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Seasonal Adjustment of Consumer Price Index as Against December Previous Year on Fuels in Romania between 2020 ynd 2022 Using Jdemetra+ 2.2.3

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ABSTRACT

Modelling Consumer Price Index as strategy for inflation targeting is of significance in the existing global context. Moreover, in the current economic state, identifying seasonal patterns and modelling short term time series becomes essential in building a sustainable economy. The paper analyses a dataset on fuel prices, made available by National Institute of Statistics Romania with values from 2001 to 2022. Promising results on the seasonally adjusted series are obtained by employing the X13 package in JDemetra+ 2.2.3. The results show that the series has been log-transformed and no calendar effects are present. Moreover, seasonality tests show that the residuals are not affected by seasonality. The plot of the series components reveals a strong irregular component.

Keywords: Consumer Price Index, Romania, JDemetra+ 2.2.3, seasonal adjustment, fuel

JEL Classification: *C10*

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1. INTRODUCTION

Inflation targeting is a popular approach adopted by many countries as a mean for controlling price increases, New Zealand, Canada, the United Kingdom, Finland, Sweden, Australia or Spain among others (Debelle, Masson, Savastano, & Sharma, 1998). Modelling the Consumer Price Index (CPI) as strategy for inflation targeting using ARIMA models is widely spread in the scientific literature (Gautam & Kanoujiya, 2022). Such models have proven reasonable in terms of quality for CPIs in developed countries (see for example (Nyoni, 2019)) as well as developing ones (see for example (Mohamed, 2020); (Nyoni, 2018); (Saz, 2011)). Also, ARIMA models with seasonal component produced better predictions compared to other approaches such as Holt-Winters triple exponential smoothing (Lidiema, 2017).

In addition to inflation targeting, modelling the CPI as a seasonally adjusted series might be important for policy makers, as seasonally adjusted data help them understand seasonal patterns and respond to them accordingly (Mirica, Glavan, Toma, & Patrascu, 2019). Many statistical offices do not publish seasonally adjusted CPI as "the common practice is to omit seasonal adjustment even though many of the price series are seasonal" as stated by the United Nations Economic Commission for Europe (UNECE, 2020). Yet, the US Bureau of Statistics and the European Central Bank publish a seasonally adjusted CPI and HCPI respectively ((ECB, 2023); (US Bureau of Statistics, 2022)). Bundesbank also produces such series (Deutsche Bundesbank Eurosystem, 2022).

The paper aims to model the Consumer Price Index as against December previous year on fuels in Romania applying an easy-to-use automated procedure. The paper contributes to the field in two ways. Firstly, it offers some insights on how to model a very short time series with seasonal patterns. The topic is extremely important for practitioners in official statistics as time series in official statistics are relatively short, reflecting a delicate balance between coverage and the need for continuous uptakes (Buono, Infante, & Mazzi, 2018). Secondly, the National Institute of Statistics of Romania currently does not publish a seasonally adjusted version of the selected time series. Should the need of such a series arises, our research may be useful in determining the best approach to perform seasonal adjustment.

2. LITERATURE REVIEW

Bell and Hillmer (1984) pointed out in their seminal work on policy issues related to seasonal adjustment of time series that "the society is conditioned to expect and even demand seasonally adjusted data" as monetary and economic policies rely on them (Bell & Hillmer, 1984). The use of seasonally adjusted data instead of raw data has multiple advantages both in the context of a single series analysis as well as in econometric modelling. For example, (Granger, 1978) pointed out that using seasonally adjusted data in a regression analysis removes a crucial cause of spurious relationship and improves forecasts. In a single series analysis, seasonally adjusted data allow for large masked seasonality effects to reveal themselves; this is often the case of winter holidays during the recession years that cause an increase in raw monthly series from November to December but a decrease in seasonally adjusted series ((Jiann, 2005); (United States Census Bureau, 2023)).

An acceptable alternative to seasonal adjustment in the analysis of short-term time series is the comparison of data on a year-over-year basis (Majaski, 2023). However, this method, while it reduces the seasonal fluctuations, it does not permit the user to observe significant changes in the business cycle in a timely manner but rather late after they occur (The Federal Reserve Bank of Dallas, 2023). Also, such comparisons don't account for Easter effects, as Easter is a moving holiday that may fall on different months is consecutive years (International Monetary Fund, 2017). Therefore, the use of seasonally and calendar adjusted data for studying the underlying trends within a series, when the series present such pattens, is recommended (Fortier & Gellatly, 2023).

With regard to the Consumer Price Index, seasonally adjusted data should be used for analysing short term price trends in the economy, while unadjusted data should be used for escalation purposes ((U.S. Bureau of Labour Statistics, 2023); (U.S. Bureau of Labour Statistics, 2020)). Also, the seasonally adjusted Consumer Price Index may be used to find inflection points in the economic activity (Zhang, 2017).

One of the most delicate issues in the process of seasonal adjustment is choosing the length of the time series because the quality of the results reduces with the number of observations included in the process (European Commission, 2005). From a theoretical point of view, in order to perform time series modelling with a SARIMA model the number of observations must exceed the number of estimated parameters with just one, yet in practice a considerably higher number of observations is needed (Hyndman & Athanasopoulos, 2018). When long time series are not available or are

not suitable, choosing the appropriate method for seasonal adjustment is problematic. Scientific literature reports that the X12 methods are more suitable than model-based ones such as TRAMO-SEATS in such circumstances (European Commission, 2005).

3. METHODOLOGY

For the purpose of this paper, data on the Consumer Price Index as against December previous year on fuels is retrieved from the Tempo-Online database provided by the National Institute of Statistics Romania on March 20th 2023. Dataset containing values from 2001 to 2022 is downloaded and JDemetra+ 2.2.3 was employed in order to further perform the analysis on the time series. By comparison, Bundesbank (Deutsche Bundesbank Eurosystem, 2023) uses JDemetra 2.2.2. The software, freely available on Github, was developed according to the Eurostat Guidelines on Seasonal Adjustment, being officially recommended for this purpose (JDemetra, 2023). All products in the JDemetra+ family have key advantages: multi-platform availability (Windows, MacOS, Linux, Solaris); modularity (its capabilities can be extended by plugins); possibility to reconvert in other languages (JDemetra, 2023). The latest version of JDemetra+ is 2.2.4 but it was only released on January 2023. On the other hand, JDemetra 2.2.3 as released on July 2020, providing enough time for practical tests, including on time series severely affected by the COVID pandemic.

In order to establish the series length, a graphical inspection was performed. According to the Eurostat ESS Guidelines on Seasonal Adjustment, the graphical analysis should be performed on the unadjusted series (Eurostat, 2015). If the series pattern drastically changes at some point in time, analyzing a shorter series span is considered, respecting the minimum length of three years for monthly data recommended by UNECE (UNECE , 2021).

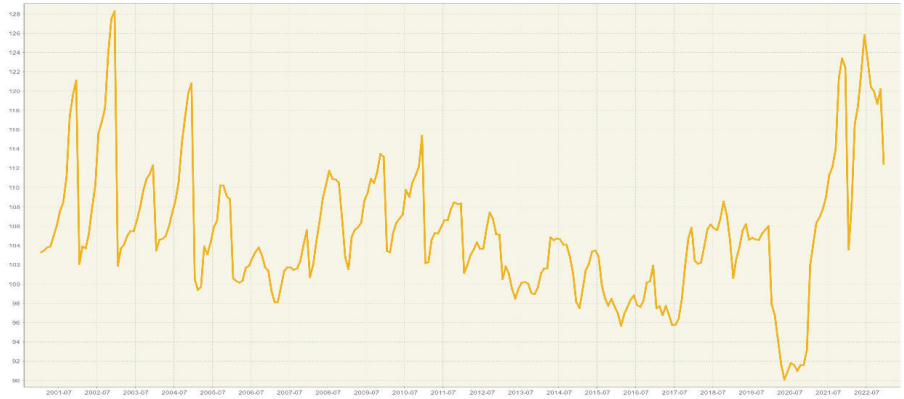
Next, the outlier detection tool was used in order to observe the outliers in the time series. Finally, the automatic procedure for seasonal adjustment was applied, as suggested in previous studies on monthly data (see for example (Toma, Mirica, & Paunica, 2018)). The procedure for seasonal adjustment comprises of several steps: pre-adjustment (calendar adjustment, outlier detection and correction, series transformation); series modelling (estimating the coefficients based on the SARIMA model) and series decomposition (JDemetra, 2023). For the calendar adjustment step, all the legal holidays in Romania were considered relevant for the series and thus incorporated within the analysis. Indicators from the main results in the output were reported and analyzed.

4. RESULTS

Figure 1 shows the evolution of the Consumer Price Index as against December previous year on fuels in Romania between January 2001 and December 2022. A clear seasonal pattern can be observed from the graph. However, the pattern drastically changes since the beginning of the Covid-19 pandemic, more specifically January 2020. As such, before continuing to the seasonal adjustment phase, the series is cut and the now time frame considered is January 2020 – December 2022.

Consumer Price Index as against December previous year on fuels in Romania between January 2001 and December 2022; source: designed by the authors using JDemetra+ 2.2.3

Figure 1



Outliers generated by the COVID-19 pandemic within the time series may create incorrect revisions (Enright, 2023). Moreover, they can affect one or more components of the time series (Tiller, Oh, & Liu, 2021). Thus, identifying and correcting them, preferably using an automated procedure is necessary (Mirica, Catrina, Ceban, Partas-Ciolas, & Calota, 2022).

In the case of the Consumer Price Index as against December previous year on fuels in Romania, four outliers are identified, as observed in Figure 2: one level shift in January 2021, one level shift in October 2021, one transitory change in January 2022 and an additive outlier at the end of the series. The outlier in January 2021 followed just as the number of cases in the November 2020 pandemic wave was diminishing in Romania; the one in October 2021, occurred as the October-November 2021 pandemic wave was at its peak; the one in January 2022 also occurred at the peak of a pandemic wave (more details may be consulted at (WHO, 2023)). The last outlier is located at the

end of the series, thus suggesting an economic change; however, more data need to be available in order to properly interpret it (Eurostat, 2020).

Consumer Price Index as against December previous year in Romania on fuels between 2020 and 2022 – Outliers; source: designed by the authors using JDemetra+ 2.2.3

Figure 2

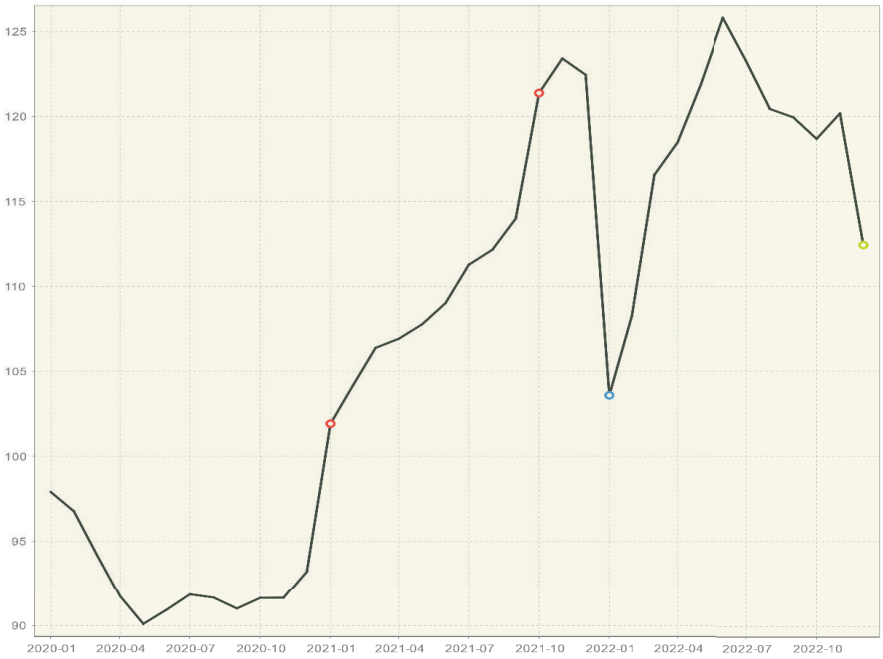


Table 1 displays the results of the seasonal adjustment process using two customized specifications: the RSA 5c form the X13 package and the RSA full from the Tramo-Seats package. Both specifications returned a log-transformed series, no trading day effects and no Easter effects. The basic checks show promising results. The residual seasonality tests show no seasonality present in the residuals. However, the entire process was diagnosed as good using X13 and severe using Tramo-Seats. The results are in concordance with those obtained by (Buono, Infante, & Mazzi, 2018) who explain the better performance of X13 though "its intrinsic non-parametric nature, so that the choice of the moving average filters is less influenced by the changes in the length of the series." (Buono, Infante, & Mazzi, 2018).

