# The impacts of monetary policy of the Czech National Bank on selected economic indicators

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**Abstract:** The aim of the paper is to determine the impact of monetary policy of the Czech National Bank (CNB) on selected economic variables between the years 1996 and 2017. We will therefore examine the long-term relationships between M3 and short-term interest rates in relation to inflation and other economic variables, i.e., gross domestic product (GDP) and bank loans to the private non-financial sector. Time series analysis is performed using Engle-Granger co-integration analysis to find long-term relationships and Granger causality testing to determine mutual short-term relationships between the monitored variables. The empirical results show that there are no long-term relationships between the monitored variables there are only short-term ones. This leads to the conclusion that the development of the inflation rate, GDP, and loan volume can be predicted based on the development of the M3 monetary aggregate and the CNB's basic interest rate to Granger causality. Therefore, we can positively assess the CNB's decision to leave the targeting money supply.

**Keywords:** central bank; GDP; gross domestic product; Granger causality; interest rate; monetary policy; money supply.

**Reference** to this paper should be made as follows: Černohorská, L. (2021) 'The impacts of monetary policy of the Czech National Bank on selected economic indicators', *Int. J. Monetary Economics and Finance*, Vol. 14, No. 1, pp.35–53.

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This paper is a revised and expanded version of a paper entitled 'The impacts of monetary policy of the Czech National Bank on selected economic indicators' presented at *17th International Conference on Finance and Banking*, Ostrava, 16–17 October, 2019.

## 1 Introduction

One of the main issues of monetary policy is the fact that there is no direct connection between the goals of monetary policy and the instruments used by central banks. Central banks try to achieve set goals with monetary policy tools by using a transmission mechanism that effects multiple monetary policy channels simultaneously. According to monetary theory, the central bank can, as a result, influence not only inflation but also the evolution of GDP, unemployment, the trade balance, and other variables – including the economic cycle – over the short term. Currently, the central bank monetary policy regime that is the most accepted – inflation targeting – works with a transmission mechanism different from the central bank monetary policy regime that was used in the past, i.e., targeting the money supply. Today, many central banks around the world use inflation targeting, including the European Central Bank (ECB), the Czech National Bank (CNB), and the Federal Reserve System (FED). Roughly, over the last 20 years, monetary policy has been trying to effect aggregate demand by setting interest rates, which are considered an exogenous variable. By changing interest rates, central banks can react when inflation deviates away from the inflation target as well as when production oscillates around potential production. Short-term interest rates are one of the monetary policy tools that central banks use to implement monetary policy in order to achieve price stability.

In the past, monetary policy was based on a quantitative theory of money based on the knowledge that money supply growth effects price levels. This causality is empirically proven over a long period. Money supply growth only effects the price level in the long run. In the short term, it is possible to find the influence of money supply on the development of the output of the economy. Many central banks chose monetary aggregates as intermediate goals during the 1970s and monetary aggregates have become an important instrument in the conduct of monetary policy.

Since 1998, the CNB has been trying to achieve a set goal by using its chosen monetary policy regime, inflation targeting. In past years, the CNB simultaneously used the regimes of fixed exchange rate targeting and money supply targeting. With the changing nature of the Czech economy, which has been constantly becoming more a more open economy, the CNB became the first post-communist country to use inflation targeting. At the time, there was a global trend towards an evident departure from money supply targeting being included in monetary policy, and central banks turned to inflation targeting, which was first implemented by the Reserve Bank of New Zealand in 1990. Currently, many central banks around the world use the regime of inflation targeting, including the European Central Bank; as of 2012, the Federal Reserve System (FED) also uses this regime. The CNB was one of the first central banks in the world to ease monetary policy in response to the eruption of the financial crisis. As early as August of 2008, the CNB began to gradually lower its interest rates from a value of 3.5% down to 1% in December of 2009. At the end of 2012, the value of the basic interest rate (the 2 W repo rate) stopped at 0.05%, where it remained until 3 August, 2017. After exhausting the interest rate channel, the CNB decided to prescribe a remedy against the development of a weak economy threatened by continuously decreasing prices, wages, salaries, and pensions. It began to use the foreign exchange rate as another tool to ease monetary policy and avoided price instability in the form of deflation. On 11 November, 2013, the CNB began intervening in the foreign exchange market by weakening the koruna, which it achieved by selling korunas on the foreign exchange market and setting a peg at

27 CZK/EUR. In this way, it used a parallel monetary policy tool, which was intended to achieve higher inflation. Certain other central banks that already had zero or negative interest rates also instigated unconventional monetary policy to minimise the effects of the financial crisis or to turn back the risk of inflation. The FED, ECB, and Bank of England implemented so-called quantitative easing, whereas the Swiss National Bank – the same as the CNB – resorted to currency intervention. The financial crisis led to increasing emphasis on the interconnection between the CNB's monetary policy and questions concerning the Czech economy's stability. On the basis of new findings on the subject of monetary policy after the financial crisis, the CNB was forced to expand its set goal (price stability) by incorporating financial stability. The CNB has been trying to achieve financial stability via macroprudential policy, which can be used to lower the interaction between asset bubbles and loan provision. The stability of the financial and banking sectors in the European Union has been dealt with in more detail by Kočišová and Stavárek (2018), for example. The CNB has also been using a new central banking trend, i.e., the instrument of forward guidance, which makes it easier for the public to better understand the CNB's monetary policy and also subsequently leads to economic entities having correct future expectations.

In this paper, we focus on the impact of selected monetary policy strategies monetary policy's effect on selected economic variables in the Czech Republic (CR) for the years 1996 to 2017. Based on the CNB's choice of monetary policy regime since 1997, we can expect to see proof of a relationship between the 2T repo rate and inflation. With regards to the fact that the monetary targeting monetary policy regime was abandoned, there should be no relationship confirmed between the M3 monetary aggregate and inflation, which is the monetarists' assumption.

When investigating the relationship between economic time series, it is necessary to distinguish short-term and long-term relationships. We have conducted time series analysis to determine mutual relationships using cointegration analysis for determining the long-term relationships and Granger causality for determining the short-term relationships. We have investigated the long-term and short-term relationships between the M3 money aggregate and short-term interest rates as they relate to inflation and other economic variables, i.e., gross domestic product (GDP) and bank loans provided to the private non-financial sector.

