Assessing inflation in CR using artificial intelligence

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Abstract

Research background: Unemployment and inflation are among the basic macroeconomic indicators of the national economy. Both these phenomena are inextricably linked to market economy and have undisputable social and economic impacts on the population of the countries where these processes take place. The relationship between the inflation and unemployment can be expressed by means of Philips curve.
Purpose: The objective of the research is to compile Philips's curve for the years 2000-2021 and compare the resulting curve with the initial short-run Philips curve.
Methods: The validity of the mutual relationship between unemployment and inflation is examined using the method of neural networks. The data on inflation and unemployment rate are available from the period of 31 January 2020 and 28 February 2021. The data on inflation were obtained from the database of the Czech Statistical Office; the data on unemployment, from the official websites of the Czech National Bank.
Findings & Value added: During the period under review, unemployment rate and inflation fluctuated constantly. Currently, both variables have stabilized at around 3%. Compared the long-term trend, in the years 2008-2009, the inflation rate was higher than unemployment rate. The analysis performed shows that the actual Philips curve for the Czech Republic in the period under review does not copy the initial short-run Philips curve, which indicates that the prediction of inflation rate development cannot be based on the development of unemployment rate, and the development of inflation rate cannot be a basis for exact prediction of unemployment rate development.

Keywords: *Phillips curve; inflation; unemployment; artificial neural networks*

JEL Classification: *E12; E13; E24; E31*

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Introduction

Unemployment and inflation are among the basic macroeconomic indicators of the national economy. Both of them are inextricably linked to the market economy and have clear social and economic consequences for populations of countries where such processes occur. Unemployment and inflation directly affect purchasing power and thus the social status of an individual. Neoclassical economists portray the Phillips curve as exogenous nature of money as well as an assumption that much unemployment is related to an employee trade-off between paid work and leisure (Rochon and Rossi, 2018).

Haskova et al. (2019) state that unemployment has an impact on individuals as well as society. Considering an individual, the impact is economic consisting particularly in the loss of regular income not only for the unemployed, but also for their families. There is also a social impact manifested by reducing one´s social contacts, the loss of his/her work habits and an inability of being up to date with events in a given field of work, and also the resulting reduction of one´s qualifications. All of that may lead to a gradual change in the unemployed individual´s position in his/her family, and hence a possible disruption of family ties and relationships as well as mental and physical problems. As regards society, the impact is also economic, where the unemployed do not pay taxes to the state budget and yet draw funds in the form of social benefits. Unemployment is therefore one of the factors having a direct impact on economic performance (Antosova et al., 2015; Kotikova and Kotrusova, 2008). Additionally, that is reflected in a certain quality decrease of society due to degrading human capital and growing social problems.

Furthermore, negative consequences of inflation largely affect the population´s income, particularly wages, which results in decreasing of purchasing power. If the inflation rate exceeds the nominal interest rate, deposit and loan values tend to fall. As a result of the purchasing power decrease, demand is lower and total sales drop. On the other hand, inflation as such does not affect property owners as prices rise with inflation in that respect. Therefore, inflation more intensively affects socially disadvantaged groups.

The Phillips curve represents the relationship between inflation and unemployment. At present, the prevailing view is that the curve is relevant for a short period indicating that there is a negative relationship between inflation and unemployment (Kotlan, 2005). Moreover, there is no consensus among economists on how to model and estimate the Phillips curve. Ideally, all factors that could affect aggregate supply and demand curves should be included in a modelling process, including exchange rates, transport costs, infrastructure, weather, income distribution, etc. (Leightner and Jonathan, 2020).

Here, the objective is to create such a curve for the Czech Republic taking account of the 2000-2021 period. To achieve the objective, the following research questions (RQ) were defined:

RQ1: How did unemployment develop over the period under review?

RQ2: How did inflation develop over the period under review?

RQ3: Does the Phillips curve shape for the Czech Republic correspond to the original model?

