationship on the basis of equation proposed by Crowley, et al. (1996) could be applied.

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

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 the demand.

Since price increase will tend to depress demand, it must consequently decrease sale of water. While y is proportional to the inverse of x, hence a_2 must be negative. When a_2 equals zero, changes of prices have no effect on demand (Crowley et al., 1996). There is a big inelasticity of demand in households: When a_2=-1 then y is proportional to $1/x_t$ (reverse of x_t), small changes of x_t cause almost proportionate changes in y_t.

From economics, we know that low a_2 value indicates a high degree of inelasticity. When a_2 equals –0.2 a 29 per cent price increase is required to reduce demand by 5 per cent. 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 and Nijkamp, 2000).

Second described relation is relation between production of water and sale of water. By production we understand water withdrawal and treatment, by sale –amount of water delivered to inhabitants. Not all the water is sold to the customers. There are leakages and some water is used for technological purposes. The problem associated with leakages are related to quality of water transported, not only the state of network (EEA. pp 23-25, 2001). Loses of water in distribution network can reach high percentages of the volume introduced. Nevertheless, there are countries, where the leakages are below 10 percent of water taken from the source. For this class of countries belong Germany, Austria and Denmark. To the next group of countries we can count countries such as France, Spain, Sweden, United Kingdom and, where looses are up to 25 percent. For the third group we can count Croatia, Czech Republic, Portugal, and Switzerland where this fraction is bigger than 30 percent. In Albania they are much higher, equal even up to 75 percent. Leakages cover different areas: in network, in user installations and before meters, in 30-60 percent of total amount of water taken from the source. It need to be emphasized that tracing and repairing leakages can be very expensive. We propose linear relation between production of water and sale of water.

$$p_t = b_1 * y_t + b_2, \qquad (2)$$

where
y_t - demand for water in period t
p_t – production of water in period t,
b_1 - constant,
b_2 - constant,

Then relation between average cost and production of water will be given. Water delivery service has a high fixed cost and a low variable cost. The total fixed cost amounts even up to 80-90% of the total cost and the rest is the total variable cost, which depends on production of water, see (Moll, 1995). Because of the high share of the total fixed cost in the total cost, the total cost strongly depends on the fixed cost. While the average variable cost is constant, the average cost strongly depends on production of water. On the basis of our knowledge, we propose following relation on the basis of empirical data.

$$k_t = c_1 \, p_t^{c_2}, \qquad (3)$$

where:
k_t – average cost of water production, demand for water in period t
p_t – production of water in period t.
c_1 - constant,
c_2 - a coefficient which measures the elasticity of the demand.

At the end relation between cost and rate will be presented. This relation strongly depends on the water tariff policy applied and the way of setting rates of water consumption i.e. relation between price of water and water cost sand tariff applied. Therefore, we do not show any mathematical formula of this relation. We assume this relation is close to linear one It was assumed that prices are considerably higher than the costs of water supply.

$$x_{t+1}=g(k_t), \tag{4}$$

where:

x_{t+1}-price of water in the next period

k_t – average cost of water production, demand for water in period t

The price is set on the basis of planned annual cost of water production. If the real consumption of water in the next period is lower than planned, waterworks will have financial losses. The price is set on the basis of planned annual cost of water production. Very often price should be approved by local government which are not interested in increasing burdens for inhabitants. If the real consumption of water in the next period is lower than planned, waterworks will have financial losses.

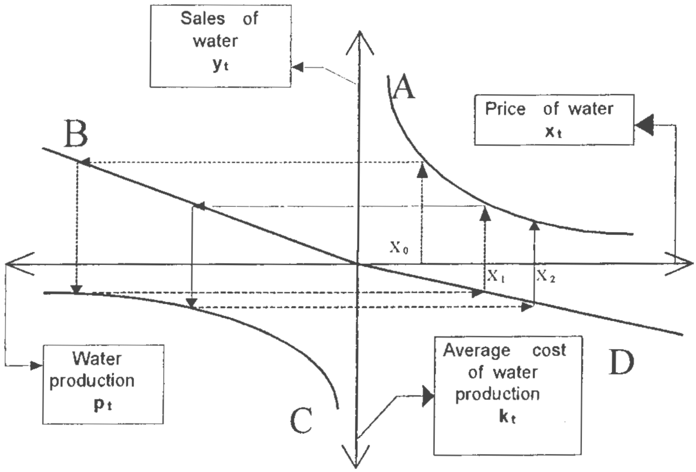

Figure 1

Process of creating successive values of prices, sale, production and cost of water treatment

By substituting t=1 for price x_1 we get the price in the next period $f(x_1)= x_2$, Then for $t=2$ we receive price in the period $f(x_2)= x_3$, and so on until we receive the price x^*. The sequence $x_{t+1}=f(x_t)$ is convergent to that price and its boundary is the value x^*, for which $f(x^*)=x^*$. Price x_2 is certainly higher than price x_1 (if process (4) is an increasing process), because an increase of cost of water production is caused mainly by decrease of water production.

