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COMPARISON OF THE PRICE LEVEL OF THE WATER AND SEWERAGE CHARGE RATES AND MACROECONOMIC INDICATORS IN THE CZECH REPUBLIC

Key words: water and sewerage, charge rates, water supply and sewerage, gross domestic product, net household income

Introduction

Water supply and sewerage system operation is a public service that is supplied to the citizens of the state both in the Czech Republic and many other countries. As this is a public service, its price level should be acceptable to all citizens, in other words, the citizens should be able to pay for this public service. This article is focused on comparing the development of the price level of the water and sewerage charge rates in the regions of the Czech Republic to the development of macroeconomic indicators expressing the performance of the individual region. The above raised to the research hypothesis of whether regions with lower performance also have a lower price level of water and sewerage charge rates from the point of view of the purchasing power of the inhabitants of this region. Tsur focused in his article on optimal water pricing, where he states that "A pricing-based mechanism that implements the optimal water policy while accounting for environmental externalities is developed" (2020, p. 1). Wait and Petrie (2017) conducted research into the comparison of water prices of public and private water companies in the United States. The relation between water utility ownership structure and water price was

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researched in this study, along with other factors such as water source, population size, population density, population growth trends, service area size, and drought condition. In their article, Ashoori, Dzombak and Small (2017) dealt with the identification of water price and population criteria to meet future urban water demand targets. The research concluded that water demand in Los Angeles should increase by 36% between 2014 and 2050 and that future household water demand will be largely driven by the price and population rather than climate change and environment protection. The same approach applies to the price level of water and sewerage charge rates which represent the supply of public service in the sense of the water supply and sewerage system operation. Borhan, Ridzuan, Subramaniam, Amin and Saad (2021) addressed the relationship between polluted water and economic growth by using the environmental Kuznets curve analysis for the situation in Malaysia. In their study, they proposed how to focus on supporting investment in the appropriate technologies, especially sewerage systems and others.

The Czech Republic is not a very large country, it has about 10.5 million inhabitants. The state is divided into 14 regions and their performance varies. This performance is mainly related to the macroeconomic indicators, i.e. gross domestic product (GDP), unemployment rate and others. A number of authors have examined the differences in various macroeconomic aspects in the individual regions of the Czech Republic. For example, the relationship between tourism entities and economic performance expressed in terms of GDP was addressed by the research of Tuckova and Sverak (2016). The website www.czso.cz of the Czech Statistical Office (*Český statistický úřad*) publishes the values of macroeconomic indicators of the Czech Republic, which are used for comparison with other countries, as well as macroeconomic indicators of individual regions, which can be used for regional comparison within the country. In their paper, Behun, Gavurova, Tkacova and Kotaskova (2018) worked with time series of selected macroeconomic indicators and monitored the dependence between the manufacturing industry and GDP, which represents the economic cycle in the European Union.

Zhukova and Sobolieva-Tereshchenko (2021) dealt with the method of analysing the dynamics of macroeconomic indicators in selected European countries in their article. The tool for predicting the indicators of the GDP type in 44 countries and three country aggregates is described separately in the article by Garnitz, Lehmann and Wohlrabe (2019). The website www.eagri.cz of the Ministry of Agriculture of the Czech Republic (*Ministerstvo zemědělství*) lists the price level of water and sewerage charge rates nationwide and also for individual regions. Since the 1990s, the water supply and sewerage operators transformed from state-owned enterprises into mostly joint-stock companies, i.e. capital companies that aim to satisfy their shareholders on dividends paid, so it is not always the case that the region with high performance has the highest water and sewerage charge rates. Therefore, the team of researchers focused both on the performance of the regions and the water management companies, which are water supply and sewerage system operators. Liu, Wu, Xu and Pan (2018) monitored the link between wastewater discharge, river water quality in the Pearl river delta and GDP per capita between 1999 and 2015. They used the logarithmic mean

division index decomposition model as well as the environmental Kuznets curve model for their research. Changes in the profit, productivity and price performance in the water and sewerage management industry within the empirical application for England and Wales were addressed by Maziotis, Saal, Thanassoulis and Molinos-Senante (2014). Their study analyses the impact of the regulation on the financial performance of water and sewerage companies in England and Wales in the period 1991–2008.