1 Literature review

The so-called Phillips curve has been used since 1958 to express the relationship between inflation and unemployment. There are a number of important findings about the curve´s ability to explain the process of inflation dynamics, with the curve describing cross-sectoral inflation dynamics provided data from the microeconomic and sectoral levels are used (Abbas et al. 2016). There is a simple reason why experts have pointed out that inflation follows a seemingly exogenous statistical process unrelated to the output gap, which leads to

arguments that the Phillips curve has weakened or disappeared. If monetary policy is set to minimize welfare losses, central banks will (in connection with the Phillips curve) strive to increase inflation when the overall output is below potential (Mcleay and Tenreyro, 2020). Also, Phillips curves can improve inflation prognoses over a random reference scale in periods when central banks explicitly target inflation (Gabrielyan, 2018; Furuoka et al. 2020).

Based on the Phillips curve, various models are created expressing the relationship between inflation and unemployment effects on the economy. Dennery (2020) looked into one of the Phillips' models, i.e. the monopsonistic Phillips curve model, stating that if wages are determined by companies facing nominal inflexibility in the presence of inflation, such companies cannot fully adjust their wages. The real wage is falling and so is the labour supply. Another model is the Phillips multiplier that non-parametrically characterizes a compromise between inflation and central bank unemployment. The derivation is based on a simple variable regression of cumulative inflation and cumulative unemployment using monetary shocks (Barnichon and Mesters, 2021; Ngalawa and Komba, 2020).

Regarding the Visegrad Group countries, Kaderabkova et al. (2020) compared a slope of the Phillips curve for employees being at a risk of unemployment in individual phases of the 2000 – 2016 economic cycle with particular findings of international authors. Throughout the observed period, a statistically significant negative slope of the Phillips curve was found in all four countries, with the highest intensity being in the Czech Republic and the lowest in Hungary. The empirical analysis of available data showed that the inflation and unemployment dynamics can be described by the Phillips curve if positive parallel movement between trend-adjusted productivity and unemployment is allowed (Salazar, 2019).

Other Visegrad Group countries where the Phillips curve has been used include Poland and Slovakia. During excessive disinflation in Poland, flattening of the Phillips curve may be partly explained by under-utilization of workforce, while a stronger impact of global factors on core inflation suggests strengthening of indirect effects. Changes in estimated parameters indicate that macroeconomic costs of returning inflation to the desired target increased. For example, we can see Slovak economy and its transformation process, low workforce mobility and great openness of the economy (Cihovska a Hudec, 2018).

In order to be able to answer the above research questions, individual methods dealing with the issue will be pointed out. The first method is the NARDL method used in a study examining a certain asymmetry in the impact of domestic inflation drivers in the Baltic States, focusing on the output and unemployment gap. The results show a long-term asymmetry, since inflation in Estonia and Lithuania responds more significantly to positive changes in the output gap, whilst negative changes in unemployment show a stronger long-term impact on inflation in all three countries. In particular, the findings suggest a degree of price rigidity in the Baltic economies, denoting a non-linear Phillips curve, and relatively high costs of disinflationary policy aimed at reducing aggregate demand (Mihajlovic and Marjanovic, 2020). The second method is used in a study examining stability of the New Keynesian Phillips curve in emerging small open economies of the Central and Eastern Europe over the time, and performing Bayesian inference in the time-varying parameter of stochastic volatility of the model version. The results do not indicate that the NKPC has levelled off. The dynamics of inflation have not separated from the domestic economy state, hence a balanced approach to monetary policy is well justified, which does not neglect domestic or external drivers of inflation and focuses on anchoring inflation expectations (Zobl and Ertl, 2020).

Then, the non-linear autoregressive distributed lag method was employed in a study discussing the relationship between environmental degradation, energy consumption and economic growth. The study findings confirm importance of the EKC hypothesis in Nigeria

as GDP growth first reduces the environment quality and yet increases it over the time (Musibau et al., 2020).

In a study concerned with exchange rate forecasts, artificial neural networks were used to determine a methodology for considering seasonal fluctuations in time series balancing with the use of artificial neural networks on the example of trade balance between United States (USA) and People's Republic of China (PCR). Multilayer neural networks (MLP) performed better than radial basis function networks (RBF) – Vrbka et al. (2020).