## 2 Theoretical background

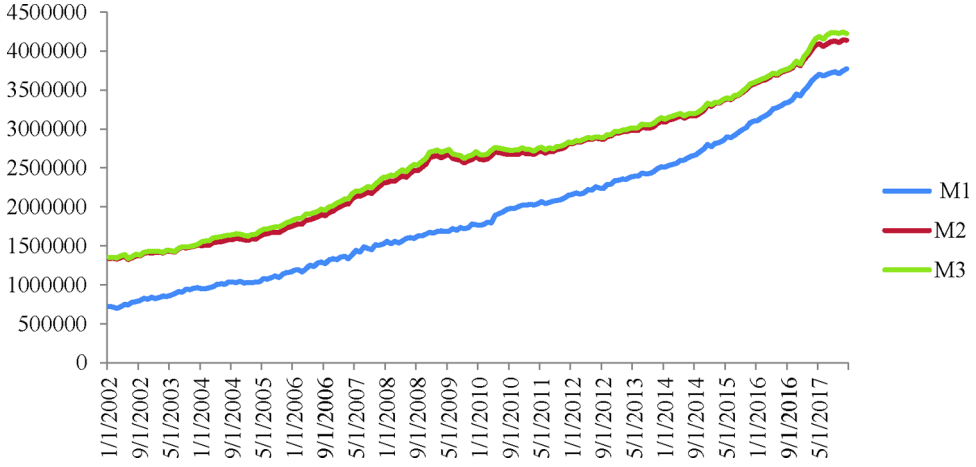
Monetary policy's impact is often evaluated according to how monetary aggregates or central bank interest rates affects economic variables. Monetary aggregates provide important information when implementing monetary policy. The monetarists start with the thesis that over the long term, monetary aggregates have been considered the decisive factor for conducting monetary policy. Friedman and Schwartz (1963) explain the economic cycle's development using changes in the money supply and inflation. As Friedman (1968) and Brunner and Meltzer (1969) state, money only has a short-term impact on the real economy. The same as other monetarists, they also emphasise that monetary policy should not be used as an active instrument for stabilising the economic cycle.

The amount of money in the banking system is primarily determined by the banks' willingness to provide non-cash loans to non-bank clients and the demand for these loans.

Money multipliers represent the ratio of the relevant monetary aggregate to the monetary base. Commercial banks issue cashless money primarily by providing non-cash loans to non-bank clients.

Revenda (2016) mentions, different monetary aggregate multipliers may develop in various ways although their behaviour is similar over the long term. Figure 1 depicts the behaviour of the M1, M2, and M3 monetary aggregates for the Czech Republic. Certain authors (e.g., Revenda, 2014, 2016) work with money multipliers derived from the M1 or M2 monetary aggregates. However, Haghighat (2011) and Badarudin et al. (2012) dealt with determining the endogenous money supply using the M3/monetary base multiplier. The process of money creation is based on how the money multiplier functions. If the money multiplier is constant, the central bank can effectively control the money supply. The monetarists, whose approach is based on the quantitative theory of money, start with the assertion that central banks can exogenously change the monetary base according to their concerns in order to achieve their money supply target level, because the money multiplier is considered stable. With a stable money multiplier, increasing or lowering the money multiplier does not compensate for restrictive or expansionary monetary policy. Changes in the money supply via the monetary base correspond to changes in deposits, which influence the amount of loans provided by banks.

**Figure 1** Monetary aggregates in the Czech Republic (in CZK mil.) (see online version for colours)




*Source*: CNB (2020)

At the same time, central banks also use their instruments to influence the volume of loans issued. Both Mishkin (1995) and Howells and Bain (2009) emphasise the possibility of monetary policy effectively influencing aggregate demand, because they see inflation as the result of an excessive money supply, because an increase in aggregate demand caused by an increase in the money supply results in rising pressure on price growth.

In recent decades, there has been constant growth in the amount of money in individual economies, which – according to economic theory (e.g., Mishkin, 2001; Trecrosi and Vega, 2002; Bruggeman et al., 2005) – should subsequently have a causal effect on other economic variables, such as an increase in inflation or economic growth.

Despite this, when central banks use or have used unconventional monetary policy to increase the amount of money in circulation in the present day, this does not cause an increase in inflation. Mishkin (2017) dealt with necessary changes within the field of recent monetary policy, emphasising the necessity of reevaluating the paradigm of central bankers when targeting inflation.

The assumption used when adopting a monetary aggregate as the intermediate goal of monetary policy is that there is a stable relationship between changes in money and subsequent changes in the price level. This type of stable relationship exists under the assumption that demand for money is stable over time. In various countries, recent changes on the financial markets in have led to instability in the demand for money. Artis and Lewis (1984) monitored the unstable demand for money in Great Britain, Hafer and Jansen (1991) in the USA, Bahmani-Oskooee and Barry (2000) in Russia, Bahmani-Oskooee and Rehman (2005) in developing Asian countries, and Bahmani-Oskooee and Bohl (2000) in Germany. Setzer and Wolff (2013) dealt with monetary demand's traditional role in the eurozone since 2001, finding it to be unstable. Dreger et al. (2019) investigated the nature of M3 demand's stability in the eurozone for 1983 to 2015, and as part of cointegration analysis, they created a model incorporating real cash balances, long-term interest rates, and the M3 monetary aggregate.

As the result of various countries' unstable monetary demand, a number of central banks have abandoned monetary aggregates as an intermediate monetary policy goal and have implemented a new monetary policy regime – inflation targeting. As presented by Svensson (1997, 1999), inflation targeting is derived from monetarism and the thesis that monetary policy should focus on maintaining price stability. Inflation targeting is employed in monetary policy without the use of monetary aggregates, which is in contrast to monetary targeting strategies. Baltensperger et al. (2001) analysed and confirmed the relationship between the M3 monetary aggregate and inflation in Switzerland from 1978 to 1999. The Deutsche Bundesbank (1997) dealt with M3's influence on inflation, finding that the impact of shocks in M3 significantly affected the price level but not the opposite. The findings support the opinion that M3 is a useful ratio for controlling inflation. In 1998, the ECB decided to strengthen the role of money within its monetary policy; this consisted of analysing monetary aggregates more thoroughly and providing additional information for monetary policy decision making. The ECB's decision spurred an increase in interest by many authors, who dealt with monetary aggregates' influence on future price development. Studies by Gerlach and Svensson (2003), Trecrosi and Vega (2002), and Altimari (2001) prove that M3 fundamentally influences the development of inflation in the eurozone. Černohorský (2018) dealt with the relationship between the size of provided loans in relation to interest rate behaviour on the financial markets in selected European Union countries between 2005 and 2011. Vozková and Teplý (2020) deals with the European banking sector and in the Czech Republic in a low interest rate environment.