Seasonal adjustment on Consumer Price Index as against December previous year on fuels in Romania between 2020 and 2022- Main results; source: designed by the authours using JDemetra+ 2.2.3

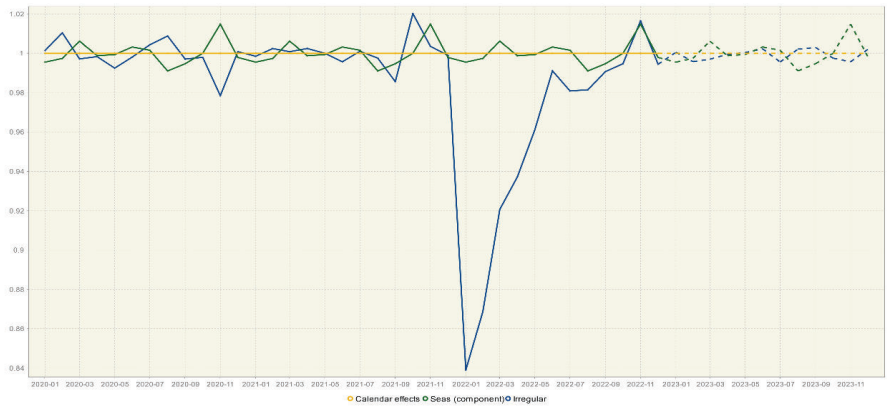
Table 1

	X13 – RSA 5c custom specifcation	Tramo-Seats – RSA full custom specifcation
Series transformation	log-transformed	log-transformed
Trading day effects	none	none
Easter effects	none	none
Basic checks	definition:Good(0.000) annual totals:Good (0.000)	definition:Good (0.000) annual totals:Good (0.000)
Regarima residuals	normality:Good (0.444) independence: Good (0.189) spectral td peaks: Good (0.450) spectral seas peaks: Good (0.138)	normality: Good (0.247) independence: Good (0.917) spectral td peaks: Uncertain (0.085) spectral seas peaks: Good (0.185)
Outliers	number of outliers: Bad (0.056)	number of outliers: Severe (0.111)
Residual seasonality tests	qs test on sa: Good (1.000) f-test on sa (seasonal dummies): Good (0.998) qs test on i: Good (1.000) f-test on i (seasonal dummies): Good (0.985)	qs test on sa: Good (1.000) f-test on sa (seasonal dummies):Good (0.934)
Summary	Good	Severe

Figure 3 displays the series components as generated using X13. The seasonal and the irregular component are very strong. However, there are no calendar effects.

Series components (calendar effects, seasonal and irregular) generated using X13 RSA 5c custom specification source: designed by the authors using JDemetra+ 2.2.3

Figure 3



5. CONCLUSIONS

The paper contributes to the field as it offers insights on how to model a very short time series with seasonal patterns. Our research concluded that the Consumer Price Index as against December previous year in Romania during the COVID pandemic presents outliers strongly linked to the pandemic waves. As such the automatic procedure available in JDemetra+ 2.2.3 offers promising results for modelling monthly time series of just 3 years length.
Further research, including manually entering the SARIMA model (Mirica, Andrei, Dascalu, Mincu Radulescu, & Glavan, 2016) is needed in order to improve the estimations. Such procedure would require executing several ARIMA models and seasonal filters and choosing the best model based on the magnitude of the revisions; more specifically, the model that leads to minimum revisions should be chosen (Mirica, Andrei, Dascalu, Mincu Radulescu, & Glavan, 2016). Thus, our paper presumed that the most relevant holidays for this particular time series are the legal holidays in Romania. Other important celebrations may be added to the calendar used in the seasonal adjustment process to assess whether or not they are relevant.

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Selected Economic Time Series Analysis Using the Fuzzy Linear Regression

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ABSTRACT

The adequacy of mathematical models of economic systems is reduced by the complexity of their structures, the number of parameters and influencing factors. The mathematical regression model assumes that the structure and functional dependence of the input and output variables of the modeled system is precisely defined. However, real systems are complex and indeterminate, and their adequate models must formalize their vague phenomenon. Artificial intelligence methods use fuzzy set mathematics and fuzzy logic approaches to synthesize models of indeterminate systems. We provided our research of defined fuzzy linear regression models using data series of economic variables, namely the evolution of the discount rate, inflation rate and the rate of unemployment between 2019 and 2021. These data series were chosen with regard to the selected economic cycle before, during and after the Covid-19 pandemy. It is precisely due to the cyclical development of the economy that some level of uncertainty and vagueness of data of monitored variables is manifested. Results of the work reflect outputs of the proposed fuzzy regression model of indeterminate variables during the selected time series. These confirmed the assumptions of the authors that there is a mutual interdependence between the selected economic variables, in particular the amount of the discount rate in relation to the inflation rate, the amount of the inflation rate in relation to the rate of unemployment and thus the amount of discount rate in relation to the rate. The existence of time lags in deciding on economic policy measures and their subsequent implementation was also confirmed in all cases, even during the analyzed time series of three years. Only variable unemployment behaved less standardly, as its essence in many respects lies outside of purely pure market mechanism and is under the influence of market inelasticity, legal measures, free movement of labor in the EU, etc.

Keywords: *fuzzy set, fuzzy linear regression, genetic algorithms, time series, discount rate, inflation, unemployment*

JEL Classification: *C22, C51, C65, B22, B23*

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1. INTRODUCTION

Linear regression is a basic and widely used type of predictive analysis of the interdependence of two or more variables. Today, the regression analysis is used in practically every area of economics and applied science.

Linear regression is a mathematical method used to define a set of points on a graph with a straight line. The points representing the measured data are assumed to have their x-coordinates exact, while the ypsilon-coordinates may be subject to random error, while we assume that the dependence of the variables on the individual axes can be graphically expressed by a straight line. If we interpolate the resulting measured points with a straight line, then when subtracting m the graph, there will be a divergency between ypsilon value of the measured point and ypsilon value lying on the straight line. The essence of linear regression is to find such a straight line that the sum of the squares of these deviations is as small as possible [1].

There is not a strong need for a lot of statistics and mathematics for a well and normally functioning business, as well as the system of the national economy. Most relationships are straightforward. Interdependence looks like a straight line in the graph, from the mathematical point of view it is a linear function. If two variables are linked by such a dependency, the value of one of them - dependent variable - could be calculated using the other - independent variable. In essence, it is a „simple“ variant of complicated structural models, where we use a series of regression coefficients to assess the links between a large number of variables, which often appear simultaneously at the level of explained and explanatory.

Although linear regression has many practical uses in economics and applied sciences, in practice its use encounters a number of problems, some of which are not very certain and some of which cannot be removed from the analysis [2]. The most common problem is a small data set, whether it is a small number of values of individual variables or their short observation over time [3].

In classically conceived linear regression, the point is that relationships among dependent and independent variables are clearly determined and are just as clearly interpreted and discussed afterwards. Another problem is therefore the vagueness of the data and not always completely certain and clearly defined relationships between them. The interpretation of individual variables, their different content according to static processing, etc. can also be conceived differently [4].

The time lags of individual variables, their measurement over time and the delay in their acquisition and interpretation are a special and distinctive range of issues in linear programming. This is related to the aforementioned

issue of small data sets and working with these data. The human point of view, the creation of one‘s own linear regression model and interpretation of results are indispensable, which burdens the accuracy of the outputs.

Since at least 2019, we have also witnessed sudden reversals in the economy and economic policy, which makes the regression outputs imprecise, indeterminate, and sometimes misleading. The so-called black swan enters the observation system, which indicates an event or fact that cannot be predicted, cannot be counted on, and cannot be prevented in advance [5]. When observing economic events in recent decades, we come to the clear conclusion that such phenomena - referred to as black swans - are increasing.

Through its methods, statistics tries to describe things as accurately as possible and draw accurate conclusions. However, economic and social science variables in general can never be measured exactly. If we were to get down to very small scales, we wouldn‘t be able to cope with a 100% accurate description anyway, because on the one hand, the description would be very complex and difficult to understand, and its reliability would be very low.

It is possible to describe the environment, where uncertainty is omnipresent, with vague linguistic terms, even if we want to manage a system or simply predict its behavior. In the 1970s, L. A. Zadeh came up with fuzzy set theory, which affects precisely these vague - fuzzy – concepts [6].

The application of fuzzy set theory has been a great contribution in the field of modeling complex uncertain systems [7]. The development of the indeterminate regression model is the development of the model of vagueness, using the formalization of uncertainty rather than numerical intervals [8]. Regression models reflecting the vagueness of the modelled systems using approaches of fuzzy set theory are called fuzzy regression models [9], [10], [11], [12]. The indeterminate nature of the fuzzy regression model is represented by the fuzzy output values and the fuzzy regression coefficients in the form of specialized fuzzy sets - fuzzy numbers [8]. Modern and powerful artificial intelligence methods are used to identify the structures and parameters of fuzzy models [13].

The fuzzy regression analysis presented in this paper is built on analysis of time-specific data series of economic variables. The independent variable is the amount of the interest discount rate (DIS) and the dependent variables are the amount of inflation rate (INF) and amount of the rate of unemployment (UNE) in the Czech Republic in the years 2019 to 2021. These data were selected with regard to their topicality and with regard to the global economic downturn due to the Covid-19 pandemic. The data with which the study works were obtained from the official database of the Czech National Bank (DIS) and the Czech Statistical Office (INF and UNE).

The selection of the selected macroeconomic variables was made with regard to real practice in the area of the state‘s economic policy and also with regard to their seasonality. Discount rate is interest rate announced by central banks. For this rate, the central bank provides discount loans to commercial banks, these are mostly short-term loans with a maturity of up to 3 months. Through this rate, the central bank regulates and moderates the amount of short-term loans on the interbank market, i.e. the price of money.

The increase in the discount rate is an anti-inflationary measure, as it increases the cost of servicing the loan, increases repayments, and thus dampens the demand for loans. And even if commercial banks can obtain credit resources elsewhere, primarily from their clients in the form of deposits, this is a very fundamental intervention within the framework of the discount policy. A decrease in the discount rate works in the opposite direction – it reduces the amount of installments and makes loans more affordable, thus supporting the demand for them.

The price of money and its quantity in circulation is directly related to the level of the inflation rate. Inflation is always and everywhere a monetary phenomenon, in the sense that it is and can be produced only by a more rapid increase in the quantity of money than in output [14]. Even if inflation rate reacts to adjustment of the central bank‘s interest rates with a certain time delay, the mutual interrelationship is quite obvious and scientifically proven. When adjusting interest rates, central banks consider other circumstances and connections in addition to the rate of inflation, such as the cost of mortgages, the effect on the rate of economic growth, etc., however, inflation is the primary and priority goal of monetary policy.

The situation regarding unemployment and its rate is also quite complex. If the central bank raises interest rates, it generally makes investment more expensive, which can lead to a decline in economic growth and an increase in unemployment. However, the labor market can behave non-standardly here as well. The cause may be low elasticity of the labor market, low wages elasticity, strong effect of labour unions, the setting of the social system, unemployment benefits, the existence of the gray economy, etc. These connections will be carefully discussed in the results of the work.

The following section of text is organized as follows. Chapter 2 concisely presents the principal concept and concept of fuzzy regression linear analysis, chapter 3 is devoted to the presentation of fuzzy regression model used in the work and a proper fuzzy regression analysis series of the selected macroeconomic variables. The article traditionally ends with the Conclusions section.

2. FUZZY REGRESSION ANALYSIS OF ECONOMIC TIME SERIES

The development of the indeterminate regression model is the development of the model of vagueness [8]. Regression models reflecting the vagueness of the modelled systems using approaches of fuzzy set theory are called fuzzy regression models [9], [11], [12]. The indeterminate nature of the fuzzy regression model is represented by the fuzzy output values and the fuzzy regression coefficients in the form of specialized fuzzy sets - fuzzy numbers [8]. The fuzzy linear regression model has the opportunity to express not only the analytical linear approximation of multivariate functions, but also the size of its uncertainty (vagueness, fuzziness) in the form of an indeterminate possibility area.

Fuzzy regression modelling

The shape of fuzzy linear regression model is given by

$$\widetilde{Y} = \widetilde{A}_0 x_0 + \widetilde{A}_1 x_1 + ... + \widetilde{A}_n x_n = \sum_{i=0}^{n} \widetilde{A}_i x_i \qquad i = 0,1,...,n \tag{1}$$

where $(\widetilde{A}_0, \widetilde{A}_1, ..., \widetilde{A}_n)$ are fuzzy regression coefficients (fuzzy numbers). The fuzzy number $\widetilde{A}$ is defined using its triangular shape membership function $\mu_{\widetilde{A}}(x)$ - Figure 1a

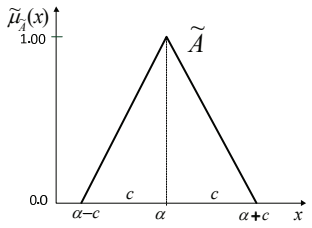


Figure 1a. Fuzzy regression coefficient $\widetilde{A}$

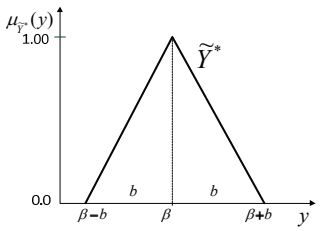


Figure 1b. Estimated fuzzy value $\widetilde{Y}^*$

where α is the mean value (core) of fuzzy number $\widetilde{A}$ and c is a half of the width of the carrier bearing $\widetilde{A}\{\alpha, c\}$.

The output variable $\widetilde{Y}$ of fuzzy regression model (1) is fuzzy number defined using the triangular membership function – Figure 1b. The estimated value $\widetilde{Y}^*$ is defined in the form $\widetilde{Y}^*\{\beta, b\}$, respectively.

The observed value $\widetilde{Y}^0$ is defined in the form $\widetilde{Y}^0\{y^0, d\}$. Estimated value β is the mean value (core) of estimated output fuzzy number $\widetilde{Y}^*$ and *b* is a half of the width of the carrier bearing $\widetilde{Y}^*\{\beta, b\}$.