In another study, Molinos-Senante, Maziotis and Xue (2021) examined productivity growth, saving resulting from the scope and extent of the water and sewerage industry: the case study of Chile. In this article, they focused on performance evaluation and cost factor analysis of water companies, where they used quadratic cost functions to examine the existence of savings in the Chilean water and sewerage industry in the period 2010–2017. In their article, Frone and Frone (2014) dealt with the correlation between water supply and sewerage infrastructure and the economic development indicator GDP per capita at the regional county level. The article by Somlyódy and Patziger (2012) outlines the development of the technical infrastructure (water supply, sewerage and wastewater treatment) since 1990 in six countries, including the Czech Republic as well as influencing factors such as GDP, water charge rates, etc. The relationship between the industrial wastewater discharge and gross domestic product (GDP) per capita and urban domestic sewerage and GDP per capita is researched in his article by Liu (2019).

The presented article focuses on a part of the research, namely on presenting a comparison of the price level of the water and sewage charge rates and macroeconomic indicators, which represent the performance of individual regions of the Czech Republic.

Material and methods

The Czech Republic consists of 14 regions: the Capital City of Prague, South Bohemian Region, South Moravian Region, Karlovy Vary Region, Vysočina Region, Hradec Králové Region, Liberec Region, Moravian-Silesian Region, Olomouc Region, Pardubice Region, Plzeň Region, Central Bohemia Region, Ústí nad Labem Region and Zlín Region (Fig. 1).

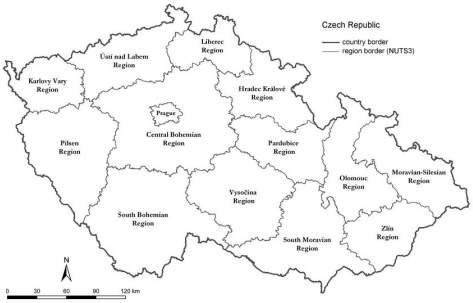

FIGURE 1. Regions of the Czech Republic (Kostin & Halounová, 2019)

The development, construction and operation of water supply and sewerage systems, which serve public needs, is addressed by the Water Supply and Sewerage Act of 2001 (274/2001 Coll.). Section 2 states that water supply and sewerage systems for public use are set up and operated in the public interest. For this reason, the following research hypothesis whether there is relation between regions and the price level of water and sewerage charge rates arose, i.e. that

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"Do the regions with lower macroeconomic performance have lower price level of water and sewerage charge rates than the regions with higher macroeconomic performance?".

Table 1 shows the price level of water and sewerage charge rates in individual regions of the Czech Republic for the last five years (the research is based on a 14-year period, 2007–2020).

Many authors deal with the influence of various factors on the efficiency in water management, respectively, in water and sewage companies. For example, Molinos-Senante, Sala-Garrido and Lafuente (2015) addressed the impacts of environmental variables on the efficiency of water and sewerage companies: in a case study from Chile. The same authors also assessed the relative efficiency of water companies: a cross-border approach in the English and Welsh water industries, pointing to different services provided by water and sewerage companies as there are companies providing only water supply and the water and sewerage companies (Molinos-Senante, Maziotis & Sala-Garrido, 2015).

The case study, which deals with the development of the level of water and sewerage charges and the development of macroeconomic indicators focuses on the regions in the Czech Republic. The case study examined 14 regions in the 2007–2020 period. One hundred ninety-six items of data were compared for the purposes of comparing the price level of water and sewage charge rates. One thousand one hundred seventy-six items of data were compared within macroeconomic indicators and the following factors were monitored: population, gross domestic product at current prices, gross domestic product per capita, net disposable income of households, net disposable income per capita and average gross monthly wage per capita.

The comparison of the development of the price level of water and sewerage charge rates and macroeconomic indicators was created using a matrix expression.