As Jílek (2013) states, models have been created in the past that focus on the relationship between monetary aggregates and GDP. At the start of the 1980s, the American central bank, the FED, relied on the M1 monetary aggregate for estimating the development of GDP and inflation. In later analyses, however, the FED also used the M2 and M3 aggregates in analyses for predicting GDP and inflation. However, it was subsequently demonstrated that the development of GDP and inflation can not be predicted by these monetary aggregates on account of the deregulation of the USA's financial system. Certain authors (Borio, 1997; Haghighat, 2011) have monitored the

relationship between real GDP and the money supply, which is determined by demand for credit.

Wu and Xia (2016) dealt with the macroeconomic impact of the FED's monetary policy when the main interest rate (the federal funds rate) was essentially zero; this meant that traditional monetary policy had not worked, and the FED had been forced to implement unconventional monetary policy.

Gertler and Hofmann (2018) studied the ties between the amount of money in the economy and inflation and the relationship between increases in provided loans and the financial crisis for 46 countries between 1950 and 2011. They concluded that the relationship between the amount of money and inflation is weak, whereas the one between loans provided and the financial crisis is stronger.

## 3 Data and methodology

We conducted time series analysis to determine mutual relationships by using tests for cointegration and Granger causality. We examined the causal relationship between the M3 monetary aggregate and price level as measured by the harmonised index of consumer prices (HICP), gross domestic product, and loans provided by commercial banks to the nonfinancial sector. Similarly, we investigated causal relationships between the basic CNB interest rate – i.e., the 2W repo rate – and these economic variables.

We conducted statistical analysis with the use of the program Gretl 1.9.4 for econometric analysis. We performed logarithmic transformation on the time series in order to achieve log-normal distribution for these series. As part of ADF testing and when testing for Granger causality, we worked with time series that had been differenced. The time series we used incorporate quarterly data for the period of the first quarter of 1996 through to the second quarter of 2017. This makes 86 observations. We obtained the quarterly data for inflation and seasonally adjusted GDP from Eurostat's statistics (Eurostat, 2017a, 2017b). The seasonally adjusted quarterly data for the M3 monetary aggregate was obtained from the OECD (2017), and the overall volume of bank loans provided to the private nonfinancial sector was derived from the statistics of the Bank for International Settlements (BIS, 2017). As the interest rate, we used the basic 2W repo interest rate, which we obtained from the statistics of ARAD ČNB (ČNB 2003-2017b). Table 1 presents a description of the variables used in the time series analysis.

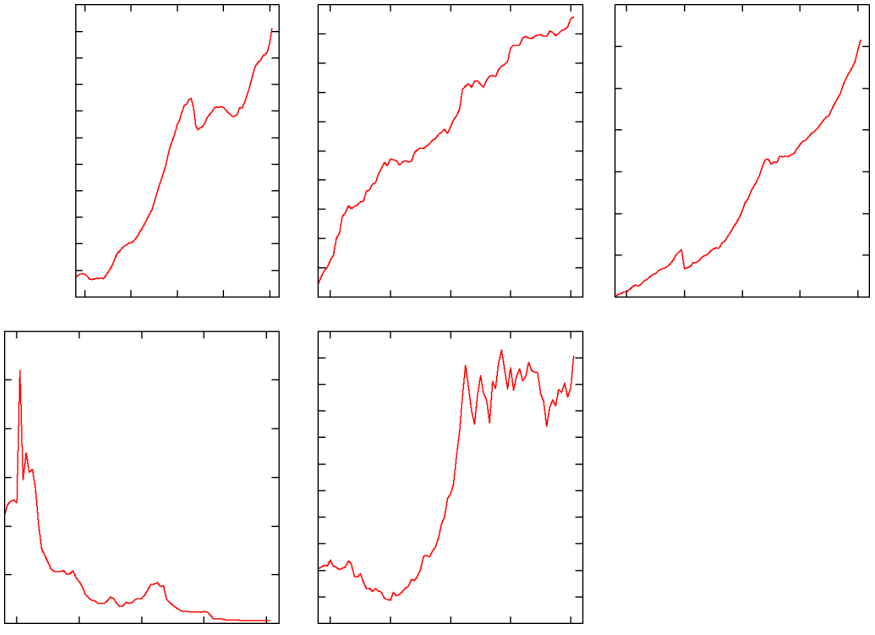
**Table 1** Description of the variables used for analysis

| *Variable abbreviation* | *Description of variable* |
|---|---|
| *M3_CZE* | The M3 money aggregate for the Czech Republic |
| *GDP_CZE* | Real gross domestic product in the Czech Republic |
| *HICP_CZE* | Harmonised Indices of Consumer Prices in the Czech Republic |
| *CRED_CZE* | Loans provided by banks to the nonfinancial sector in the Czech Republic |
| *2W REPO_CZE* | 2 week repo rate |

*Source*: Author

Figure 2 depicts the behaviour of the M3 monetary aggregate, GDP, HICP, provided loans and repo rates in the Czech Republic for the years 1996 to 2017.

**Figure 2** The development of the ratios monitored for the Czech Republic between 1996 and 2017 (see online version for colours)



*Source*: Author's own work based on the results of Gretl 1.9.4

Table 2 shows summary statistics of used variables reporting the mean, median, standard deviation, minimum and maximum.