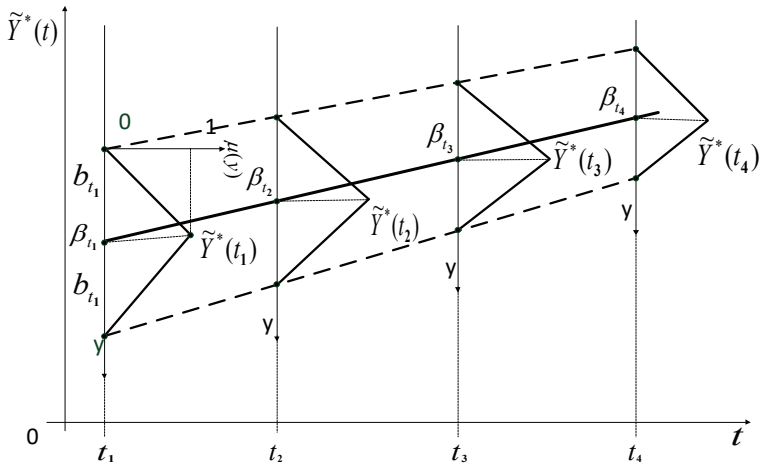
Finding values α_i and c_i as searched parameters of fuzzy regression coefficients $\widetilde{A}_i$ is defined as an optimization issue (see next).

Time series fuzzy regession modelling

The graph of a one-dimensional fuzzy regression function we can see in Figure 2 together with the appropriate linear approximation and the possibility area of the estimated fuzzy output $\widetilde{Y}^*$

Fuzzy Linear Regression Function

Figure 2.



The fuzzy time series regression model has the ability to express its trend and seasonal cycles, respectively. The fuzzy linear regression model of a time series trend is given

$$\widetilde{Y} = \widetilde{A}_0 + \widetilde{A}_1 t \qquad t = 1, 2, \ldots \tag{2}$$

The value of a seasonal deviation in every month MSD (as fuzzy number) is calculated for each year $r = 1,2,...,L$ and for each month k = 1, 2, …, 12 as the difference between the trend value and the actual value to be estimated

$$MSD = (\widetilde{Y}^{0}_{r,k} - \widetilde{Y}^{*}_{r,k}),\ \ r = 1,2,...,L,\ \ k = 1, 2, \dots, 12 \tag{3}$$

The central value of fuzzy number MSD is calculated as the difference of the central values $\widetilde{Y}^{0}_{r,k}; \widetilde{Y}^{*}_{r,k}$, the fuzziness is calculated as the sum of fuzziness of fuzzy numbers $\widetilde{Y}^{0}_{r,k}; \widetilde{Y}^{*}_{r,k}$.

The seasonal cycle is then defined as the time series of 12 seasonal deviations for 12 months. A seasonal deviation for a given month k = 1, 2,..., 12 is calculated as the average value of the month of year r = 1 , 2, ... , L of the considered time series.

$$\widetilde{Y}^{*}_{k} = \frac{1}{L}\sum_{r=1}^{L} (\widetilde{Y}^{0}_{r,k} - \widetilde{Y}^{*}_{r,k}),\ \ r = 1,2,...,L,\ \ k = 1, 2, \dots, 12 \tag{4}$$

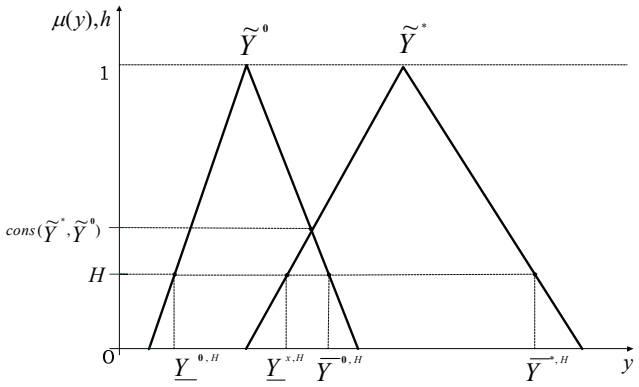
The values of monthly deviations are calculated as fuzzy numbers. The core of fuzzy number $\widetilde{Y}^{*}_{k}$ is calculated as the mean difference of the cores, the uncertainty is calculated as the mean of the sum of fuzziness. Thus, we calculate 12 fuzzy numbers, which pass into the timeline of 12 months as a curve of cores and their possibility areas.

Identification of fuzzy regression model

Fitness of the linear regression fuzzy model to the given data is measured through the Bass-Kwakernaaks´s index H – see Figure 3 [9], [15]. Adequacy of the observed and estimated values is conditioned by the relation (3) – the maximum intersection (consistency) of two fuzzy sets – the estimated $\widetilde{Y}^{*}$ and the examined $\widetilde{Y}^{0}$ - must be higher than the aspiration limit H (see Figure 3) [10].

$$\max_{y}\left\{\mu_{\widetilde{Y}^{0}}(y) \wedge \mu_{\widetilde{Y}^{*}}(y)\right\} = Cons(\widetilde{Y}^{0}, \widetilde{Y}^{*}) \geq H \tag{5}$$

Figure 3



The requirement on adequacy of the estimated and observed values (5) will be complemented by the requirement on minimum possible total uncertainty of the identified fuzzy regression function

$$\sum_{i=0}^{n}\sum_{j=1}^{m} c_{i,j} \to \min, \quad i = 0, 1, \dots, n, \quad j = 1, 2, \dots, m \tag{6}$$

where $i = 1,2,\dots,n$ is the number of input values of the regression function and $j = 1, 2, \dots, m$ is the number of observations. Then we can set the optimization problem - minimization of fuzzy model vagueness (6) under the condition (5). For the identification of the mean value (core) α_i of fuzzy number $\widetilde{A}_i$ the minimization of the fitness function J_1 is defined in the form

$$\min J_1 = \min \frac{1}{m} \sum_{j=1}^{m} \left(y_j^0 - \beta_j \right)^2 \tag{7}$$

For the identification of c_i as a half of the width of the carrier bearing $\widetilde{A}_i$ the minimization of the fitness function J_2 is defined in the form

$$\min J_2 = \min \sum_{j=1}^{m} \sum_{i=0}^{n} \left| c_{j,i} \right| \tag{8}$$

Genetic algorithms

To solve the minimization problem under the conditions (6), (7) we use the genetic algorithms [13]. Genetic algorithms (GA) belong to stochastic heuristic optimization methods. They find their greatest application in solving

optimization problems, most often minimizing the so-called fitness function of the solved problem. The general formulation of the GA optimization problem is expressed by the relation

$$\bar{x}_{opt} = \arg opt\left\{f\left(\bar{x}\right)\middle|\bar{x} \in C\right\} \tag{9}$$

where C is the set of admissible solutions, f is the fitness function, $\bar{x}$ is the admissible solution, and $\bar{x}_{opt}$ is the optimal solution sought. What is important is the strategy of finding generate possible solutions in the set C. GA uses a strategy inspired by natural evolution.

GAs are iterative in nature. In individual iterations, one does not work with an isolated solution, but with a so-called *population*. GA works in each iteration with a set of solutions contained in the population and tries to use genetic operations on these solutions to ensure the appearance of increasingly better solutions in subsequent iterations.

Each solution in the population is represented by a so-called *chromosome.* For each chromosome, the value of the objective function J is calculated.

Generation of the population for the next iteration is done based on the existing population by genetic operations called *crossover* and *mutation.* In the crossover operation, the chromosome of the new population is obtained by combining two chromosomes of the existing population. The solutions entering this operation are determined so that the use of each member of the population in the crossing operation is proportional to the quality of its value of its fitness function *J.* The mutation operation is applied to the population thus obtained and the procedure continues with the next iteration.

The iterative GA run is represented by a sequence of individual solutions whose fitness function gradually decreases (minimizes), i.e. converges to zero. The number of chromozomes in population (PopulationSize) must be set. The GA run is terminated when the size of the reduction in the value of J in the next two iterations falls below the specified limit (FunctionTolerance) or the prescribed maximum number of iterations (MaxGeneration) takes place. Parameter StallGenLimit option controls the number of steps GA looks over to see whether it is making progress. The optimal solution is then the best solution contained in the last iteration step.

In the case of identifying the fuzzy regression model (1), the values of the mean value (core) α_i of fuzzy number $\widetilde{A}_i$ are sought such that the value of the fitness function $J_{1\ i}$is minimized (5) while minimizing c_i as a half of the width of the carrier bearing $\widetilde{A}_i$through the minimization of the fitness function J_2 (6). In the case of model identification, two genetic algorithms are

used – namely *GA1* for function minimization J_1 searching α_i and *GA2* for function minimization J_2 searching c_i.

The implementation of genetic algorithms *GA1* and *GA2* was performed in the Global Optimization Toolbox of the MATLAB simulation system [20]. The parameters of new population generation, crossover and mutation procedures are predefined in the system. During the tuning of the GA, such values of the GA parameters are sought that minimize the computation time of the genetic algorithm and at the same time minimize the probability of the GA getting stuck in the local minimum of the fitness function value.

The *GA1* tuning results in the following parameter values: *PopulationSize* = 100, *MaxGenerations* = 100, *StallGenLimit* = 200, the *GA1* tuning results in *PopulationSize* = 100, *MaxGenerations* = 10, *StallGenLimit* = 200. The aspiration limit is set to $H = 0.50$.

The running of the *GA1* and *GA2* genetic algorithms is documented by the graphs of the convergence of the size of the fitness function in Figures 4a and Figure 4b.

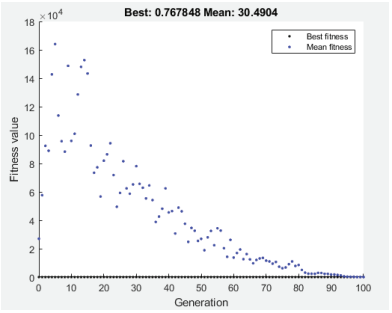


Figure 4a Course of *GA1* convergence

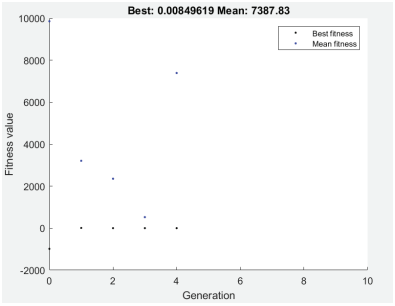


Figure 4b Course of *GA2* convergence

Fuzzy regression models of the trend and seasonal cycles of time series of economic variables bring new information and enable a deeper understanding of their behavior. In the following chapter, time series of selected variables, namely the discount rate, inflation rate and unemployment, are analyzed in this way.

3. ANALYSIS OF SELECTED ECONOMIC VARIABLES

Analysis and modeling of economic variables is a complex and very demanding task, especially in the period of two successive crises: the Covid-19 pandemic and unprecedentedly high energy prices as a result of the war and the tense world situation. This also applies to the analysis of long time series, during which revolutionary changes in economic reality can and do occur, when during the analyzed time period from 2019 to 2021 the global and Czech economy went through pre-crisis, crisis and post-crisis phases and is on the verge of another crisis. This makes the need for fuzzy regression analysis even more important, both for its scientific purpose and for use in practice.

For these reasons, the main economic entities - state, households and companies - are under continuous pressure, to which they submit their decisions in the area of demand, supply, investments, consumption and savings. New conditions force them to make decisions in situations of high uncertainty and high risk. Because of the rapid changes and also because of the new nature of crises, previously best practices and decisions are shown to be inadequate or flawed. Purely economic decisions are thus under the pressure of psychology, behavioral sciences, but also demographic development, immigration, environmental issues, etc.

The time series analyzed in this work consist of twelve monthly data for each of the monitored years 2019 to 2021. The analyzed time period was chosen due to the use of completely up-to-date data and also due to the fact that the first monitored year 2019 was the year before the outbreak of the crisis due to the Covid-19 pandemic, 2020 was the peak of this crisis and 2021 its gradual decline. The monitored period is therefore a classic cycle starting with a day, through a rise, a peak and a fall again. The economic variables were chosen with regard to their mutual connection and interconnectedness, as well as their dominant importance for public and private economy and finance.

The discount rate as an independent variable plays an important and irreplaceable role for both households and companies, as it generally determines the price of capital. Both external resources in the form of operating loans, investment loans and mortgages, as well as deposits and term deposits and financial market products. It also indirectly affects the exchange rate of the national currency through indirect foreign exchange interventions and foreign exchange interest. However, the central bank‘s decision made today will have the greatest impact on inflation in 12 to 18 months, which is why a macroeconomic forecast is important when deciding on rates, which mainly describes and estimates the future development of the economy with a focus on risks and uncertainties.

However, the central bank‘s measures to change interest rates will be reflected in the economy with a certain delay. The so-called time lags is the total time that elapses between the detection and recognition of economic problems and the moment after the implementation of corrective measures, when these measures begin to have a measurable effect on the economy. Recognition lag is the time that elapses from the actual occurrence of an economic disturbance to its recording and measurement by the relevant institutions. Decision lag is the period necessary to find a consensus and take relevant measures, in this case a change in the discount rate. And finally, the implementation lag is the period of time required for the measures adopted through the national economic transmission mechanism to be reflected in the economy in a desirable way.