To achieve the given objective, the method of balancing time series using artificial neural networks was selected as it appeared to be the most appropriate and interesting.

2 Data and methodology

Inflation and unemployment rate data are available for the period from 31st January, 2020 to 28th February, 2021, with the former coming from the Czech Statistical Office database and the latter from the Czech National Bank´s official website. The data used are always as of last day of the month of the given year.

The TIBC Statistica software, Version 13.5.0.17, will be used for data processing, whereas the neural network method will be applied to data analysing (with a time series analysis selected here). Considering inflation, it is to be selected as the first variable given in monthly intervals. The time series will be divided into three parts. The first part will comprise a training set containing 70% of the input data and generating neural structures. The remaining 30% is to be symmetrically divided between a test set and a validation set that verify the correctness of arising neural networks. As regards a time series delay at the input, 1 will be selected as the main value, and the same is to be applied to a time series delay which determines how many steps to forecast in advance. Multilayer perceptron (MLP) networks will be generated and their training algorithm will be used in the case of networks (for the MPL networks, it will be BFGS). Then, radial basis function (RBF) networks will be generated as well. Taking the hidden layer and the output layer for the MLP networks into account, the following activation functions will be factored – Identity, Logistics, Tanh, Exponential, Sine, where:

- Identity: $Id(x) = x$ (1)
- Logistics: $f = (t, a, m, n, \tau) = a * (1 + \frac{me^{-\frac{t}{\tau}}}{1} + ne^{\frac{t}{\tau}})$ (2)
- Hyberbolic tangent: $Tanh\ x = \sinh x / \cosh x$ (3)
- Exponential: $f(x) = a^x$ (4)
- Sine: $f(x) = sin\ x$ (5)

By applying the aforementioned methodology, the following results will be obtained:

- a statistical description of inflation time series,
- an inflation development model – balanced time series,
- a statistical description of unemployment time series,
- an unemployment development model – balanced time series,
- a specific Phillips curve for the Czech Republic.

The first research question will be answered with a statistical description of inflation time series and an inflation development model of balanced time series. The second research question will be answered using a statistical description of unemployment time series and an unemployment development model of balanced time series. The third research question will

be answered by creating a specific Phillips curve and comparing it with the original short-run Phillips curve.

3 Results

Basic characteristics of actual time series are prepared. The inflation rate data come from the Czech Statistical Office database. The Table illustrates the basic statistics of the data used to create the time series model.

According to the already established procedure, thousand neural networks were generated. Of the networks, five networks with the best values were retained. Their parameters are displayed in Table 1, with a network quality being evaluated in training, test and validation sets. In most cases, a network model showing high values is selected, but fluctuations in individual sets are not significantly different. Index determines numbering of the networks whose structure and type are indicated by their name. Here, they are the RBF neural networks, where there is always one neuron at the input and a hidden layer of neurons in the middle. This is a parameter through which the best neural structure is sought, and there is always only one continuous quantity at the output (i.e. inflation). Overall performance in the Table below is divided into three sets. The model is tested on the training set, and a model forecast determines deviation size from the original data. A network with the highest performance in all three sets and minimum errors is sought. A sum of least squares (i.e. absolute square residues) is chosen as the error function. When regarding the RBF networks, a Gaussian curve is always selected as the activation function from the input layer to the hidden layer and the identity function from the hidden layer to the output layer.

Table 1. Overview of networks.

Index	Network Name	Training Performance	Test Performance	Validation Performance	Training Error	Test Error	Validation Error	Training Algorithm	Error Function	Hidden Layer Activation	Output Activation Function
1	RBF 1-24-1	0.984329	0.987779	0.992332	0.000003	0.000003	0.000002	RBFT	Sum of squares.	Gaussian	Identity
2	RBF 1-23-1	0.991710	0.991444	0.990101	0.000001	0.000002	0.000002	RBFT	Sum of squares.	Gaussian	Identity
3	RBF 1-24-1	0.985244	0.985974	0.990268	0.000003	0.000003	0.000002	RBFT	Sum of squares	Gaussian	Identity
4	RBF 1-28-1	0.987629	0.989090	0.991132	0.000002	0.000003	0.000002	RBFT	Sum of squares	Gaussian	Identity
5	RBF 1-30-1	0.982273	0.987522	0.989149	0.000003	0.000003	0.000003	RBFT	Sum of squares	Gaussian	Identity

Source: authors (2021)

As can be seen in Figure 1, the blue curve illustrates the actual course of inflation. The other curves show balanced time series. Ideally, the other curves should completely overlap the blue curve. The Figure shows that all neural networks partially revealed the curve´s direction.