**Table 2** Summary statistics of used variables

| | *GDP_CZE* | *HICP_CZE* | *M3_CZE* | *2W repo_CZE* | *cred_CZE* |
|---|---|---|---|---|---|
| Mean | 8.9090E+005 | 84.645 | 2145.9 | 4.0542 | 62.208 |
| Median | 9.5229E+005 | 83.450 | 1920.9 | 2.3300 | 53.550 |
| Minimum | 6.8271E+005 | 57.300 | 1000.9 | 0.28000 | 18.748 |
| Maximum | 1.1557E+006 | 102.90 | 4078.7 | 25.990 | 112.92 |
| Std. dev. | 1.4636E+005 | 12.552 | 865.75 | 4.8229 | 34.946 |
| Coefficient of variation | 0.16428 | 0.14829 | 0.40345 | 1.1896 | 0.56176 |

*Source*: Author's own work based on the results of Gretl 1.9.4

To analyse these time series, we first needed to determine the optimal lag length and whether the data under analysis were stationary. We always searched for the information criteria's minimum value, which we then used in the following steps (Černohorský, 2017). We determined the optimal lag using the Hannan-Quinn information criteria (HQC):

$$\mathrm{HQC} = n * \ln(RSS/n) + 2kcln \tag{1}$$

The tests are conducted on the basis of the relationship of the values in equation (1), where *RSS* is residual sum of squares, *k* expresses the number of parameters, *RSS/n* denotes residual variance, *c* is added constant and *n* is the number of observations (Arlt and Arltová, 2007).

For all the variables selected for the CR, we conducted tests with no constant and no trend, with a constant, and with a constant and a trend. We tested the optimal lag length for the HQC at six lags, which corresponds to a lag length of six quarters, which is in line with economic theory (for more detail, see Mankiw, 2014). This is also the upper limit of the monetary policy lag time specified by most central banks. We then used these findings in the ADF test and the Engle-Granger cointegration test.

The stationarity of the time series is determined by conducting ADF testing. ADF tests were applied to a modified version of the model for autocorrelated error terms assuming that *r* is known (Dickey and Fuller, 1979):

$$Y_t = \gamma + \delta_t + \alpha Y_{t-1} + \sum_{j=1}^{r-1} \alpha j \Delta Y_{t-1} + ut \tag{2}$$

where $\gamma = \delta_1(1-\alpha) + \delta_2\alpha$; $\delta_1$ and $\delta_2$ indicate the trend parameter; $u_t$ is the stationary error term.

Verifying the null theory with regards to stationarity is done using the *p*-value, which is compared to $\alpha$ (the level of significance). In these tests, we used a level of significance of 0.05. The hypotheses for the ADF test were established as follows:

*$H_0$: The time series are nonstationary.*

*$H_1$: The time series are stationary.*

When the differences of the modified time series were stationary, we proceeded to conducting the Engle-Granger test, which establishes whether or not there is a cointegration relationship between these time series. If both variables $Y_t$, $X_t$ are integrated and if there is the existence of a non-null parameter β, their linear combination is stationary:

$$u_t = Y_t - \beta X_t \tag{3}$$

where $Y_t$ and $X_t$ can be called cointegrated variables. Cointegration analysis, i.e., the Engle-Granger test, was designed by Engle and Granger (1987). For this test, the following hypotheses were established:

*$H_0$: The time series are not cointegrated.*

*$H_1$: The time series are cointegrated.*

If the time series were not cointegrated, we continued by testing for Granger causality and testing the following hypotheses:

*$H_0$: The variable $X_t$ does not Granger-cause the variable $Y_t$.*

*$H_1$: The variable $X_t$ Granger-causes the variable $Y_t$.*

in the following way (Hušek, 2007):

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{i-r} + \sum_{i=1}^{p} \beta_i X_{t-i} + u_t \tag{4}$$

where $i$ is the parameter, $u_t$ is random error (residual) and where it is possible to set the maximum lag of $p$ at an arbitrary length.

If the coefficients $i = 0 (i = 1, 2, \ldots, p)$, then the variable $X_t$ does not fit the prerequisites for Granger causality. In the test, we used stationarised time series, i.e., the first difference. In the case that the second difference is the one that becomes stationarised, academic literature (Lűtkepohl, 2005; Hamilton, 1994) recommends – in conjunction with subsequent interpretation – using the first difference, even despite the fact that the given time series has not yet been stationarised. This is because the first difference of the given ratio's logarithmic transformation in fact expresses a relative rate of growth for this ratio.

## 4 Empirical results

### *4.1 Specifying the optimal lag length and testing the stationarity of the time series for M3 and 2W repo rates and inflation*

Due to the large number of tests performed, we only present test results between the monetary aggregates M3 and GDP for ADF test. The results of the tests performed among the variables under review are presented in Sections 5 and 6. Based on the tests we conducted, we determined that the optimal lag length for M3 and GDP in the CR was a lag of two quarters, proceeding to use the test with a constant and a trend; for M3 and HICP in the CR, we determined a lag length of six quarters, proceeding to use the test with a constant; and for M3 and loans in the CR, we determined a lag of one quarter and the use of the test with a constant. On the basis of the optimal lag length test for the 2W repo rate and GDP in the CR, we determined a lag of two quarters, proceeding with the test with a constant; for 2W repo interest rate and HICP in the CR, we determined a lag length of six quarters and proceeded with the test using a constant and a trend; for the 2W repo rate and loans in the CR, we determined a lag of one quarter and proceeded using the test with a constant and a trend. The findings from the optimal lag test were used in the following procedure for testing time series stationarity (ADF tests) and in the cointegration tests. Nonstationarity of the time series means that spurrios correlation could occur when conducting correlation analysis. Stationarity for all the time series was achieved only after they had been differenced. As part of the ADF test, we subjected the time series to differencing, using the first difference, in order to achieve their stationarity (Table 3).

Table 3 captures the resulting p-values, which implies that all $p$-values are greater than the significance level. As a result, we can claim that time series are non-stationary and therefore we do not reject the null hypotheses.

Stationarity for all the time series was achieved only after they had been differenced. As part of the ADF test, we subjected the time series to differencing, using the first difference, in order to achieve their stationarity (Table 4).

Because we determined that the time series *d_l_GDP_CZE* and *d_l_M3_CZE* were nonstationary even after differencing the variables, we continued to the second difference of the variables for the nonstationary time series. The results of the ADF tests for the second difference of *d_d_l_GDP_CZE* and *d_d_l_HICP_CZE* are depicted in Table 5.