Inflation as an analyzed dependent variable is, according to the prevailing opinion mainstream, the main and most significant economic disorder and imbalance. It is the subject of scientific research all over the world and the leading target of central banks. Inflation is very complicated state of economic imbalance, which manifests itself mainly in the growth of common price level of goods and services in the economy and, in some time, in growth of GDP and the decrease in unemployment. The price level expresses the relationship between the total amount of money and the total volume of goods and services for which it is exchanged.

High inflation rates make markets inefficient and causes difficulties for businesses to make long term plans, price calculations and budgets. Inflation can cause a drop in productivity, as businesses are required to advance resources from providing goods and services to financial operations with a goal to hedge against losses. Insecurity about the future value of money reduces investments and savings. Inflation also causes tax inflation – a hidden increase in taxation when nominally higher incomes push taxpayers into higher income tax rate bands.

Unemployment is another dependent economic variable that is analyzed in the paper. It is a condition where there is an imbalance in labour market, when demand for jobs is higher than supply of jobs. A certain level of unemployment is natural, as not all able-bodied people can be employed at any given time. It is related on the one hand to their social behavior and on the other hand to the fluctuation of the real economy around the potential GDP. This simultaneously creates a certain reserve on the labor market and a reservoir of labor for companies and the state. Unemployment is also relatively seasonal, and the labor market is also characterized by a low degree of elasticity. The seasonal, inelastic and also the political and social dimension of unemployment and the behavior of trade unions make this phenomenon a difficult economic construct that is difficult to predict and influence.

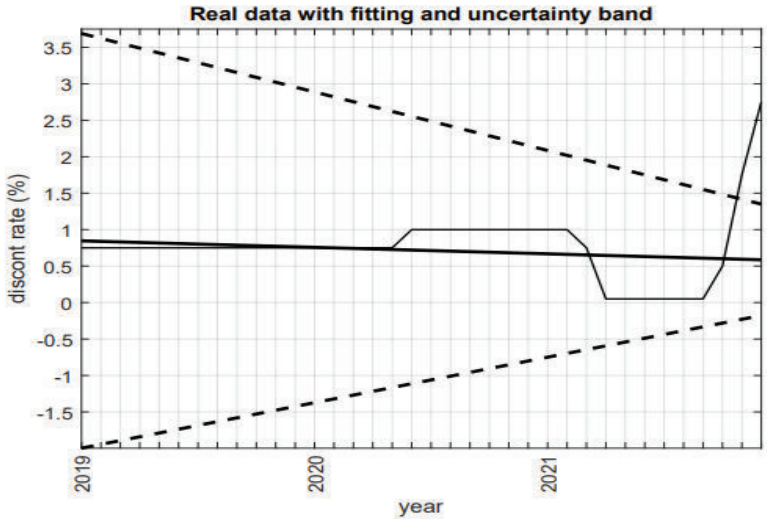
Relationship between dependent analyzed variables - inflation and unemployment - is interconnected, it is inverse. This fact is described by the so-called Phillips curve, which illustrates the inversely proportional relation among the rate of inflation and the unemployment rate. A lower unemployment rate in national economy correlates to higher inflation rate and vice versa. Modern Phillips curve models define two different models: the short run Phillips curve and the long run Phillips curve. It is due to the fact, that in the short run, there is general a fair inverse relationship between inflation and unemployment rate. In the long period of time, however, this phenomenon does not hold, and the whole economy might returns to natural rate of unemployment, regardless on the rate of inflation. Since the presented paper deals with a period of 3 years, i.e. a medium-term period, we will try to confirm the existence of the Phillips curve using the fuzzy linear regression method.

The presented fuzzy linear regression of economic variables was performed using classical algorithms in Global Optimal Toolbox of MATLAB software [20].

The results are presented as fuzzy regression models of time series for the discount rate (DIS; figures 5 and 6), the inflation rate (INF; figures 7 and 8) and unemyployment (UNE; figures 9 and 10). These figures (5 – 10) reprezent their fuzzy trends and fuzzy seasonal cycles.

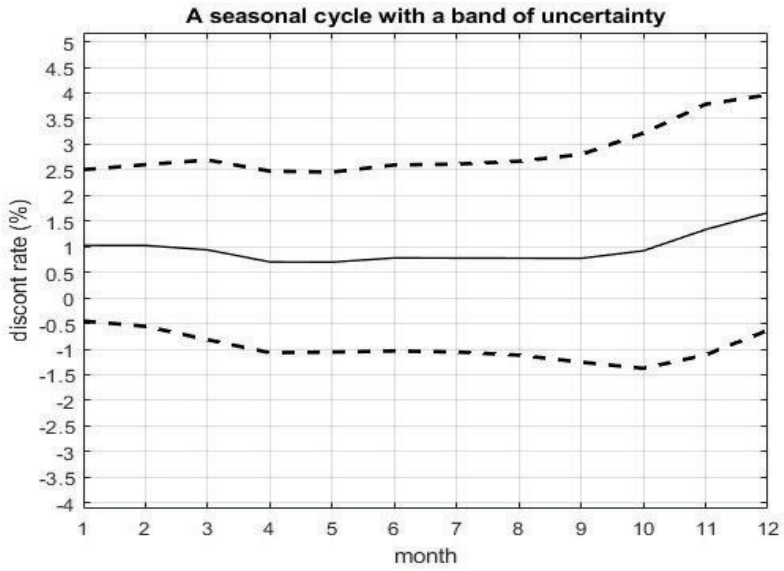
Discount Rate – Fuzzy Linear Regression Function

Figure 5



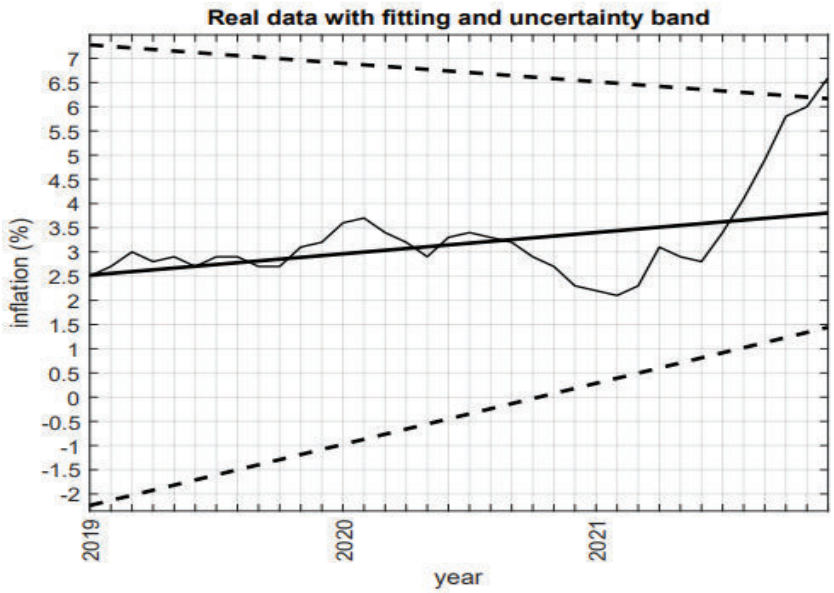
Discount Rate – Fuzzy Seasonal Cycles Function

Figure 6



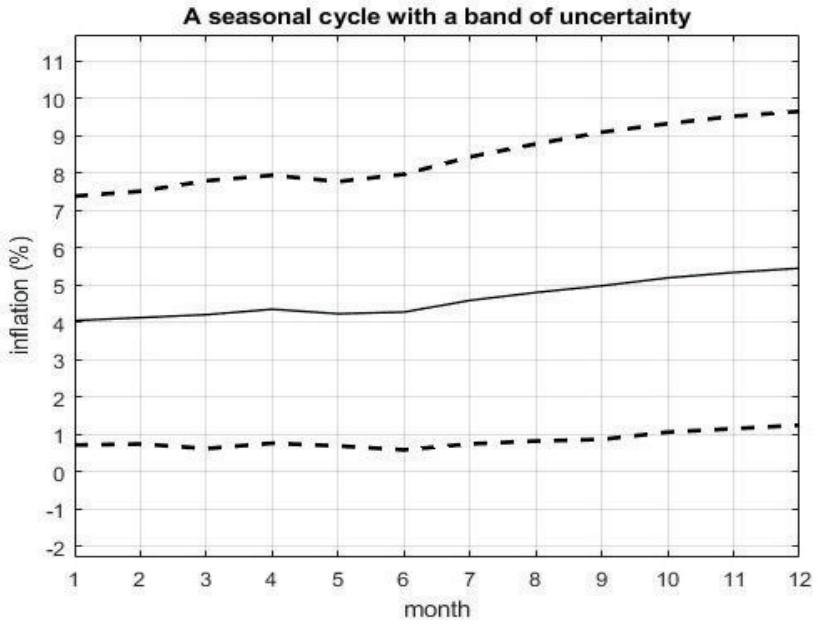
Inflation – Fuzzy Linear Regression Function

Figure 7



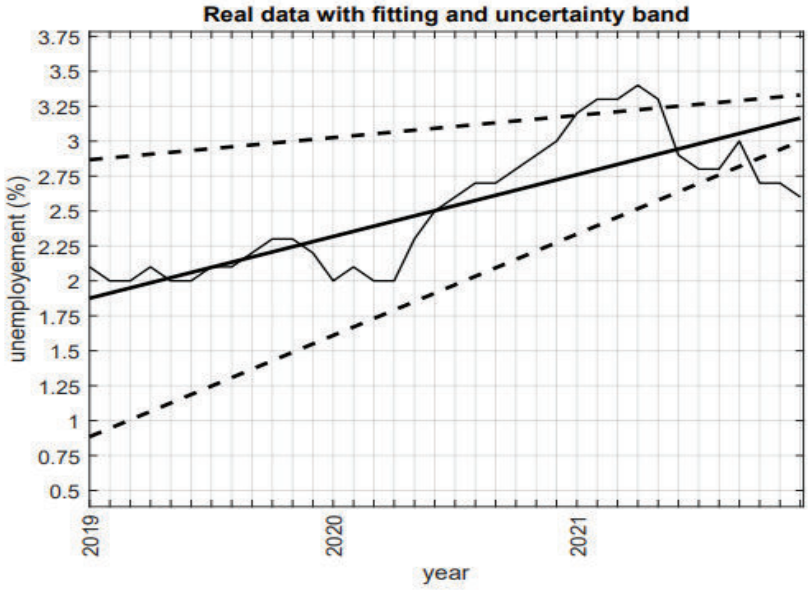
Inflation – Fuzzy Seasonal Cycles Function

Figure 8



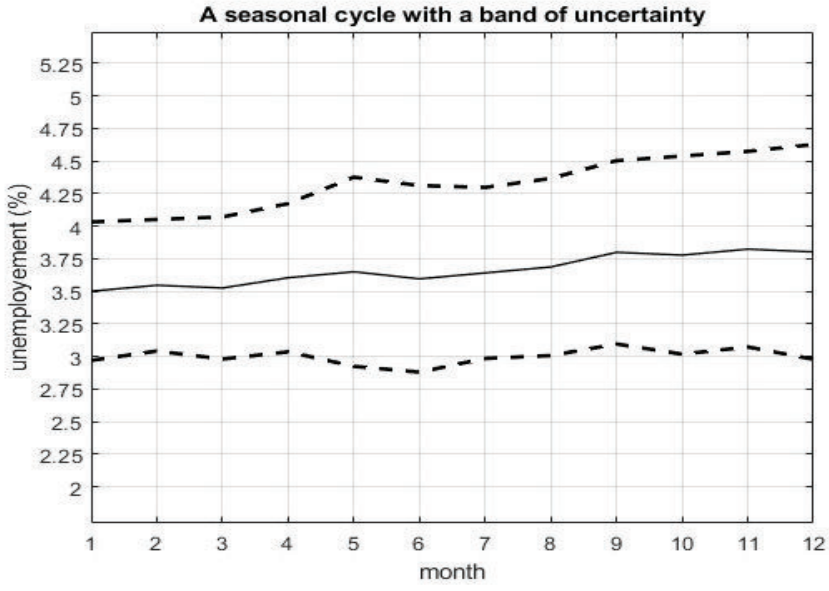
Unemployment – Fuzzy Linear Regression Function

Figure 9



Unemployment – Fuzzy Seasonal Cycles Function

Figure 10



The results of the fuzzy linear regression of the analyzed quantities (DIS, INF and UNE) showed in the monitored period of time series 2019 – 2021 the interrelatedness and dependence of the selected quantities, but in some cases they showed a demonstrable degree of vagueness and fuzziness.

The DIS variable ranged from 0.05 % to 2.75 % in the monitored period, with considerable fluctuations over the three years monitored. Its amount followed the course of crisis caused by pandemy of Covid-19. For approximately half of the observed period - since its beginning - its amount reached 0.75 %. If we start with the assumption that the Covid-19 pandemic started in the spring of 2020, then with a time delay of 1 year, the central bank sharply reduced the discount rate to the so-called technically zero level of 0.05 %. A delay of 1 year corresponds to the cumulative sum of the recognition and decision lags mentioned above. The rate cut was supposed to support economy affected by a sharp drop in demand due to the government‘s administrative measures. In the end of analyzed time series, i.e. in the end of 2021, central bank proceeds to gradually increase the DIS again up to 2.75 %, due to the onset of accelerating inflation, which still persists in the economy. DIS is generally characterized by a significant degree of volatility, which is also evident from the regression results and which accelerates at the end of the monitored time series period. This is clearly evident from the figure showing real data with fitting and uncertainty band. From the point of view of monetary theory, it can be assessed that the behavior of the central bank in times of crisis and in times of rising inflation was standard and corresponded to the mainstream of monetary policy in developed countries.