TABLE 1. Development of the price level of the water and sewerage charge rates in CZK·m^{-3} in the regions of the Czech Republic in 2016–2020 (own processing based on data from eAGRI portal)

Item	2016	2017	2018	2019	2020
Capital City of Prague	72.40	74.40	76.00	78.00	84.00
Central Bohemia Region	70.30	72.70	74.00	76.10	81.70
South Bohemia Region	64.00	65.00	66.40	67.50	70.10
Plzeň region	64.20	65.10	67.00	71.30	75.40
Karlovy Vary Region	70.40	71.20	73.80	76.90	79.70
Ústí nad Labem Region	84.40	84.80	85.10	86.00	89.00
Liberec Region	84.10	84.90	86.70	87.70	90.00
Hradec Králové Region	67.30	67.80	69.10	71.70	74.60
Pardubice Region	66.60	68.00	70.30	73.20	76.00
Vysočina Region	61.70	63.90	65.40	67.30	70.30
South Moravian Region	66.70	67.10	69.00	72.30	76.60
Olomouc Region	63.10	63.80	65.20	68.00	71.30
Zlín Region	65.20	65.60	66.60	69.20	71.70
Moravian-Silesian Region	63.80	65.00	65.90	69.10	72.60

Note: 1 EUR = 25.50 CZK.

The partial matrix expression, separately for the price level of the water and sewage charge rates and macroeconomic indicators, is two-dimensional, where 14 rows and single column were specified, $\mathbf{A} = (a_{ij})$.

$$\mathbf{A} = \begin{matrix} a_{11} \\ a_{21} \\ a_{m1} \end{matrix}, \quad (1)$$

where:
$m = 14$.

Fourteen two-dimensional matrices were created for the price level of water and sewage charge rates, i.e. matrices **A–N**, from which the **AA** matrix was subsequently created.

$$\mathbf{AA} = \begin{matrix} a_{11} & a_{12} & a_{1n} \\ a_{12} & a_{22} & a_{2n} \\ a_{m1} & a_{m2} & a_{mn} \end{matrix}, \quad (2)$$

where:
$m = 14$,
$n = 14$.

Seventy two-dimensional matrices were created for the macroeconomic indicators, i.e. the **A'–SSS'** matrix, from which the **BB** matrix was created.

$$\mathbf{BB} = \begin{matrix} b_{11} & b_{12} & b_{1n} \\ b_{12} & b_{22} & b_{2n} \\ b_{m1} & b_{m2} & b_{mn} \end{matrix}, \quad (3)$$

where:
$m = 14$,
$n = 14$.

The final **AAA** matrix for the price level of the water and sewerage charge rates is based on the sum of the matrices **A–N**.

$$\mathbf{AAA} = \mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D} + \ldots + \mathbf{N}, \quad (4)$$

$$\mathbf{AAA_{ij}} = \mathbf{A_{ij}} + \mathbf{B_{ij}} + \mathbf{C_{ij}} + \mathbf{D_{ij}} + \ldots + \mathbf{N_{ij}}. \quad (5)$$

The final **BBB** matrix for the macroeconomic indicators is based on the sum of matrices **A'–SSS'**.

$$\mathbf{BBB} = \mathbf{A'} + \mathbf{B'} + \mathbf{C'} + \mathbf{D'} + \ldots + \mathbf{SSS'}, \quad (6)$$

$$\mathbf{BBB_{ij}} = \mathbf{A'_{ij}} + \mathbf{B'_{ij}} + \mathbf{C'_{ij}} + \mathbf{D'_{ij}} + \ldots + \mathbf{SSS'_{ij}}. \quad (7)$$

The output matrix, which combines the outputs of the matrix expressions of the price level of water and sewerage charge rates (a) and the matrix expressions of macroeconomic indicators (b), has the following form:

$$\mathbf{AB} = \begin{matrix} a_{11} & b_{12} & b_{1n} \\ a_{12} & b_{22} & b_{2n} \\ a_{m1} & b_{m2} & b_{mn} \end{matrix}, \quad (8)$$

where:
$m = 14$,
$n = 7$.

Results and discussion

As already mentioned in the introduction to this article, water supply and sewerage management in the Czech Republic is regulated by the Water Supply and Sewerage Act of 2001. This law clearly defines that water supply and sewerage systems for public use are established and operated in the public interest. This statement can be understood as a public service. The Czech Republic has about 10.5 million inhabitants, for whom it is necessary to supply water and discharge sewerage. The Czech Republic is divided into 14 regions, which are diverse in terms of both performance and economic efficiency. The Capital City of Prague is one of the regions with the highest performance which always influences all national statistics by its above-standard values.

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Based on the collection of data on the price level of the water and sewerage charge rates in individual regions of the Czech Republic, their analysis in the monitored years 2007––2020 where the order was determined for each year (1– the lowest price, 14 – the highest price) and the matrix expression created, a two-dimensional Table 2 was compiled.