**Table 3** The results of the ADF test for a unit root

| *Time series* | *Value of p – parameter* | *Evaluation of ADF test results* | $H_0$ |
|---|---|---|---|
| *l_M3_CZE* | 0.5981 | Time series non-stationary | Not rejected |
| *l_GDP_CZE* | 0.5630 | Time series non-stationary | Not rejected |
| *l_M3_CZE* | 0.9725 | Time series non-stationary | Not rejected |
| *l_HICP_CZE* | 0.1176 | Time series non-stationary | Not rejected |
| *l_M3_CZE* | 0.9698 | Time series non-stationary | Not rejected |
| *l_CRED_CZE* | 0.9284 | Time series non-stationary | Not rejected |
| *l_2W repo_CZE* | 0.8344 | Time series non-stationary | Not rejected |
| *l_GDP_CZE* | 0.9575 | Time series non-stationary | Not rejected |
| *l_2W repo_CZE* | 0.4057 | Time series non-stationary | Not rejected |
| *l_HICP_CZE* | 0.2675 | Time series non-stationary | Not rejected |
| *l_2W repo_CZE* | 0.6440 | Time series non-stationary | Not rejected |
| *l_CRED_CZE* | 0.8020 | Time series non-stationary | Not rejected |

*Source*: Author's own work based on the results of Gretl 1.9.4

**Table 4** The results of the ADF test for a unit root – first difference

| *Time series* | *Value of p – parameter* | *Evaluation of ADF test results* | $H_0$ |
|---|---|---|---|
| *d_l_M3_CZE* | 0.00023 | Time series stationary | Rejected |
| *d_l_GDP_CZE* | 0.22120 | Time series non-stationary | Not rejected |
| *d_l_M3_CZE* | 0.12240 | Time series non-stationary | Not rejected |
| *d_l_HICP_CZE* | 0.00338 | Time series stationary | Rejected |
| *d_l_M3_CZE* | 1.055E-006 | Time series stationary | Rejected |
| *d_l_CRED_CZE* | 7.49E-006 | Time series stationary | Rejected |
| *d_l_2W repo_CZE* | 0.0002034 | Time series stationary | Rejected |
| *d_l_GDP_CZE* | 0.06636 | Time series non-stationary | Not rejected |
| *d_l_2W repo_CZE* | 0.003098 | Time series stationary | Rejected |
| *d_l_HICP_CZE* | 0.006982 | Time series stationary | Rejected |
| *d_l_2W repo_CZE* | 9.992E-005 | Time series stationary | Rejected |
| *d_l_CRED_CZE* | 6.843E-005 | Time series stationary | Rejected |

*Source*: Author's own work based on the results of Gretl 1.9.4

**Table 5** The results of the ADF test for a unit root – second difference

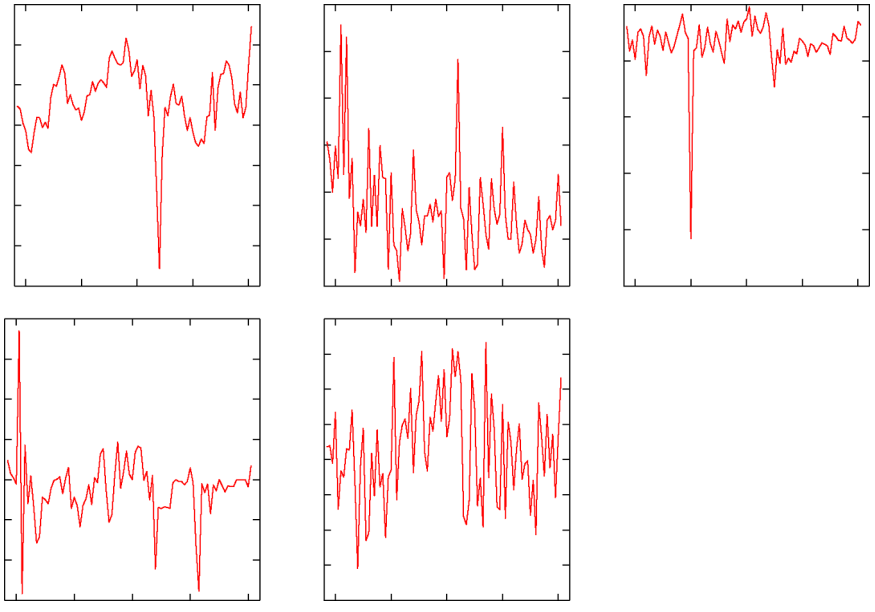
| *Time series* | *Value of p – parameter* | *Evaluation of ADF test results* | $H_0$: |
|---|---|---|---|
| *d_d_l_GDP_CZE** | 5.944E-006 | Time series stationary | Rejected |
| *d_d_l_M3_CZE* | 1.551E-005 | Time series stationary | Rejected |
| *d_d_l_GDP_CZE*** | 5,002E-007 | Time series stationary | Rejected |

*When testing the time series *d_l_M3_CZE* and *d_l_GDP_CZE*, ** when testing the time series *d_l_2W repo_CZE* and *d_d_l_GDP_CZE*.

*Source*: Author's own work based on the results of Gretl 1.9.4

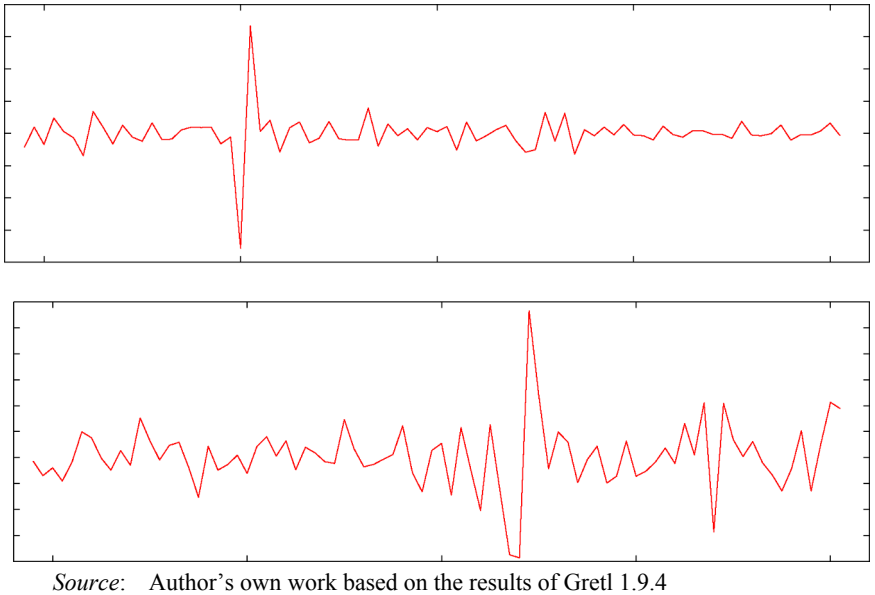
A visualisation of the time series (Figures 3 and 4) serves to verify and help illustrate these results; from this, it is clear that the selected differenced time series (*d_d_l_GDP_CZE* and *d_d_l_M3_CZE*) have become stationary with the help of the second difference.