The INF variable shows a value above the central bank‘s inflation target throughout the monitored period. It was 2 % throughout the monitored period with a tolerance band of ± 1 %, with the ideal and desirable rate of inflation being close to and below the targeted 2 %. In most of the monitored period, however, the inflation rate exceeded the tolerated 3 %, and by the end of the monitored period, it was already very significant. The mandate of the central bank was exceeded twice at the end of 2021, or even three times. The linear regression of the variables demonstrates the interconnectedness of DIS and INF in two respects. Firstly, the data of both variables develop in the same time series trend throughout the monitored period, and secondly, a time delay in the implementation of monetary policy measures was confirmed in this case as well. The regression clearly shows a lag of about half a year in the increase in DIS after INF started to rise. The seasonal monthly cycle with a band of uncertainty clearly illustrates the dependence of the INF variable on the DIS variable and safely demonstrates the time delay of DIS after INF throughout the observed period. Thus, the traditional concept of monetary policy and the

use of interest discount rates as a basic and standard monetary policy tool was confirmed. From the linear regression, it can also be proven that if the INF is relatively unchanged in the long term and is within its inflation target, central bank does not make sudden changes, or even any changes in the field of interest rate policy or monetary policy at all.

Variable UNE - unemployment is calculated by the unemployment rate, what is the number of people who are unemployed as a percentage of total labour force (the total number of people employed added to those unemployed). UNE variable in seasonal cycles with a band of uncertainty graph has an increasing trend, which can be explained by the period of the Covid-19 pandemy crisis, especially since the beginning of 2020. Within the annual cycle, there is a classic, albeit slight, fluctuation of the unemployment rate depending at the time of year. Since unemployment rate is calculated from total amount of labour force, i.e. also seasonal employees in agriculture, construction, transport, etc., the UNE shows a cyclical character despite the crisis period of the time series. On the other hand, cyclicality is not significant, mainly as a result of global warming, a longer business cycle, the introduction of new technologies, etc.

When comparing real year-on-year data with fitting and uncertainty band, it is possible to demonstrate - in the crisis period from 2020 - a clearly interdependent inversely proportional relationship between the variables INF and UNE. The measured data and the result of the linear regression confirm the progress within the so-called Phillip‘s curve during the observed crisis period. The Phillip‘s curve is an empirical relationship between two quantities, namely the inflation rate and the unemployment rate, with these variables having a stable and at the same time inverse relationship. It states that with the growth of the real product over time comes inflation, which in turn leads to the creation of jobs and a decrease in the unemployment rate.

Unemployment rate did not exceed its natural level, which ranges between 4 and 5 %, throughout the monitored period of time series. In the monitored period, the value of UNE was the highest at the beginning of 2021 at 3.4 %. With a defined delay, INF growth did occur, but not above the level that would immediately be the cause of the rising inflation. Therefore, the so-called NAIRU vehicle - Non-Accelerating Inflation Rate of Unemployment - was monitored as a certain level of unemployment that occurs in the economy and that does not cause an increase in the inflation rate. Thus, if unemployment is within the limits of the NAIRU, inflation is unchanged. The NAIRU often represents a balance between the level of output and the stability of the labour market.

The regression curves of the INF and UNE values clearly demonstrate an inverse character. While the UNE rate is highest at the beginning of 2021, the INF value is the lowest at the beginning of this year. The value of INF reached 2.1 % (the lowest) during this period, but the value of UNE reached 3.4 % (the highest) with a delay of 2 months.

Other influences that affect the labor market also play a significant role in the sometimes non-standard course of the UNE regression. This is, for example, the inelasticity of the labor market caused by the inflexibility of wages and also the legal protection of employees given by the Labor Code. Employee unions also play their role, protecting employees as the weaker party in labor and legal relations. Last but not least, it is also necessary to count the free movement of labor force within the EU, which is currently among the basic freedoms of the single market in the EU. Employees from other EU countries come to the national economy, and Czech employees also leave to work abroad. There were approximately 650,000 people in the Czech Republic during the monitored period. foreign workers, which, given the total number of the labor force of 6.8 million, constitutes over 9 %. Geopolitical influences on the labor market are therefore unavoidable.

4. CONCLUSION

Mathematical linear regression is a statistical method used to gain a prescription using which we will be capable to predict the value of one variable from knowledge of the value of another variable on condition, that there is a causal relationship between these two variables. It is a statistical tool for modeling a linear trend for data showing a linear distribution around a defined trend and for which we assume interdependence among dependent and independent variables. Prerequisite for regression and subsequent application of data is that the source data - variables are clearly defined, their collection was reliable, they are conclusive, the time series are long enough, etc. Problems can arise precisely in these cases, when the data is unreliable, ambiguous, vague, comes from from sources that are difficult to compare with each other, time series are insufficient, etc.

To increase the adequacy quality of complex real systems modelling, the new methods of artificial intelligence are used. In the presented paper, we proposed and defined vague data as a source for fuzzy sets, and using principles of fuzzy modelling we created fuzzy linear regression model. We defined uncertainty of data sets and regression models as vague parameters. Using a genetic algorithms, we identified fuzzy data coefficients of fuzzy regression model. The linear approximation of generated vague data was used, which the work presents analytically and graphically.

In the time series from 2019 to 2021, data on the development of the discount rate (DIS), inflation rate (INF) and the rate of unemployment (UNE) were modeled in this way. Fuzzy regression model considered their mutual relationship, cyclicality and seasonality. The results were presented with the assumption of time lags, which occur by default in the transmission mechanism of monetary and fiscal policy.

DIS is an independent variable, it is the monetary vehicle of the central bank, with which the bank determines the price of money, especially short-term credit sources. Its regulatory effect and effectiveness in influencing the rate of INF was observed and proven in all three years of the monitored time series. And that even taking into account the aforementioned delays as well as exogenous and foreign inflationary influences. It has also been observed that as DIS rises, the price of money rises, cooling the economy and slowing the growth rate of real GDP. The fuzzy regression analysis performed in this paper demonstrated the interdependence of these variables in the classical structure of the market economy.

Partial interdependence was also demonstrated in relation between amount of DIS and the rate of unemployment (UNE). Changes in the amount of DIS affected the behavior of households and firms in relation to consumption and investment, which had a consequence in the amount of UNE. The price of resources, i.e. money, affects the real GDP through consumption and investments and thus the UNE, which was proven in all three monitored years. However, the relationship between DIS and UNE was looser, due to the existence of market disturbances in the labor market, market distortions, inflexibility of the labor market, free movement of labor to the Czech labor market, etc. However, the dependence and connection between the amount of INF and the amount of UNE was proven, and inversely proportional. Built on time series analysis from 2019 to 2021, the presented paper confirmed the existence of a long-term Phillip‘s curve in the environment of the Czech economy. State interventions in the economy also played a special role - the level of independence of the central bank and the setting of DIS rate, the system of subsidies and interventions, the inflexibility of the labor market and the protection of employees, i.e. various non-market interventions, which may be one of causes of the entirely standard and fuzzy development of selected measured economic quantities at every moment of the monitored period.

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Trade, Production And Use Of Electrical And Electronic Equipment, In The Context Of The Circular Economy

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ABSTRACT

At the level of the European Union, the implementation of circular economy principles is in early stages, despite the involvement of political decision-makers through the adoption, since 2015, of a set of dedicated policies and different national government strategies. The waste of electrical and electronic equipment (WEEE) recovery activity is of greater importance for countries that apply the principles of the circular economy, being a form of resource saving.

The research focuses on analysing the main drivers of sustaining the circular economy of the electrical and electronic equipment (EEE) sector, pointing out the importance of resources efficient use and waste recovery. Our panel dataset consider the period 2008-2020, for EU-27 countries. The analysis carried out highlights the importance of the EEE sector in implementing the principles of the circular economy by promoting products with medium and high level of technology and saving resources for households.

Keywords: *Circular economy, Sustainable Development, Waste of electrical and electronic equipment*

JEL Classification: *D16, Q01, Q53, O13, O14*

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INTRODUCTION

The concept of „circular economy" represents one of the main points of interest for decision-makers at the international level, representing a way by which the objectives of sustainable development related to the reduction of the massive consumption of natural resources can be achieved, but through which economic benefits can be obtained by companies (Lieder and Rashid, 2016; Kirchherr et al., 2018; Rizos V., Bryhn J, 2022).

Global economic development is closely related to the consumption of electrical and electronic equipment (EEE) that have become an essential aspect of our everyday life. A large part of the world's population now enjoys high standards of living based on the availability and widespread use of these equipment.

Although the advantages for users are major, the ways of manufacturing, of using and recycling e-waste are contrary to the principles of sustainable development. Due to the reduced logistical facilities for the collection and recycling of waste of electrical and electronic equipment (WEEE), the impact on the environment is worrying through the consumption of resources, the toxic substances released during the recycling procedures, the emissions of greenhouse gases (Juchneski, 2022).

1. REVIEW OF THE SCIENTIFIC LITERATURE

At the level of the European Union, the implementation of circular economy principles is in early stages, despite the involvement of political decision-makers through the adoption, since 2015, of a set of dedicated policies and different national government strategies (Salvatori et al., 2019).

The phenomenon of urbanisation and the increasing mobility of the population, higher levels of income but also the continuous process of industrialization, led to an increase in the amount of electrical and electronic equipment in the global economy. On average, the total weight of global electrical equipment consumption (excluding photovoltaic panels) increases by 2.5 million metric tons annually (Forti et al., 2020). An inadequate management of electronic waste affects both the environment and human health (Juchneski, N.; Antunes, A. 2022).

In order to improve the performance of electrical and electronic products, the profile industry is growing, the products put on the market being modified and improved (Mori de Oliveira et al., 2022). The COVID19 pandemic has further affected the sales of these products, as many people have

been working or learning from their personal homes. In addition, users are mainly interested in devices that incorporate the latest technology, which are more expensive but provide an improved user experience (Schumacher et al., 2019; Scarsella, 2022).

At EU level the growth of the WEEE (also known as e-waste) is very fast, with current annual growth rates of 2%. According to the EU's Circular Economy Plan, it is estimated that around 40% of e-waste is recycled within the EU (EC, 2021a). The EU Circular Economy Action Plan envisages the promotion and launch of initiatives applied to the entire product life cycle, from production to consumption, repair and processing, waste and raw material management.

The increase in demand for electrical and electronic equipment is accompanied by problems such as the amount of energy used for production but also for their use, water consumption and the production of toxic waste water from the stage of exploitation by the user or the use of finished materials in the EEE composition. For the European Union, most of these materials have a critical degree of availability, such as precious metals or rare metals (Reuter et al., 2013; Weetman et al., 2016)

Electrical and electronic equipment is made of many components, which can be manufactured in different countries, exported to another country to be processed or assembled, and then delivered to customers around the world. The pattern of international trade transactions thus becomes very complex as the demand increases. The largest producers and exporters of electrical and electronic equipment are China, US, South Korea, Taiwan, Japan and Germany (ITC, 2021a), while US, Japan, China and Germany were the main consumer markets in 2021 (ITC, 2021b).

The European Union treaties analyzeraw materials with maximum priority, with a special monitoring system in place. The EU updates its list of critical raw materials every three years, based on demand, supply and shortage estimates for materials considered critical (EC, 2021b). The 2020 EU list of critical raw materials contains 30 materials, compared to 14 materials in 2011, 20 materials in 2014 and 27 materials in 2017. Supply of critical raw materials is concentrated in countries such as China, which supplies 98% of rare metals, Turkey covering 98% of the EU's borate needs, South Africa providing 71% of the EU's platinum needs. (EC, 2021b).

The main problem raised by the use of electrical and electronic equipment is the short time of use, as they are not designed and manufactured to serve the users in the long term. Thus, electrical and electronic equipment available at a given time on the market are obsolete faster and the possibilities of repair are reduced (Mori de Oliveira et al., 2022; Bachér et al., 2020)

From a user perspective, based on European Commission studies, two out of three Europeans would like to use their digital devices for longer, provided that performance is not significantly affected (Special Euro Barometer, 2020). To address these challenges, as part of the European Green Deal, the European Commission presented in March 2020 a new circular economy action plan (EC, 2021c-f), which addresses shortcomings in terms of product durability, the presence of hazardous substances and harmful, recycled content, repairability, access to spare parts, e-waste reduction, collection, reuse and recycling. In the resolution of February 10, 2021 on the New Circular Economy Action Plan, the European Parliament supported the European Commission's Initiative and additionally requested the integration of aspects related to the early obsolescence of products caused by software changes as well as the harmonisation and improvement of the waste recycling infrastructure electrical and electronic equipment in the EU to guarantee efficient material recovery and environmental protection.

At EU level, the share of EEE production in the whole manufacturing industry was 3.1% in 2019 (the last year for which detailed data is available at Eurostat). In Romania, the EEE production counted for 2.6%, with 0.2 pp greater than previous year. This explains the concerns raised at national level about the WEEE treatment and recovery.

WEEE, if not treated properly, is harmful to the environment, as it often containscomplex combinations of highly toxic substances. Burning untreated WEEE can release hazardous chemicals, such as dioxins (Perkins et al, 2014). The use of certain metals in such equipment, such as lead and mercury, has been restricted in the EU since 2003, but those may still be present in older products (Directive 2011/65/EU).