TABLE 2. The final order for the monitored years 2007–2020 for the price level of water and sewerage charge rates in the regions of the Czech Republic (own processing)

Description	Point evaluation	Final order
Vysočina Region	31	1
Olomouc Region	41	2
Plzeň Region	47	3
Moravian-Silesian Region	47	4
South Bohemian Region	81	5
South Moravian Region	96	6
Zlín Region	98	7
Hradec Králové Region	102	8
Pardubice Region	111	9
Central Bohemian Region	144	10
Capital City of Prague	147	11
Karlovy Vary Region	147	12
Liberec Region	187	13
Ústí nad Labem Region	190	14

Based on the data collection on the following macroeconomic indicators:
- gross domestic product (GDP),
- gross domestic product per capita (GDP per capita),
- net disposable income of households (NDI),
- net disposable income of households per capita (NDI per capita),
- average gross wage,

in individual regions of the Czech Republic, their analysis in the monitored years 2007–2020, where the following order was determined for each year:
- gross domestic product: 1 – the highest value, 14 – the lowest value,
- gross domestic product per capita: 1 – the highest value, 14 – the lowest value,
- net disposable income of households: 1 – the highest value, 14 – the lowest value,
- net disposable income of households per capita: 1 – the highest value, 14 – the lowest value,
- average gross wage: 1 – the highest value, 14 – the lowest value,

a matrix expression was performed from the following outputs (Table 3).

Table 4 combines output data related to the price level of water and sewerage charges and individual macroeconomic indicators in the regions of the Czech Republic. This output table contains data that answers the basic research question stated in the introductory part of this article: whether regions with lower performance have a lower price level of water and sewage charge rates if this service to the population is considered to be a public service by law.

The Plzeň Region is not one of the regions with the lowest performance in terms of macroeconomic indicators. On the other hand, the Plzeň Region is one of the most efficient regions in terms of gross domestic product per capita, net disposable income of households per capita and net disposable income of household performances. An overview of the order for the level of water and sewerage charges and individual macroeconomic indicators is shown in Table 5, which shows the sum of individual matrix expressions within macroeconomic indicators and shows two dimensions: namely the order of the level of the water

TABLE 3. The final order for the monitored years 2007–2020 within individual macroeconomic indicators in the regions of the Czech Republic (own processing)

Description	GDP	GDP per capita	NDI	NDI per capita	Average gross wage
Capital City of Prague	1	1	1	1	1
Central Bohemia Region	2	4	2	2	2
South Bohemia Region	6	7	6	7	7
Plzeň Region	7	3	8	3	3
Karlovy Vary Region	14	14	14	13	13
Ústí nad Labem Region	5	12	5	14	14
Liberec Region	13	11	13	10	10
Hradec Králové Region	10	5	10	5	5
Pardubice Region	12	10	12	8	8
Vysočina Region	11	9	11	6	6
South Moravian Region	3	2	3	4	4
Olomouc Region	9	13	7	12	12
Zlín Region	8	6	9	9	9
Moravian-Silesian Region	4	8	4	11	11

TABLE 4. The final order for the monitored years 2007–2020 for the price level of the water and sewage charge rates and macroeconomic indicators in the regions of the Czech Republic (own processing)

Description	W/S	GDP	GDP per capita	NDI	NDI per capita	Average gross wage
Capital City of Prague	11	1	1	1	1	1
Central Bohemia Region	10	2	4	2	2	2
South Bohemia Region	5	6	7	6	7	7
Plzeň Region	3	7	3	8	3	3
Karlovy Vary Region	12	14	14	14	13	13
Ústí nad Labem Region	14	5	12	5	14	14
Liberec Region	13	13	11	13	10	10
Hradec Králové Region	8	10	5	10	5	5
Pardubice Region	9	12	10	12	8	8
Vysočina Region	1	11	9	11	6	6
South Moravian Region	6	3	2	3	4	4
Olomouc Region	2	9	13	7	12	12
Zlín Region	7	8	6	9	9	9
Moravian-Silesian Region	4	4	8	4	11	11

and sewerage charges and the sum of the order of macroeconomic indicators. They are always sorted from the lowest to the highest values.