**Figure 3** The course of development time series – first difference (see online version for colours)



*Source*: Author's own work based on the results of Gretl 1.9.4

**Figure 4** The course of development time series – second difference (see online version for colours)



*Source*: Author's own work based on the results of Gretl 1.9.4

### 4.2 Time series cointegration – the Engle-Granger test for the influence of M3 and the 2W repo rate on the other variables

Cointegration relationships can be active in both directions. Therefore, we have conducted the cointegration test for all the dependent and independent variables on each other reciprocally, i.e., for M3 as an independent variable and GDP as a dependent variable, as well as for M3 as a dependent variable and GDP as an independent variable. The results of the Engle-Granger test are depicted in Table 6, where the variable listed first indicates the dependent variable and the variable listed second indicates the independent variable. From the determined *p*-values, which acquired values greater than the set level of significance ($p > 0.05$), we can state that these time series are not cointegrated, i.e., there are no long-term relationships between them.

**Table 6** The results of the Engle-Granger cointegration test

| *Time series* | *Value of p – parameter* | *Conclusion* | $H_0$ |
|---|---|---|---|
| *l_M3_CZE/l_GDP_CZE* | 0.6709 | No cointegration | **Not rejected** |
| *l_GDP_CZE/l_M3_CZE* | 0.8409 | No cointegration | **Not rejected** |
| *l_M3_CZE/l_HICP_CZE* | 0.8706 | No cointegration | **Not rejected** |
| *l_HICP_CZE/l_M3_CZE* | 0.6445 | No cointegration | **Not rejected** |
| *l_M3_CZE/l_CRED_CZE* | 0.6137 | No cointegration | **Not rejected** |
| *l_CRED_CZE/l_M3_CZE* | 0.6013 | No cointegration | **Not rejected** |
| *l_2W REPO /l_GDP_CZE* | 0.4449 | No cointegration | **Not rejected** |
| *l_GDP_CZE/l_2W REPO* | 0.5478 | No cointegration | **Not rejected** |
| *l_2W REPO /l_HICP_CZE* | 0.6587 | No cointegration | **Not rejected** |
| *l_HICP_CZE/l_2W REPO* | 0.9031 | No cointegration | **Not rejected** |
| *l_2W REPO /l_CRED_CZE* | 0.1342 | No cointegration | **Not rejected** |
| *l_CRED_CZE/l_2W REPO* | 0.5412 | No cointegration | **Not rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

Taking into consideration the results of the ADF and Engle-Granger cointegration tests, we again proceeded to further determine the Granger-causal relationships.

### 4.3 Granger causality for M3 and 2W repo rate and the other variables

Based on the calculations, we can state that for the Czech Republic, the variable *M3* effects *GDP* with Granger causality at a lag length of one quarter (Table 7). This means that using the *M3* variable can improve prediction of *GDP* in the CR with this lag length. On the other hand, we can state that *GDP* also Granger-causes the *M3* variable with a lag length of one quarter. Using the variable *GDP* allows us to improve prediction of *M3* with this lag.

Likewise, we continued to test the variables in question for Granger causality. On the basis of these tests, we determined that in the Czech Republic, the variable *M3* Granger-causes *HICP* at a lag of one quarter and *HICP* Granger-causes *M3* with lag lengths of one, four, and five quarters (Table 8).

**Table 7** The results of the Granger causality test – M3 and GDP

| *M3_CZE/ GDP_CZE* | *Value of p – parameter* | $H_0$ | *GDP_CZE/ M3_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_GDP_CZE_1* | 1.2E-09*** | **Rejected** | *d_l_M3_CZE_1* | 0.0009*** | **Rejected** |
| *d_l_GDP_CZE_2* | 0.1719 | **Not rejected** | *d_l_M3_CZE_2* | 0.4995 | **Not rejected** |
| *d_l_GDP_CZE_3* | 0.2923 | **Not rejected** | *d_l_M3_CZE_3* | 0.4303 | **Not rejected** |
| *d_l_GDP_CZE_4* | 0.7455 | **Not rejected** | *d_l_M3_CZE_4* | 0.3135 | **Not rejected** |
| *d_l_GDP_CZE_5* | 0.1105 | **Not rejected** | *d_l_M3_CZE_5* | 0.8437 | **Not rejected** |
| *d_l_GDP_CZE_6* | 0.2511 | **Not rejected** | *d_l_M3_CZE_6* | 0.6655 | **Not rejected** |

We have marked the significant coefficient at the relevant level of significance with a star – 0.01 (***), 0.05 (**) and 0.1 (*). Regarding the results, only *p*-values less than 0.05 (i.e., ** and ***) are of interest to us.

*Source*: Author's own work based on the results of Gretl 1.9.4

**Table 8** The results of the Granger causality test – M3 and HICP

| *M3_CZE/ HICP_CZE* | *Value of p – parameter* | $H_0$ | *HICP_CZE/ M3_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_HICP_CZE_1* | 0.0009*** | **Rejected** | *d_l_M3_CZE_1* | 0.0164** | **Rejected** |
| *d_l_HICP_CZE_2* | 0.4963 | **Not rejected** | *d_l_M3_CZE_2* | 0.1824 | **Not rejected** |
| *d_l_HICP_CZE_3* | 0.4264 | **Not rejected** | *d_l_M3_CZE_3* | 0.3718 | **Not rejected** |
| *d_l_HICP_CZE_4* | 0.3359 | **Not rejected** | *d_l_M3_CZE_4* | 1.1E-05*** | **Rejected** |
| *d_l_HICP_CZE_5* | 0.8559 | **Not rejected** | *d_l_M3_CZE_5* | 0.0017*** | **Rejected** |
| *d_l_HICP_CZE_6* | 0.7041 | **Not rejected** | *d_l_M3_CZE_6* | 0.3157 | **Not rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

We also found that in the Czech Republic, the variable *M3* Granger-causes loans at a lag of six quarters and that loans Granger-cause the *M3* variable at a lag of one quarter (Table 9).