Proper treatment of e-waste can yield significant economic benefits and reducedemand for raw materials. For instance, 1 tonne of smartphones contains about 100 times more gold than 1 tonne of gold ore (World Economic Forum, 2019). E-waste may also contain other important metals such as copper, nickel, indium or palladium (Intosai, 2016). Recycling e-waste also contributes to climate change mitigation, given that it avoids emissions of greenhouse gases resulting from the production of new materials, in particular metals (Golsteijn et al, 2017).

The WEEE Directive establishes a range of collection targets for WEEE, first phase from 2006 at least 4 kg/per inhabitant per year collected from private households, second phase from 2016 electronic equipment placed on the market in the 3 preceding years in the member state for 10 states and the third phase 65% of average weight of electrical and electronic equipment placed on the market in the 3 preceding years in the member state

or 85% of WEEE generatedon the territory of the Member States and also sets several recovery targets with minimum targets for preparing for reuse and for recycling. Recovery relates to recycling and extraction of metals and metal compounds, as well as incineration to generate energy (Directive 2008/98/EC).

The EU finances research and capacity building in the area of e-waste, having provided close to €100 million through Horizon 2020 (CORDIS European Commission, 2022), and over €8 million through the LIFE Programme (Life Public Database European Commission, 2021). The EU budget also provides some funding for general waste infrastructure through the Cohesion Fund and the European Regional Development Fund, but the data published by the Commission do not make it possible to determine whether a share of this funding goes towards infrastructure that is relevant to e-waste (Cohesion open data platform 2014-2020, 2022).

Global statistics on e-waste show higher rates of e-waste collection and treatment in the EU than in most parts of the world. Data from the Global E-Waste Statistics Partnership identify Europe (including both EU and non-EU countries) as the continent with the highest generation of e-waste per capita, but also as the part of the world with the highest WEEE collection and recycling rates. Europe generates a per capita amount of e-waste comparable to the Americas and Oceania, but has a collection and recycling rate that is over four times (European Court of Auditors, 2021).

EU Member States tend to outperform most non-EU countries in the collection of e-waste, including developed countries such as the United States and Japan.

2. RESEARCH METHODOLOGY

The research focuses on analysing the main drivers of sustaining the circular economy of the electrical and electronic equipment (EEE) sector. Our panel dataset contains data for the period 2008-2020, for all the EU-27 countries, except Croatia. We have excluded Croatia because its information for almost all the indicators was unavailable for the given period.

The following data sources were used:

- Eurostat database, for the following indicators: *GDP per capita, Import/Export waste of EEE, Import/Export of EEE, Waste of EEE (WEEE) collected from households, WEEE treatment, WEEE Recovery, Products (EEE) put on market, Consumption of EEE in households,*

- Online database for the Sustainable Development Report 2022, for Sustainable Development Indices (*Spillover Index, General Index*).

- The interactive database of the Global Innovation Index 2021, for *Research and Development Index.*

According to the data sources mentioned above, the indicators used for the purpose of this paper have the following content:

GDP per capita is calculated as the ratio of GDP to the average population in a specific year. (Eurostat, 2022).

Data on Waste electrical and electronic equipment (WEEE) is collected on the basis of Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE). The purpose of the collected data is to monitor compliance of countries with the quantitative targets for collection, preparing for re-use and recycling, and recovery of WEEE that are set out in Article 7 (collection rate) and Article 11 and Annex V (recovery targets). This decision is applicable on the following categories: EEE put on the market, WEEE generated, WEEE collected (from private households; from users other than private households; total), WEEE collection rate, WEEE preparing for re-use, WEEE recycling, WEEE preparing for re-use and recycling, WEEE recovery, WEEE treated.

GDP per capita, WEEE collected from households, WEEE treatment, WEEE Recovery, EEE put on market, Consumption of EEE in households, selected for NACE Rev2 codes: 2620 - Manufacture of computers and peripheral equipment, 2630 - Manufacture of communication equipment, 2640 - Manufacture of consumer electronics, 2740 - Manufacture of electric lighting equipment, 2751 - Manufacture of electric domestic appliances, 2823 - Manufacture of office machinery and equipment (except computers and peripheral equipment). These codes correspond to EEE for private households classified in Annex III and Annex IV in Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE).

Import/Export WEEE, identified using the Combined Nomenclature code 8548 "Waste and scrap of primary cells, primary batteries and electric accumulators; spent primary cells, spent primary batteries and spent electric accumulators; electrical parts of machinery or apparatus, not specified or included elsewhere chapter 85"

Import/Export of EEE, identified using the Combined Nomenclature code 85 "Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles" except CN code 8548 "Waste and scrap of primary cells, primary batteries and electric accumulators; spent primary cells, spent primary batteries and spent electric accumulators; electrical parts of machinery or apparatus, not specified or included elsewhere chapter 85"

In a highly interdependent world, countries' actions can have positive or negative effects on other countries' ability to achieve the Sustainable Development Goals (SDGs). *The Spillover Index* assesses such spillovers along three dimensions: environmental & social impacts embodied into trade, economy & finance, and security. A higher score means that a country causes more positive and fewer negative spillover effects. Environmental and social impacts embodied into trade (Sustainable Development Solutions Network, 2022).

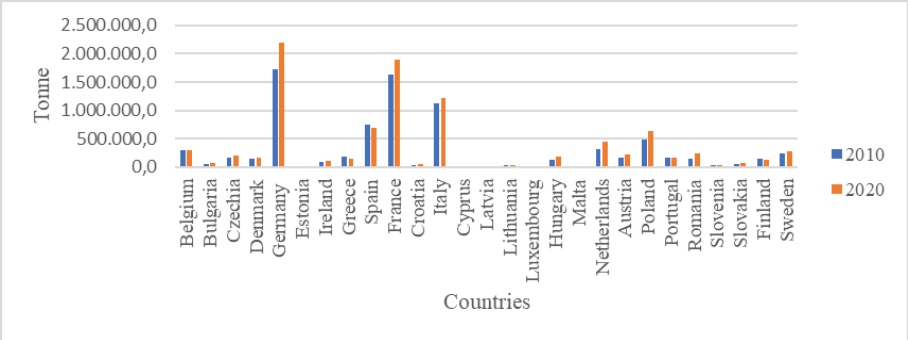
At the EU level, the Import of Waste recorded higher values in 2020 compared to 2010 in Germany, Netherlands, Poland, Belgium, Hungary, France and constant values in Latvia, Lithuania, Malta, Luxembourg, Cyprus, Greece and Croatia.

Waste Export values are directly proportional to waste import values, with Germany, the Netherlands, France, Belgium and Poland seeing increases in waste export values in 2020 compared to 2010.

The values of Import and Export of Waste are in an interdependent relationship with the products put on the market, so Germany, France, Italy, Spain, Poland, the Netherlands recorded increases in the products put on the market in 2020 compared to 2010.

Products put on the market in EU

Figure 1



Source: Authors own processing based on Eurostat Database

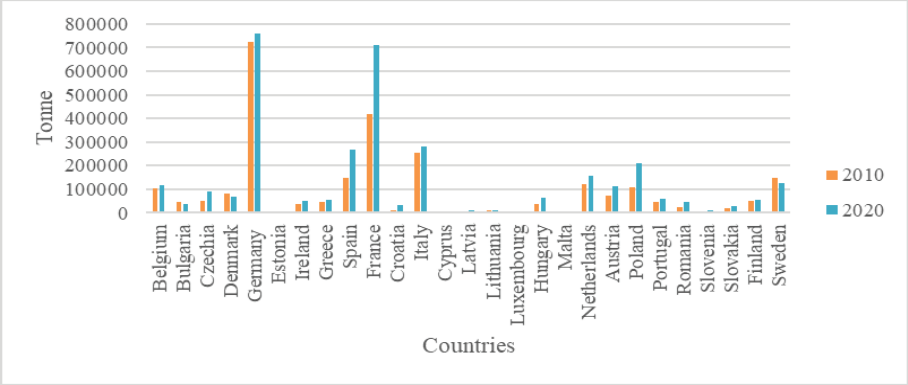
The trend regarding the consumption of EE in households has remained constant in the period 2010-2020, the countries that have registered gradual increases in the analyzed period are: Bulgaria, Romania, Croatia, Lithuania and Greece.

EE waste collected from households saw slight increases in 2020 compared to 2010 in Germany, Italy and Poland, and a significant increase in

France, which is due to a national program through which citizens receive a sum of money to repair their electronics and household appliances, a unique program in Europe aimed at extending the life of equipment and reducing waste (Gouvernement du France, 2022).

Waste of EE collected from households in EU

Figure 2



Source: Authors own processing based on Eurostat Database

Waste treatment (the activities required to ensure that waste has the least possible impact on the environment and in many countries various forms of waste treatment are required by law) has seen a significant increase as a result of government measures in France (see the Figure 2) and a decrease in these measures in Italy and Denmark.

Research Development Index recorded increases in 2020 compared to 2010 in Germany, Netherlands, Italy, Ireland, Hungary, Greece and recorded decreases in Finland, Estonia, Czech Republic, Romania, Croatia.

At the EU level the Spillover Index and General Index registered increases in all EU Member States in 2020 compared to 2010.

Effective waste management in many EU states is due to the application of EU legislation in the community space, the purpose of European waste legislation is to encourage waste prevention, to specify requirements on the reuse and recycling rate for certain waste streams, to minimize disposal in landfills compliant and eliminate disposal in non-compliant landfills. The benefits of the Circular Economy Action Plan, one of the main components of the European Green Deal, cannot be fully exploited as long as illegal dumping practices persist in another countries.

In order to analyse the level of correlation between the previously defined indicators, we have constructed the following research hypotheses:

H1. The economic development of the EEE sector is a factor that drives products' competitiveness.

H2. Is the level of economic development of the countries a cause or an effect for a circular economy defined by export and import?

H3. The import of EEE waste is correlated with the products put on market, collected, treated and recovered.

H4. The level for accessing the sustainable development goals is correlated with the level of R&D sector and EEE products put on the market. At a first stage, we have computed the correlation matrix, using the Person product--moment method, implemented in R.

We have used panel regression models and the software used for all the analysis is R (R Core Team, 2021). In table no. 1 the dependent and independent variables used in the econometric models were listed.

Variables used in the analysis

Table no. 1

Dependent variables	Independent variables
1. Spillover Index 2. General Index 3. GDP per capita in current prices (euro) 4. Import waste of EE	1. Import waste of EE
	2. Export waste of EE
	3. Products put on the market (tonne)
	4. Consumption of EE in households
	5. Waste of EE collected from households (tonne)
	6. Waste treatment
	7. Waste recovery (tonne)
	8. Research.Development.Index

Source: Authors' selection from databases of Eurostat, SDG Index.org, Global Innovation Index

3. Short overview of electric and electronic equipment sector in European UnionThe EEE sector is naturally integrating in the principles of sustainable development and could be defined by it. Developing and implementing effective and ambitious environmental and climate strategies and policies aimed at achieving net-zero greenhouse gas emissions by 2050 and commensurate medium-term targets in line with this pathway. Achieving these objectives requires the implementation of transparent, objective-based policies to ensure the long-term conservation of biodiversity and its sustainable use.

Waste management is included in the list of fundamental principles of accession for the OECD committees, of the candidate countries, among which

are also three member countries of the European Union, respectively Bulgaria, Croatia and Romania (Council at Ministerial Level OECD, June 2022).

The OECD principles with respect to sustainable management of resources, implementing integrated life-cycle-oriented approaches to waste and materials (including plastics) management and establishing framework conditions for a more resource-efficient and circular economy. Ensuring that generation of waste, including hazardous waste, is reduced, export of waste for final disposal is minimised, and that waste is managed in an environmentally sound manner. Controlling exports and imports of hazardous waste while allowing trade in waste as end-of-life materials and products destined for economically efficient and environmentally sound recovery operations within the OECD area.

The European average was made for general index, spillover index, products put on market, waste collected, waste treatment and recovery.

The correlation analysis revealed significant relationships between most of the factors, except consumption (table no. 2). Consequently, they were successively introduced in the models.

Correlation matrix

Table no. 2

Variable	Import waste of EEE	Export waste of EEE	Products put on the market	Consumption of EEE in households	Waste of EEE collected from households	Waste treatment	Recovery
Import waste of EEE	1						
Export waste of EEE	0.840494	1					
Products put on the market	0.746248	0.786959	1				
Consumption of EEE in households	0.012771	-0.016505	-0.057122	1			
Waste of EEE collected from households	0.776765	0.811679	0.963293	-0.044954	1		
Waste treatment	0.729430	0.743071	0.945551	-0.076383	0.941663	1	
Recovery	0.782863	0.795416	0.963819	-0.064516	0.976531	0.985726	1
Research. Development. Index	0.402573	0.473240	0.421908	-0.352802	0.486145	0.434084	0.463825

Source: Authors' calculation performed in R

The equations corresponding to the models are the following:

Model 1:

Spillover.Index ~ Import.Waste.euro + Export.Waste.euro + Products.put.on.the.market.tonne + Consumption.of.electric.equipment.in.household (1)

Model 2:

GDP.per.capita.current.prices.euro ~ Import.Waste.euro + Export.Waste.euro + Products.put.on.the.market.tonne + Consumption.of.electric.equipment.in.household (2)

Model 3:

Import.Waste.euro ~ Products.put.on.the.market.tonne + Waste.collected.from.households.tonne+ Waste.treatment.tonne + Recovery.tonne (3)

Model 4a:

General.Index ~ Products.put.on.the.market.tonne + Research.Development.Index (4)

Model 4b:

Spillover.Index ~ Products.put.on.the.market.tonne + Research.Development.Index (5)

3. RESULTS AND INTERPRETATION

The econometric model used for testing the hypotheses is a panel regression (table no.3). In all five models the country has been considered as factor.