Conclusions

The research focused on the basic research question "Do the regions with lower macroeconomic performance have a lower price level of water and sewage charge rates than the regions with higher macroeconomic performance?". Values from the timeline were taken for the research, namely from the years 2007–2020.

Thus, the researchers worked with 1,176 items of data on macroeconomic indicators and 196 items of data on the price level of the water and sewerage charge rates. Macroeconomic indicators focused on the performance of the region, which was represented by gross domestic product, gross domestic product per capita, net disposable income of households, net disposable income of households per capita and average gross wage.

The research shows that the lowest price level of water and sewerage charge rates was in the Vysočina, Olomouc, Plzeň and Moravian-Silesian Regions (Table 2). On the contrary, the highest level of the water and sewerage charges was in the Karlovy Vary, Liberec and Ústí nad Labem Regions. Further from the research shows that the Karlovy Vary, Liberec and Olomouc Regions are among the regions with the lowest performance, while the Capital City of Prague, Central Bohemia and South Moravia Regions range among those with the highest performance (Table 5). It is clear from the above-stated facts that the research question

TABLE 5. The order of the price level of water and sewage charge rates and the sum of macroeconomic indicators in the regions of the Czech Republic (own processing)

Order of the price level of the water and sewerage charge rates in the regions	Order of the sum of the macroeconomic indicators in the regions
Vysočina Region	Karlovy Vary Region
Olomouc Region	Liberec Region
Plzeň Region	Olomouc Region
Moravian-Silesian Region	Ústí nad Labem
South Bohemian Region	Pardubice Region
South Moravian Region	Vysočina Region
Zlín Region	Zlín Region
Hradec Králové Region	Moravian-Silesian Region
Pardubice Region	Hradec Králové Region
Central Bohemia Region	South Bohemia Region
Capital City of Prague	Plzeň Region
Karlovy Vary Region	South Moravian Region
Liberec Region	Central Bohemian Region
Ústí nad Labem Region	Capital City of Prague

has not been confirmed as only one region out of 14 meets this condition, namely the Olomouc Region. The research found that the difference in the price level of the water and sewerage charge rates with the lowest level in the Vysočina Region and the highest level in the Ústí nad Labem Region is on average 31.94% for the observed years 2007––2020. Similarly, the average percentage differences in macroeconomic indicators between the Capital City of Prague and the Karlovy Vary Regions were determined, namely:

- gross domestic product differs on average by 1,291.6%,
- gross domestic product per capita differs on average by 230.5%,
- net disposable income of households differs on average by 534.4%,
- net disposable income of households per capita differs on average by 50.5%,
- the average gross wage differs on average by 48.8%.

It is clear from the above-listed information that the equality between the price level of water and sewerage charge rates and macroeconomic indicators in the regions of the Czech Republic is not apparent. Further research will focus on determining the correlations between the price level of the water and sewerage charge rates, individual macroeconomic indicators and other technical indicators related to the water supply and sewerage systems operation, such as the length of the connections or the number of customers.

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Summary

Comparison of the price level of the water and sewerage charge rates and macroeconomic indicators in the Czech Republic. This article focused on comparing the development of the price level of the water and sewerage charge rates in the regions of the Czech Republic to the development of macroeconomic indicators expressing the performance of the individual region. The following were selected as macroeconomic indicators: gross domestic product, gross domestic product per capita, net disposable income of households, net disposable income of households per capita and average gross wage. The Czech Republic is divided into 14 regions. In each region, a different price level of the water and sewerage charge rate was determined. At the same time, each region had a different performance which is represented by the above-mentioned macroeconomic indicators. The regions with the lowest performance are the Karlovy Vary, Liberec and Olomouc Regions. It follows from the definition of Act 274/2001 Coll. on the water supply and sewerage systems operation is in the public interest. This raised

the research hypothesis of whether regions with lower performance also have a lower price level of water and sewerage charge rates from the point of view of the purchasing power of the inhabitants of this region. Confirmation or rejection of this hypothesis was based on the creation of matrix expressions, in total 91 matrices. The input data for the creation of matrices contained 196 items of data on the price level of the water and sewerage charge rates and 1,176 items of data on macroeconomic indicators. The hypothesis was not confirmed as only one region met the condition (Olomouc Region), which had a lower price level of water and sewerage charge rates and lower efficiency.