Empirical evidence of existing relations

The empirical evidence was taken from one of the countries in Central Europe-Poland. The parameters for the formulas were obtained from the data collected from the waterworks companies in towns in the 1990s. The coefficient a_1 equals 78.829, while coefficient a_2, of the elasticity of the demand is equal –0.59. Thus there is an inelasticity of the demand for water. Moreover, we received convex relation that is curve, which does not cross either vertical or horizontal axe. It means, that when price of water is increasing until infinity, the consumption of water is decreasing in asymptotic way, and when the price is coming to zero, the consumption is increasing until infinity. This result confirms literature data accessible in the previous section.

Coefficients b_1 and b_2 equals 1.133 and 1.884, subsequently. By comparison of values of variables production and sale of water we can see the average water loses observed in existing companies, equal 20-30% of withdrawed water. It corresponds very well with existing literature concerning water loses in the network provided earlier. The formula shows us there are still possibilities to decrease water leakages and make consumption of water more sustainable.

Coefficients c_1 and c_2 of the relation (3) are equal 699.3 and –1.24, subsequently. This relation shows there is a strong inverse correlation between average cost and production of water. In this way decrease of water production may have significant influence of water company revenue, provided prices do not reflect water cost. This relation is verified by theory explained previously.

The following mathematical formula of function $g(x_t)$ was found Relation (4) was approximated by power equation:

$$g(x_t) = 1.60*k^{0.70}, \qquad (5)$$

where $t \in \{1,2,3...\}$,

Further, we will find a bounded price, for which consumption of water will be not more reduced. To simplify calculations, the following variables: sales of water, production of water and average cost (v_t, p_t, k_t) from the model equations (1)-(4) were eliminated and a recurrent process was obtained: water price in a period $t+1$ in a function of price in the period t (5):

$$x_{t+1} = 3.18 * x_t^{0.48}, \qquad (6)$$

where $t \in \{1,2,3...\}$

As an example, we take an initial price, the price in one of the towns inhabited by 100 000 inhabitants: 4.86 in national currency. The recurrent process (6) with this initial price is convergent to the price $x^*=9.27$. The number x^* is a boundary of sequence (6). For this price we obtain the sale of water 21,2 millions cubic meters per year. From the calculations we observe, that significant increase of water price leads to a decrease in water sale for about 30 percent. This calculations are valid for a domain for which the model is still valid

However, these relations can look different, when most sophisticated tariff system will be applied. In reality the authority provide subsidies and do not allow to introduce too high prices.

Conclusions

The goal of this paper was to present a method assessing the impact of increase of water prices on consumption of water. Conducted research shows that more sustainable water consumption can only be reached by proper pricing of water. The development of appropriate water pricing systems, aimed at promoting sustainability of water management is strongly needed. In the absence of economic pricing for water, society pays more for this good by subsidies. Facing low prices users have no incentives to conserve such rare good like water. This leads to the need for additional capital to expand supply system and sewerages. Such condition of water market was in attendance in the countries of Central Europe - below cost pricing, inefficient and heavy environmental impact of water systems.

Full cost pricing can lead to elimination of the need for new waterworks or expanding of old one, but it implies higher cost for producers and higher prices for consumers. Moreover, reduction of consumption is decreasing the hydraulic overload of existing wastewater facilities and municipal wastewater and leads to lower flows in pipelines.

Nevertheless, the long-term benefits in terms of more sustainable growth outweigh theses short time costs, although some aid to low-income consumers can be needed. Pricing of water will continue to play key role in both economical and environmental terms. Early economic transition in the 1990s has been characterised by decrease of water consumption both from households and industry. There were reduction of price control and subsidies. The decline of consumption and sewage disposal has caused some heavily contaminated river to improve its quality.

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