Panel regression results

Table no. 3

Models	Model 1		Model 2		Model 3		Model 4a		Model 4b	
Independent Variables	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)	Estimate	Pr(>|t|)
Import waste of EE	8.893e-09	0.135	2.235e-05	0.0101 *						
Export waste of EE	-6.084e-09	0.377	3.940e-06	0.6942						
Products put on the market	4.674e-06	0.075 .	4.603e-03	0.2276	2.755e+02	< 2e-16 ***	4.393e-06	8.72e-06 ***	7.089e-06	0.00107 **
Consumption of EE in households	-9.611e-01	2.76e-07 ***	-1.357e+03	5.93e-07 ***						
Waste of EE collected from households					-7.348e+01	0.411310				
Waste treatment					6.575e+01	0.379775				
Recovery					6.133e+01	0.679531				
Research. Development. Index							4.450e-02	0.0129 *	7.590e-02	0.05439 .

*Notes: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Source: Authors' calculation performed in R

The first hypothesis is confirmed by model 1. The Spillover Index is highly correlated with the consumption of electric equipment in households for all the member states. The economic development of the EEE sector is a factor that drives to products' competitiveness, as these products are included in the category of medium and high-tech technological intensity. The negative coefficient of the export shows clearly the lack of reusing waste: a country is exporting waste and does not use it for production. Reusing EEE waste could be associated as a valuable asset because it ensures production from the reuse of waste and consequently it saves resources.

Compared to the first hypothesis, the second one reveals that in an analysis specific to an economic sector of a national economy, it is better to use as a dependent variable complex indices such as Spillover Index, instead of the classical GDP per capita. The share of the EEE sector in the economy is relatively small, therefore it is more important to analyse the correlation

not by the effect on the economic development, but by specific and complex indicators. In conclusion, model 1 is more relevant than model 2.

According to the third model, the import of EEE waste is in correlation with the products put on market for: Austria (-2.576e+07), Denmark (-3.852e+07), Finland (-2.903e+07), France (-4.146e+08), Germany (-2.264e+08), Greece (-4.105e+07), Hungary (3.783e+07), Ireland (-2.205e+07), Italy (-2.629e+08), Netherlands (2.384e+07), Poland (-8.814e+07), Portugal (-2.503e+07), Romania (-3.318e+07), Slovenia (1.639e+07), Spain(-1.234e+08), Sweden (-3.311e+07). The import of EEE leads to increasing production of EEE in countries in which there is a policy of valuing through recovery the products resulted from waste processing. Depending on some parameters such as share of the sector in economy, technological level and household consumption, every country has differentiated policies regarding the EEE waste. If households are reusing EEE, the policy addressed to waste is different. If the households are wasting the EEE, the policies will focus on recovering.

Last two models, 4a and 4b, are testing whether the level of complying with sustainable development goals is related with the level of R&D development and with the products put on market. Because of the regionalization, the business environment ensures a convergence of economic restructuring and technological progress. Therefore we will consider two country groups, ie “old” and “new” EU member states (ie before and after 2004). For the old member states (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, Spain and Sweden), the correlation is higher between general Index and products put on the market and R&D Index, with coefficients between 6.902e+01 (for France) and 8.193e+01 (for Finland). The correlation with the Spillover Index is lower, with coefficients between 2.034e+01 (for Germany) and 3.575e+01 (for Luxembourg). Nevertheless, the significance is maximum for all the member states in both models 4a and 4b. However the influence of R&D Index and products put on market are higher on the General Index compared with Spillover Index.

CONCLUSIONS

The analysis carried out revealed the importance of the EEE sector for the national economy, taking into account the opportunities for development of economic activity and job creation in a sector characterised by medium and high level of technology. The WEEE recovery activity is of greater importance for countries that apply the principles of the circular economy, being a form of

resource saving. From this perspective, at the level of EU member states there are different political approaches. Countries with poor performance in WEEE recovery need to adjust their policies by adopting international good practices and adapting to their own economies as well as by developing/educating consumption behaviour (both private industrial and household users). By these means, the consumption of equipment/products at higher technological levels is stimulated; in the same time it is ensured the appropriate use of equipment in the context of an increased assortment diversity in private households.

A worrying aspect is lack of proper recycling and reuse facilities for EEE waste. Some countries prefer to export EEE waste produced in their own economy to other countries instead of sustaining the development of a specific infrastructure for reintegration of recovered materials into the production process. For EEE waste-importing countries, these products can be transformed into valuable assets by increasing the production of goods obtained by reusing the waste and, consequently, achieving savings in basic resources.

The import of WEEE leads to an increase in the production of EEE in countries where there is a policy of valorization of products resulting from waste processing. The waste recovery is closely related to the trade balance (export-import of WEEE) as well as to the behaviour (responsible or not) of consumers. If private households choose to repair for reuse of EEE instead of purchasing new equipment, the policy in the field will focus on increasing the products life by offering specialised repair services and ensuring maintenance. Otherwise, if households adopt a behaviour characterised by EEE waste, the recovery policy will be stronger and facilities might be created to process and relaunch the materials recovered from WEEE into production process.

In order to be in line with circular economy principles, countries can adopt development policies by changing the consumption behaviour of users. There is a mutual influence between the behaviour of companies, on the one hand, oriented towards increasing the assortment, technological level and economic efficiency under comparable conditions of use values, and the behaviour of household users, on the other hand, which is influenced by the companies' offer. When the final customer is no longer satisfied with the offer of companies on the national market, he will turn to imported goods. Therefore, the phenomenon of selectivity in purchases takes place simultaneously with assortment diversification based on complementarity and efficiency in the use of EEE. The adoption of the principles of the circular economy may be delayed as the consumption behaviour, mainly of household consumers, is more difficult to change over time.

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Improving local public administration responsiveness to citizens' needs using Quality Function Deployment

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ABSTRACT

Total quality management is one of the most spread management approaches focused on improving products, services and processes with the aim of achieving a higher organizational competitiveness. This paper emphasizes the key role of the planification process, seen the first and most important phase in achieving quality services, which significantly influences all the following phases of the quality management process. The paper analyses the way local public administration should respond to citizens needs in order to improve its responsiveness, according to internationally consecrated good governance tools. We explain what is the Total Quality Management (TQM) framework, firstly developed within the private sector, and afterwards analyse the needs expressed by the citizens of Roșiori de Vede using a questionnaire and statistical analysis in order to design local administrative services that correspond with citizens' needs and expectation. We argue on the potential of the QFD matrix, as planning tool which might help public organizations focus less on the internal environment and more on the external environment, by understanding better customers needs and designing public services accordingly.

Keywords*: quality management, local public administration, quality planning, public services, citizens' needs and expectations, Quality Deployment Function (QFD)*

INTRODUCTION

Public administration provides social justice, influences the quality of citizens' life and is recognized as a major factor in the development and economic growth of a country. Global competitiveness and the pressing demands of citizens and businesses force public organizations to redesign

their operational functions and improve the services they provide. Thus, in recent years, practices in the private sector of production and services have been replicated in the public sector, in developed countries.

These practices relate to customer-oriented approaches, quality measurement, pay-for-performance, continuous process creation and information quality. All these practices fall under the standard of the total quality management (TQM) philosophy, which aims to develop operational processes to increase citizen satisfaction.

The aim of the research to explore the potential of the quality planning process within the municipality of Roșiori de Vede using Quality Function Deployment instrument, in order to improve quality management within the institution and therefore to increase citizens' satisfaction.

The paper is structured into four sections. First we present theoretical aspects related to total quality management in the public sector, showcasing the crucial importance of the quality planning phase within the total quality management. Then we focus on the methodology, detailing the Quality Function Deployment stages and instruments. A case study of the Roșiori de Vede municipality is later on presented, revealing the results of the QFD matrix, as tool meant to bring together the "voice of the client" and the "voice of the organization".

THEORETICAL ASPECTS REGARDING QUALITY PLANNING IN THE PUBLIC SECTOR

Total Quality Management (TQM) is an integrated management philosophy and set of practices that emphasize, among other things, continuity, meeting customer requirements, reducing repairs, long-term thinking, increased employee involvement and teamwork, processes redesign, competitive benchmarking, team-based problem solving, constant measurement of results and closer relationships with suppliers (Powell, 1995).

At global level, public sector faces the reality of operating with scarce resources, but with increasing demands for accountability for the use of citizens' funds (Pollit, 2010, Profiroiu and Negoiță, 2022). From the early 1980s, there were calls for public sector reform, later called "new public management" (NPM). These reforms were and still are motivated by efforts to make government less wasteful, more efficient, and more responsive to citizens' needs and expectations. However, the actual transformation of the public sector and its projects from a closed system bureaucratic orientation to a more open system orientation has not been without challenges that are mainly concerned with the reduction of bureaucracy. Indeed, success in

government reform has been achieved by those departments and agencies that have been able to adapt to a more open operational approach fuelled by a business-oriented perspective rather than a bureaucratic philosophy.

An important element of quality management is the planning process (Juran and Gryna, 1993), because planning efforts (e.g., process design and analysis, capacity analysis and equipment selection, market research, product features and options, planned staffing levels, and training) are often related to the introduction of new products and services. Moreover, following Juran's trilogy for quality management (Plan, Check and Improve), planning is the key process, that sets the objectives and acts as a map for the following ones.

According to Huang and Dastmalchian (2006), customer orientation can increase customer satisfaction and loyalty while enhancing profitability and competitiveness. These attributes led to the adoption of the customer orientation principle, as fundamental principle of the TQM philosophy, by the public sector, as public bodies began to increasingly recognize the need to satisfy citizens explicit and implicit requests. However, most times the goal of integrating citizens' reality into the reality of public sector organizations is difficult to pursuit. In such instances, a useful tool to reflect the clients' world in organizations' logic is QFD function (Dobrin, 2005).

QFD is a product or service quality planning tool that essentially consists of a series of interlinked matrices that identify and translate customer requirements/desires into technical specifications for product/service design and production. Japanese professor Yoji Akao (1990), the creator of QFD defined it as a method for transforming customers' qualitative requirements into quantitative parameters to carry out the functions that form quality and to carry out methods for achieving quality in design in subsystems and component parts and finally in specific elements of the manufacturing process. Akao considers QFD is best suited for assuring quality in design while the product is still in the design stage.

Quality Function Deployment has been widely used in various sectors to translate customer requirements into technical features. QFD provides a robust framework to consider customer expectations together with production capabilities in a quantitative way so that the target specifications of a particular product or service are in line with customer expectations (Liden and Edvardsson, 2003). In addition, QFD is a quality system that ensures customer satisfaction within the scope of total quality management (Zultner, 1993). Basically, the implementation of the quality function aims at better products, using fewer resources. Also, with the help of this method, the number of complaints arising from technical changes, design process, start-up and product costs are reduced on a large scale. More often than not, organisations

tend to focus internally and therefore develop services or goods with a vague understanding of citizens' needs or too focused on the external environment, constantly trying to please customers at the expense of their own business (Bouchereau and Rowlands, 2000, p. 9).

The main advantage of QFD is its structural implementation. QFD is based on the philosophy of total quality management, it supports quality improvement, but unlike most theories about quality management, QFD uses tools, graphs and statistics to quantify quality (Ikiz and Masoudi, 2008). The main feature of the QFD approach to quality improvement is the "House of Quality (HOQ)". It is the basis of all QFD processes and incorporates a large amount of data from various sources such as surveys, interviews and customer complaints. It is a matrix that identifies the 'what', the 'how', the relationships between them and the criteria for deciding which of the 'how' will provide the greatest customer satisfaction (Chahal and Thareja, 2012).

METHODOLOGICAL FRAMEWORK

The aim of this research is to improve the quality planning process in local public administration institutions, in order to improve quality management in the public sector and implicitly increase citizens' satisfaction. In correlation with this goal, a series of research objectives were defined: (1) using the QFD function to identify and prioritize the requirements of the citizens; (2) Determine the level of interdependence and correlation between citizens' requirements and the services offered; (3) Identify the main aspects that determine the degree of satisfaction and dissatisfaction of citizens; (4) Identify ways to improve the planning process.

A small-scale analysis was performed, using Roșiori de Vede Municipality as a pilot case study. According to the latest national census, in Roșiorii de Vede there are 24.222 inhabitants living in 5479 buildings (Recensământ, 2022). The choice for a small town from a rather underdeveloped county of Southern Romania was based on the fact that the capacity of local authorities to implement quality management is limited and therefor the potential of TQM tools becomes significant in such contexts.

The Quality Function Deployment (QFD), which is a particular TQM planning tool was used to collect and analyse data. According to QFD methodology, the first step is to identify citizens' opinion regarding the services offered by the public institution, and thus, to complete the first "room" of the QFD matrix, the one in which the VOC (Voice of Citizens) is presented. The main source of primary data was the citizens' feedback, obtained through a questionnaire distributed to the citizens both face to face and online, through

social media platforms, on several online groups, whose members are the citizens of Roșiori de Vede municipality.

Technical requirements (HOWs) were defined and developed for the second step. The vital question is "how" could the public institution provide the necessary services to the citizens. In the QFD process, the customer requirements in the "HOQ" were translated into measurable or quantifiable features. Interviewing and talking to employees was the way to get opinions about the technical requirements.