**Table 9** The results of the Granger causality test – M3 and loans

| *M3_CZE/ CRED_CZE* | *Value of p – parameter* | $H_0$ | *CRED_CZE/ M3_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_CRED_CZE_1* | 0.4726 | **Not rejected** | *d_l_M3_CZE_1* | 0.0008*** | **Rejected** |
| *d_l_CRED_CZE_2* | 0.5077 | **Not rejected** | *d_l_M3_CZE_2* | 0.5085 | **Not rejected** |
| *d_l_CRED_CZE_3* | 0.9377 | **Not rejected** | *d_l_M3_CZE_3* | 0.4248 | **Not rejected** |
| *d_l_CRED_CZE_4* | 0.5021 | **Not rejected** | *d_l_M3_CZE_4* | 0.3348 | **Not rejected** |
| *d_l_CRED_CZE_5* | 0.2465 | **Not rejected** | *d_l_M3_CZE_5* | 0.8538 | **Not rejected** |
| *d_l_CRED_CZE_6* | 0.0235** | **Rejected** | *d_l_M3_CZE_6* | 0.7057 | **Not rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

Because of the calculations, we can state that for the Czech Republic, the 2W repo variable Granger-causes *GDP* at a lag length of one quarter. This means that using the 2W repo variable can improve prediction of *GDP* in the CR at this lag length.

On the other hand, we can state that *GDP* Granger-causes the 2W repo variable at a half-year lag length (Table 10).

**Table 10** The results of the Granger causality test – 2W repo rate and GDP

| *2W REPO_CZE/ GDP_CZE* | *Value of p – parameter* | $H_0$ | *GDP_CZE/ 2W REPO_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_GDP_CZE_1* | 9.6E-09*** | **Rejected** | *d_l_2W REPO_CZE_1* | 0.0939* | **Not rejected** |
| *d_l_GDP_CZE_2* | 0.1374 | **Not rejected** | *d_l_2W REPO_CZE_2* | 0.0389** | **Rejected** |
| *d_l_GDP_CZE_3* | 0.2921 | **Not rejected** | *d_l_2W REPO_CZE_3* | 0.4366 | **Not rejected** |
| *d_l_GDP_CZE_4* | 0.8658 | **Not rejected** | *d_l_2W REPO_CZE_4* | 0.1035 | **Not rejected** |
| *d_l_GDP_CZE_5* | 0.0575* | **Not rejected** | *d_l_2W REPO_CZE_5* | 0.3313 | **Not rejected** |
| *d_l_GDP_CZE_6* | 0.2219 | **Not rejected** | *d_l_2W REPO_CZE_6* | 0.2361 | **Not rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

The 2W repo variable Granger-causes *HICP* at a lag length of one quarter while *HICP* also Granger-causes the 2W repo variable at lag times of one, four, and five quarters (Table 11).

**Table 11** The results of the Granger causality test – 2W repo rate and HICP

| *2W REPO_CZE/ HICP_CZE* | *Value of p – parameter* | $H_0$ | *HICP_CZE/ 2W REPO_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_HICP_CZE_1* | 0.0009*** | **Rejected** | *d_l_2W REPO_CZE_1* | 0.0164** | **Rejected** |
| *d_l_HICP_CZE_2* | 0.4963 | **Not rejected** | *d_l_2W REPO_CZE_2* | 0.1824 | **Not rejected** |
| *d_l_HICP_CZE_3* | 0.4264 | **Not rejected** | *d_l_2W REPO_CZE_3* | 0.3718 | **Not rejected** |
| *d_l_HICP_CZE_4* | 0.3359 | **Not rejected** | *d_l_2W REPO_CZE_4* | 1.1E-05*** | **Rejected** |
| *d_l_HICP_CZE_5* | 0.8559 | **Not rejected** | *d_l_2W REPO_CZE_5* | 0.0017*** | **Rejected** |
| *d_l_HICP_CZE_6* | 0.7041 | **Not rejected** | *d_l_2W REPO_CZE_6* | 0.3157 | **Not rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

Further, the 2W repo rate variable Granger-causes loans at a lag of six quarters, and loans Granger-cause the 2W repo rate variable at lags of one and six quarters (Table 12).

**Table 12** The results of the Granger causality test – 2W repo rate and loans

| *2W REPO_CZE/ CRED_CZE* | *Value of p – parameter* | $H_0$ | *CRED_CZE/ 2W REPO_CZE* | *Value of p – parameter* | $H_0$ |
|---|---|---|---|---|---|
| *d_l_CRED_CZE_1* | 0.5745 | **Not rejected** | *d_l_2W REPO_CZE_1* | 0.0854*** | **Rejected** |
| *d_l_CRED_CZE_2* | 0.7568 | **Not rejected** | *d_l_2W REPO_CZE_2* | 0.2958 | **Not rejected** |
| *d_l_CRED_CZE_3* | 0.7913 | **Not rejected** | *d_l_2W REPO_CZE_3* | 0.3694 | **Not rejected** |
| *d_l_CRED_CZE_4* | 0.8951 | **Not rejected** | *d_l_2W REPO_CZE_4* | 0.1587 | **Not rejected** |
| *d_l_CRED_CZE_5* | 0.3201 | **Not rejected** | *d_l_2W REPO_CZE_5* | 0.3548 | **Not rejected** |
| *d_l_CRED_CZE_6* | 0.0147** | **Rejected** | *d_l_2W REPO_CZE_6* | 0.0037** | **Rejected** |