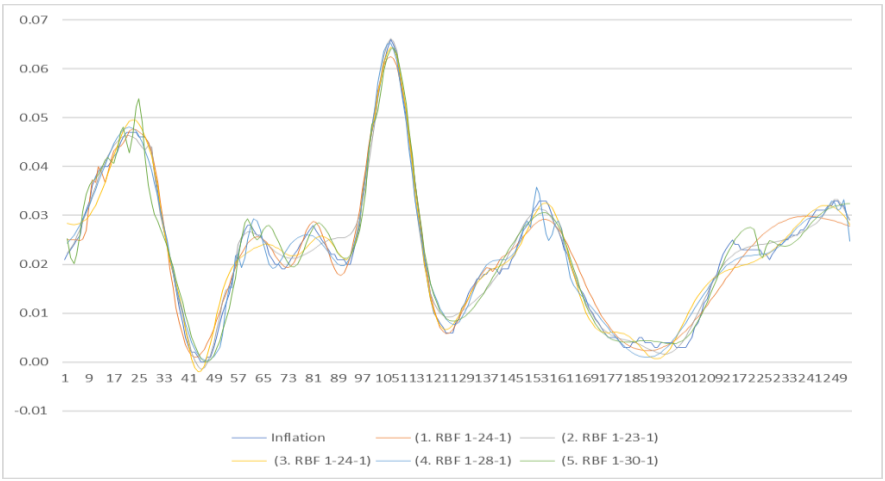

Figure 1. Development of inflation.

Source: authors with the use of data from the Czech National Bank (2021).

The unemployment rate data come from the Czech National Bank´s official website.

Similar to what has been previously mentioned, thousand neural networks were generated again. Of the networks, five networks with the best values were retained. Their parameters are shown in Table 2. Index determines numbering of networks, whereas their name denotes a structure and a type. Here, there are two types of neural networks, i.e. the RBF and the MLP networks. It may be noted that perceptron is the simplest form of a neuron. A sum of least squares is chosen as the error function. In terms of the activation function, a Gaussian curve or logistics function are selected from the input layer to the hidden layer and the identity function or hyperbolic tangent are selected from the hidden layer to the output layer.

Table 2. Overview of networks.

Index	Network Name	Training Performance	Test Performance	Validation Performance	Training Error	Test Error	Validation Error	Training Algorithm	Error Function	Hidden Layer Activation	Output Activation Function
1	MLP 1-8-1	0.994516	0.993488	0.993498	0.000002	0.000003	0.000002	BFGS (Quasi-Newton) 284	Sum of Squares	Logistics	Tanh
2	MLP 1-8-1	0.992866	0.992351	0.992692	0.000003	0.000004	0.000003	BFGS (Quasi-Newton) 168	Sum of Squares	Logistics	Logistics
3	RBF 1-30-1	0.994171	0.994287	0.992185	0.000003	0.000003	0.000003	RBFT	Sum of Squares	Gaussian	Identity
4	MLP 1-8-1	0.993103	0.992961	0.992814	0.000003	0.000003	0.000003	BFGS (Quasi-Newton) 132	Sum of Squares	Logistics	Tanh
5	RBF 1-21-1	0.994062	0.992423	0.992809	0.000003	0.000004	0.000003	RBFT	Sum of Squares	Gaussian	Identity

Source: authors (2021)

As can be seen in Figure 2, the blue curve illustrates the actual course of unemployment. The other curves show balanced time series that balance the blue curve relatively well. However, they cannot completely reveal local extremes of the blue curve.