Completing the relational matrix, between citizen requirements (WHATs) and technical requirements (HOWs), was the next step in completing the QFD matrix. The function of this step is to rank the technical requirements according to the degree of relation they have in meeting the citizens' demands.

Step four consisted of completing the "roof" of the diagram, the correlation matrix, which was intended to indicate how each technical requirement relates to the other.

To complete the "Importance" room the scores given by the citizens were used and were obtained by calculating the arithmetic average of the marks given by the citizens for each mentioned characteristic.

In the "Service Evaluation" room, the scores obtained by applying the third section of the questionnaire were entered and they show the differences between citizens' requirements and their perception of the services that were actually provided.

The room on "Planned Quality" was completed with the importance scores that the public institution can give, in the future, to the services provided to satisfy the demands expressed by citizens.

The "Growth Factor" is the room where the ratio of each of the "Planned Quality" and "Service Evaluation" room scores was calculated

The next step in completing the matrix was to determine the "Absolute Importance (1)", which was calculated as the sum of all the products between the score value in the relational matrix (9, 3 or 1) and the importance score given by the citizens for each individual requirement.

Another step followed was the calculation of the "Relative Importance 1" room, which was calculated as a percentage, by the ratio between the Absolute Importance for each individual requirement and the sum of all Absolute Importance, multiplied by 100.

The next chamber is "Absolute Importance (2)", calculated in the same way as "Absolute Importance (1)", except that the relational matrix has been multiplied this time by the scores from the "Planned Quality" chamber.

And, to calculate "Relative Importance 2", the same procedure was followed for the calculation of "Relative Importance 1", but with the scores from "Absolute Importance (2)".

The last step was to identify the most important requirements, according to the value of the results, which are relevant for increasing the quality of the services offered and to indicate where the allocation of many resources is needed.

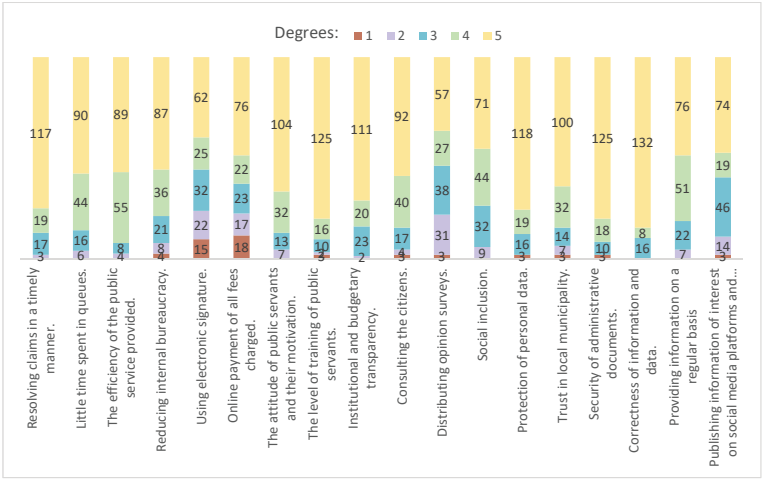
CASE STUDY DESCRIPTION

Roșiori de Vede municipality is organised in 17 departments, services and main offices, each one has subordinate offices and departments. In terms of human resources, 327 positions are occupied in the institution, of which 131 are public positions, divided as follows: 117 junior civil servants, 14 senior civil servants and 194 are contractual positions, divided as follows: 189 contractual positions and 5 contract management positions. The average age of human resources is 45 years, there are 56% women and 44% men.

The results of the second section of the applied questionnaire, the one formulated to determine the degree of importance that citizens attach to the services that the public institution offers, are represented in the form of a graph, showing both the marks and the number of citizens who granted them.

Citizens' expectations regarding Roșiori de Vede municipality administrative services

Figure 1



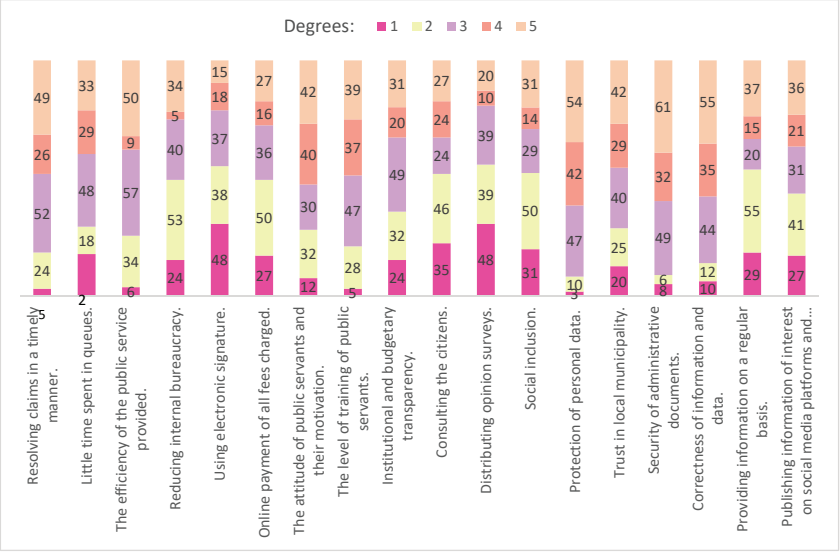
Source: Survey results, 2022

Citizens' expectations are high, with the most degrees awarded being 4 and 5. The most important aspect, in the opinion of the responding citizens, was "Correctness of information and data", the arithmetic mean being 4.74, which shows that citizens want to receive correct information from the public institution. At the opposite pole, "Distributing opinion surveys" scored the lowest at 3.62, indicating that the responding citizens do not attach much importance to surveys.

Regarding the third part of the questionnaire, the one intended to determine the actual experience of citizens with the services offered by the public institution, the results are presented in the graph below.

Citizens' perception regarding Roșiori de Vede municipality administrative services Source: survey results, 2022

Figure 2



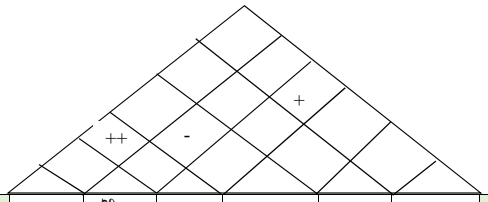
The actual experience of the citizens is below the average of the expectations expressed in the first part of the questionnaire, the most grades awarded being 2 and 3. In the perception of the responding citizens, "Protection of personal data" is the consideration with the highest score, 3, 85, indicating that the vast majority of citizens believe that the institution fulfils its mission in terms of personal data and its protection. In terms of low scores, "Using electronic signature" is the least rated by citizens, with an average score of 2.44. Then, "Distributing opinion surveys" is the next poorly rated consideration with an average of 2.45.

As it was presented both in the literature review part and in the methodology, after identifying the citizens' voice and completing the respective room, it is necessary to detail the technical requirements, those that the institution in question can implement to satisfy the citizens' requirements, that can answer the question "How can Roșiori de Vede municipality offer the services that citizens want?". Thus, the following six ways of improving services were stated, as follows: "Reducing the number of procedures", "Efficient management of existing resources", "Technological progress", "Courses of training and specialization of public servants", "Opening to feedback", "Constant data update".

Figure 3 shows the QFD matrix in detail, with all the rooms filled, the correlations established and the results of the formulas applied.

QFD Matrix

Figure 3



Technical Requirements / Voice of Citizens	Reducing the number of procedures.	Efficient management of existing resources.	Technological progress.	Courses of training and specialization of public servants.	Opening to feedback.	Constant data update.	Importance	Service Evaluation	Planned Quality	Growth Factor
Resolving claims in a timely manner.	◉	○	△	-	△	-	5	4	4	1
Little time spent in queues.	◉	-	△	-	-	-	4	3	4	1,33
The efficiency of the public	○	◉	○	○	-	○	4	3	4	1,33

service provided.										
Reducing internal bureaucracy.	◉	△	◉	-	-	-	4	3	4	1,33
Using electronic signature.	◉	-	◉	-	-	-	4	2	3	1,5
Online payment of all fees charged.	○	-	◉	-	-	-	4	3	3	1
The attitude of public servants and their motivation.	-	△	-	○	◉	-	5	3	5	1,66
The level of training of public servants.	-	-	△	◉	△	-	5	3	5	1,66
Institutional and budgetary transparency.	-	○	○	-	-	△	5	3	4	1,33
Consulting the citizens.	-	○	-	-	◉	-	4	3	4	1,33
Distributing opinion surveys.	-	-	△	-	◉	-	4	2	4	1,33
Social inclusion.	-	△	-	△	-	-	4	3	4	1,33
Protection of personal data.	-	-	△	-	-	-	5	4	5	1,25
Trust in local municipality.	-	○	△	-	-	-	4	3	4	1,33
Security of administrative documents.	-	-	○	-	-	-	5	4	5	1,25
Correctness of information and data.	-	-	△	-	-	◉	5	4	5	1,25
Providing information on a regular basis.	-	-	-	-	-	◉	4	3	5	1,66

Publishing information of interest on social media platforms and web pages.	-	-	◯	-	-	⦿	4	3	5	1,66
Absolute Importance (1)	177	103	194	76	136	134	821			
Relative Importance 1 (%)	21,5	12,5	23,75	9,25	16,56	16,32	100			
Absolute Importance (2)	156	97	160	76	126	151	766			
Relative Importance 2 (%)	20,36	12,66	20,88	9,96	16,44	19,71	100			

The QFD matrix presents all information about customer requirements and technical requirements and provides useful information to determine which of the service properties are important for meeting customer needs. As it can be seen, the public institution must improve most of the requirements in the "Voice of Citizens" room, their ratings being below average, the gap between "Importance" and "Service Rating" being easy to spot.

In the diagram presented above, it can be seen the "Relational Matrix" room completed with the specific symbols, thus it was possible to determine to what extent the proposed technical requirements can solve the citizens demands and at the same time with their help the "Absolute Importance" and "Relative Importance".

The diagram also contains the "roof" of the correlation matrix completed with the related symbols, the biggest link being between "Reducing the number of procedures" and "Technological progress", due to the fact that the digitalization of the institution would have an important impact on the reduction of procedures that in present are numerous. Between "Technological Progress" and "Constant Data Update" there is a positive correlation, because the data could be updated and sent to the citizens through the institution's website, social media platforms or even to the citizens' email, if they want. "Efficient management of existing resources" and "Courses of training and specialization of public servants" represent a negative correlation, due to the fact that material resources used for training and specialization courses could be used for other areas of interest, which would increase the quality of services.

Following the calculation of Absolute Importance (1), the strongest correlation is between "Technological Progress" and all variables in the "Voice of Citizens" room, the absolute importance being 194, or 23.75% relative importance. This fact indicates that digitization must be the first step in the process of planning and improving the quality of services offered. It is necessary for the public institution to offer its citizens the opportunity to benefit from online services, without going to the institution's headquarters for various formalities or to submit documents.

The second strongest correlation is between "Reducing the number of procedures" and the variables expressed by citizens. Thus, absolute importance scored 177 or 21.5% as relative importance. The result is not surprising, given the fact that citizens want the number of procedures and formalities to decrease, which would lead to the fulfilment of many of their demands, such as reducing waiting time in queues, reducing acts, documents, copies and signatures necessary and would even help to increase the efficiency of services.

On the other hand, the lowest score obtained was the correlation between "Courses of training and specialization of public servants" and all the expressed variables. The absolute importance being 76, and as a relative importance 9.25%. The results clearly express that such courses, although necessary for public servants, cannot solve most of the citizens' requirements, it is recommended that the institution focus on the technical requirements that obtained a higher score.

Regarding the Absolute Importance (2), the one calculated in relation to "Planned Quality", it can be seen that a significant increase following the improvements made by the institution would only be in the case of the correlation between "Constant Data Update" and the variables in the "Citizens' Voice" chamber, the score increasing from 134 to 151, or from 16.32% to 19.7%. Meaning, citizens would be more satisfied with everything about the way the institution provides information to them if "Planned Quality" increased by 1.

CONCLUSIONS

The QFD matrix is a powerful planning tool for the service industry. The case study presented in this paper is meant to illustrate that public sector institutions could indeed benefit from the QFD methodology to match citizens' requirements with the institution's internal procedures or actions, to satisfy citizens and even exceed their expectations. Thus, the case study can be used to demonstrate that the QFD process can be modified and effectively applied in services such as those provided by public sector institutions.

Even though QFD is a quality tool introduced by and for the manufacturing industry and used for product design and development, it can be transformed to suit the service sector as well. Also, the model presented can be modified and adapted for a wide range of public sector services.

The findings that result from the small-scale analysis based on QFD matrix, using Roșiori de Vede Municipality as a pilot case study, allow us to answer the research question, namely, "What do citizens expect from the services offered by the Roșiori de Vede municipality?". Citizens expect the public institution to provide them with quality services, modern and suitable for their needs, which is evident from the fact that their expectations far exceed their actual perception, as the "Importance" room scored only 4 and 5, while the "Service Evaluation" room scores were 2 and 3. In this particular context the QFD framework serves as a valuable tool which manages to achieve a trade-off between what the citizens want and what the public organization is able to provide in this respect, by focusing primarily on people, as its point of departure is the "voice of the customers" . This paper is only limited an exploratory case study, based on a small-scale analysis performed at the level of Roșiori de Vede Municipality. However, a future research direction should take into consideration to expand the sample of relevant public institutions.

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