*Source*: Author's own work based on the results of Gretl 1.9.4

## 5 Results and discussion

On the basis of these analyses – in which we observed how the M3 monetary aggregate's value influenced *GDP*, *HICP* and the volume of loans provided by banks to the nonfinancial sector in the Czech Republic – we came to the conclusion that there are no long-term relationships between the investigated time series, because we were unable to prove cointegration for any of the time series. We can thus state that the M3 monetary aggregate does not have long-term influence on GDP, HICP, or the volume of loans provided to the nonfinancial sector in the Czech Republic, however, short-term relationships do exist. At the same time, we can state that in the Czech Republic, interest rates do not visibly influence GDP, HICP, or the volume of loans provided by banks to the nonfinancial sector over the long term, because again there are no existing long-term relationships between the time series examined, only short-term relationships. These empirical findings do not correspond with conventional economic theory. Despite this, other authors (e.g., Wu and Xia, 2016; Crowder and Hoffman, 1969; Arestis and Sawyer, 2002) have come to similar conclusions. From this observed time period up until the outbreak of the financial crisis, the CNB conducted conventional monetary policy using changes in interest rates. Naturally, it was shown that during the financial crisis, not only the CNB but also the ECB, the FED, and the Bank of England needed to resort to unconventional monetary policy instruments, because conventional instruments had failed for meeting set inflation targets. The decisive point for using currency intervention, which the CNB has used only exceptionally since 1997 in the form of a managed floating exchange rate, was the essentially zero interest rates together with the course of the economy, which required a looser monetary policy.

Because we were unable to prove long-term relationships between the M3 monetary aggregate and *HICP*, we can verify that the CNB's decision to abandon its monetary policy regime of targeting the money supply and adopt inflation targeting in 1998 (CNB, 2003–2018c) was correct. On the other hand, we proved via Granger causality that there are still short-term relationships between the variables M3 and HICP. Therefore, the M3 monetary aggregate should still function as an important ratio for monetary policy. This is confirmed by the ECB's approach, which monitors M3 development with a reference growth rate of 4.5% as part of its two-pillar strategy for evaluating inflation risk. Analysing money's behaviour was always a cornerstone of the ECB's monetary analysis and thus also of its overall monetary policy strategy. In this regard, models of the demand for money provide a framework for explaining money's behaviour and evaluating price stability over the medium term. As stated by Dreger et al. (2019), if interest rates are at the lower limit of zero, analysing the money supply becomes even more important. At the same time, we also determined the following with the help of *HICP*'s Granger causality relationship to *M3*: rising price levels also simultaneously increase the demand for money, which satisfies the demand for more expensive goods, which in the end results in the growth of the money supply. Because the money supply is currently considered endogenous – as well as significantly influenced by the demand for money – we can use this in our understanding of the relationship by which the development of *HICP* can be used to better predict the development of *M3*.

## 6 Conclusion

The goal of this paper was fulfilled, the empirical results show that there are no long-term relationships between the impacts of monetary policy of the Czech National Bank on selected economic indicators; there are only short-term ones.

The CNB primarily uses interest rates to achieve price stability in the CR. At the same time, it was one of the first central banks in the world to react to the global financial crisis with a loose monetary policy conducted by gradually lowering interest rates, which entailed the 2W repo rate decreasing from 3.5% to 1% between August 2008 and December 2009. Just as for the 2W repo rate and inflation, we did not find a long-term relationship between the 2W repo rate and GDP. This means that these empirical findings are in conflict with what conventional economic theory generally considers to be true. Even despite the drop in the basic interest rate, which fell to 0.05% in 2012, the set inflation target was not achieved. Therefore, the CNB was forced to adopt an unconventional monetary policy tool, i.e., exchange rate intervention. This indicated that the CNB was not able to achieve its inflation target even using nearly zero interest rates and that conventional monetary policy was seen as ineffective. As mentioned above, there is no long-term relationship between loans provided by banks to the nonfinancial sector and the 2W repo rate for the period examined. When the 2W repo rate is lowered, the interest rate channel of the transmission mechanism for the Czech economy should result in a decrease in interest rates on the interbank market, which should lead to a drop in the interest rates announced by banks. The outcome should be a revival of the aggregate demand and decreasing pressures on price level growth. However, as we found, changing the 2W repo rate does not lead to achieving the set inflation target in the Czech Republic nor does it produce the effects predicted for loan provision to the nonfinancial sector.

Therefore, it is impossible to confirm the monetarist thesis that monetary aggregates are to be considered a decisive factor for conducting monetary policy over the long term. In the long term, the M3 monetary aggregate does not influence the selected economic variables, which naturally does not exclude the possibility that it could have short-term economic effects. These conclusions are also supported by the fact that the CNB established inflation targeting as its monetary policy regime, which works with a transmission mechanism that differs from money supply targeting, which was abandoned by the CNB at the end of 1997.

Up until 2003, significant growth in loans was primarily caused by the relatively low levels of bank debt that economic entities had maintained in the past. At that time, new loan products were introduced, and simultaneously, both the price level and interest rates dropped. We can also see a slump in the volume of loans provided during and after the financial crisis, which was given by the pro-export focus of the Czech Republic's economy. Because of decreased demand, production, i.e., GDP saw a steep drop and unemployment increased. Therefore, even lowering the 2W repo rate in 2007 did not result in the desired growth in the volume of loans being provided or economic growth.

At the present, the actual mechanisms of long-term monetary policy influence are relatively unclear but would be an interesting subject of future interest for monetary economists. Monetary policy should not focus exclusively on inflation, but rather take into consideration the actual – and potentially long-term – side effects of other economic influences that need to be included in the decision making process, as well as *GDP*, the volume of provided loans, and the exchange rate. It is not currently possible to evaluate

the effectiveness of Czech monetary policy in the sense of establishing independent monetary targets that do not rely on the outer world, because the CNB's monetary policy is determined by developments not only in the eurozone but also in the rest of the world, which is something that could provide an opportunity for further research. In view of the results and comments, it is possible to study the impact of monetary policy in other countries as part of further research and then compare the results with each other.

## Acknowledgement

This research was supported by the Czech Science Foundation (Project No. GA 20-00178S) and by the Student Grant Competition of University of Pardubice ((Project No. SGS_2020_014). A special thanks to Matěj Klofát who help the author with statistical analyses.

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