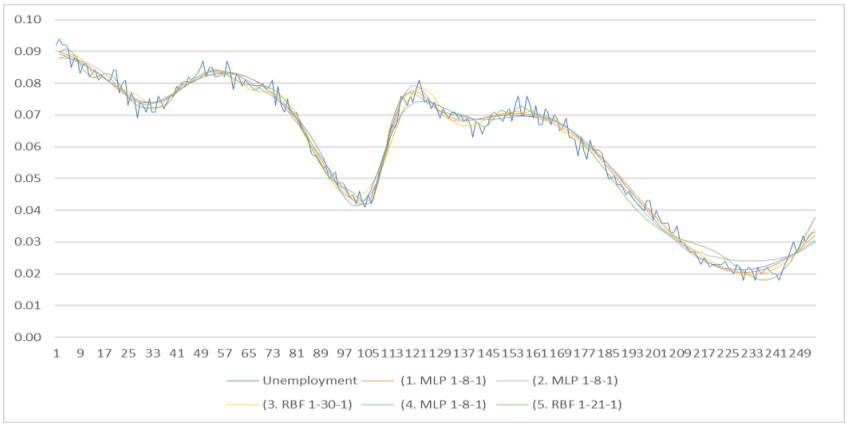

Figure 2. Development of unemployment.

Source: authors with the use of data from the Czech Statistical Office (2021)

The actual courses of inflation and unemployment are depicted in Figure 3, where the Phillips curve shows that the higher the unemployment, the lower the inflation and vice versa. At the beginning of the period under review, inflation was significantly lower than unemployment, which lasted until the turn of 2008-2009, when inflation outgrew unemployment. Afterwards, inflation started falling again and was essentially comparable to unemployment at the end of the researched period.

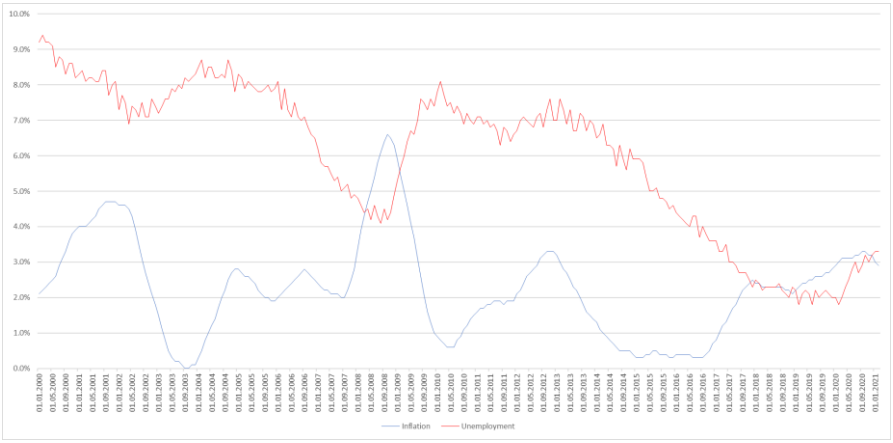

Figure 3. Actual development of inflation and unemployment.

Source: The Czech Statistical Office (2021) and The Czech National Bank (2021)

Lastly, Figure 4 captures a short-run parabolic shaped Phillips curve and the actual Phillips curve related to the Czech Republic.

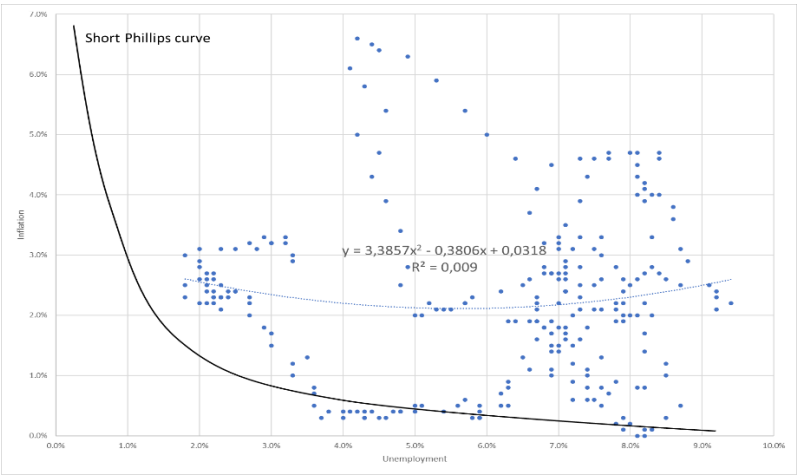

Figure 4. Comparison of Phillips curves.

Source: authors (2021)

It is clear that they do not match, and it is therefore not possible to forecast inflation in the Czech Republic on the basis of unemployment.

4 Discussion

Based on the results obtained, the above research questions can be answered:

How did unemployment develop over the period under review?

At the beginning of the 1990s, the unemployment rate in the Czech Republic was very low oscillating around 3%. The majority of economic and social analyses agreed that the causes of the low rate were both economic and political (Forum socialni politiky, 2008). In the 3rd quarter of 2020, total employment decreased by 72.9 thousand year-on-year reaching 5,233.3 thousand. According to the International Labour Organization (ILO), the number of unemployed people increased by 39.0 thousand and the number of economically inactive people increased by 54.9 thousand (SOCR ČR, 2020).

During the period under review, the unemployment rate alternately increased and decreased. At present, the unemployment rate is very low (around 3.3%).

How did inflation develop over the period under review?

In 2005, inflation measured by the HICP was 2.2% due to strong increases in commodity and energy prices and, to a lesser extent, growth in administered prices and indirect taxes, and hence was slightly higher than in the previous two years (2.1%). However, domestic inflationary pressures remained under control as continuing modest wage growth and favourable price development of imported market products compensated to some extent rising commodity and energy prices (European Central Bank, 2006). According to published data, the price level rose by 2.1% year-on-year in February 2021. As opposed to January 2021, inflation fell slightly, and is thus still close to the Czech National Bank's 2% target (CNB, 2021).

During the period under review, the inflation rate alternately increased and decreased, its highest being in 2008 (up to 6.6%). At present, it is around 2.1%.

Does the Phillips curve shape for the Czech Republic correspond to the original model?

Findings presented here challenge previous empirical evidence of the inflation output trade-off described in the hybrid New Keynesian Phillips curve. The author estimates key coefficients of the hybrid New Keynesian Phillips curve based on gaps (both with pro-inflation components and a future outlook) for the Czech Republic in relation to the 2000-2012 period (Milucka, 2014).

As previously mentioned, Figure 6 shows that the Phillips curves do not match. Thus, it is not possible to forecast inflation in the Czech Republic on the basis of unemployment.

Conclusion

The objective was to create Phillips curve for the Czech Republic with regard to the 2000-2021 period. It may be stated that the objective was met.

It was found that unemployment fluctuated during the period under review. While at its beginning it reached almost 10%, it is at a significantly lower level (around 3%) nowadays. Moreover, inflation was not stable either throughout the period under review, being lower at the beginning than at the end, though the difference is noticeably smaller than it was in the case of unemployment. It was also found that the Phillips curve for the Czech Republic in the 2000-2021 period does not coincide with the original Phillips curve. As a result, it is not possible to forecast the development of inflation in the Czech Republic on the basis of the development of unemployment.

Following from that, there is genuinely no presumed relationship between unemployment and inflation. Therefore, it is not possible to estimate the development of unemployment on the basis of the development of inflation and vice versa. This leads to a conclusion that even monetary and fiscal expansions will not work according to assumptions of economists. Based on the above facts, it will not be possible to determine what will be the effect of a possible increase in the amount of funds coming into the Czech economy. In terms of monetary expansion, it is thus not possible to forecast in advance whether prices of goods and services will rise or whether the economy will improve its performance. Also, it will be impossible to estimate in advance a reaction of the economy in the event of state tax policy changes, i.e. an increase or a decrease in taxes, a change in the volume of government expenditures. Provided that the impact of monetary and fiscal expansions cannot be clearly estimated, interventions by the state and the Czech National Bank in the future may not have the expected result and invested funds may not have the desired effect.

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