The Relationship between Monetary Aggregates and Inflation – the Case of the Czech Republic

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Abstract

Based on empirical data, this paper attempts modelling, in general terms, the relationship between money supply and inflation, i.e., the relationship between the inflation rate and monetary aggregates. Our basic idea is to estimate time-shift parameters and, subsequently, a leading indicator that would provide information on whether and with what delay changes in the money supply will be reflected in the price level evolution. The aim of the paper is to formulate and, on the basis of the data, to confirm or refute the hypothesis that changes in the value of monetary aggregates imply changes in the inflation rate and, therefore, whether or not monetary aggregates are certain indicators signalling further evolution of the inflation rate. Monthly data for the Czech Republic from the years 2002–2022 have been used to model and test our hypotheses. The analysis has failed to show a statistically significant relationship between the individual monetary aggregates and the inflation rate.[4]

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Consumer price index, monetary aggregates, time lag, regression dynamic model, estimation of dependence intensity at a given lag	*https://doi.org/10.54694/stat.2023.14*	*C22, E31, E58*

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INTRODUCTION

The high inflation rate in (not only) the Czech Republic in 2022 has raised a number of questions about the causes of price increases in this period, as well as about the differences between this period and other periods characterised by dramatic changes in inflation rate values. This approach also raises a broader economic issue of the monetary policy tools and the effectiveness of inflation targeting in unfavourable and, more recently, often very non-standard economic conditions. It also seems to have been changing the view of the relationship between price levels and the money supply and demand.

The theory of economic liberalism is based on the idea that a high inflation rate in the long run is caused by excessive growth of the money supply. However, the opposite view is also held, that growth in the money supply and deferred purchasing power do not primarily cause the price level to rise because they are not the cause but the effect of economic activity. The question then arises as to whether or not increased money supply (so-called quantitative easing, even in the broader international context) by central banks is a significant cause of price increases. Or whether the rise in the price level (as expressed by the inflation rate) is rather the result of other economic processes caused by specific phenomena at a given stage in the development of a national economy (such as wars, disasters, shortages of raw materials and supplies in supply chains, etc.). In other words, whether the growth of the money supply is not a cause but, in fact, a consequence of rising prices.

In this context, the aspect of time must also be considered. As we noted above, economists often talk about long-term high (or moderate) inflation when discussing the relationship between money supply and the inflation rate. But what is the measure of this 'long-term' aspect? It is clear that when prices rise due to a one-off price shock (a price spike in oil, gas, etc.), we cannot talk about a long-term high inflation rate in the sense of its definition. Nevertheless, such spikes are dramatically reflected in price movements for a wide range of goods and services and will be reflected in the inflation rate. The question is, of course, to what extent and for how long. And also to what extent they will disrupt the overall performance of the economy, particularly its fiscal parameters, which in turn must be reflected in the inflation rate.

This demand-side cause of the price level rise leads us to another idea. If input prices (of raw materials, energy, etc.) go up, output prices rise as well. This is soon reflected in the rise in final consumption prices and, consequently, in the rise of the consumer price index-based inflation rate. The fast-onset effect is then represented by problems in the household economy; households' standard of living falls when consumption prices rise rapidly. In such a situation, governments try to mitigate the impact of high price levels on households by increasing social benefits and introducing other measures to support low-income households. Moreover, because these measures are often not effectively targeted, they generally lead to massive inflows of money, even into segments of the economy where it is not strictly necessary. This phenomenon causes a rapid increase in general government spending and leads to a growing deficit. And, of course, it also leads to an increase in the volume of money in circulation, i.e., to an increased money supply. This is, in turn, reflected in the growth of monetary aggregates, which are indicators of the money supply or the amount of money in the economy. This is also the nature of the current inflation trend in the Czech Republic. However, is this just a short-term effect of rising input prices, or can we talk about a longer-term relationship between the inflation rate and monetary aggregates? Even in the sense that the high price level is the cause for the growth of the money supply, not its consequence.

So what is the true direction of the relationship between the money supply and the price level? Is price growth, as expressed by the inflation rate, a consequence of or a cause for the changes in the values of monetary aggregates? Or is it the ground truth that no statistically significant relationship between the evolutions of these variables can be meaningfully modelled?

We will try to answer these questions by analysing monthly data on the inflation rate and money supply (i.e., individual monetary aggregates) in the Czech Republic for the period 2002–2022.

1 STATE OF THE ART

A number of authors have addressed the relationship between inflation rates and monetary aggregates. The impact of the development of monetary aggregates or central bank interest rates on economic variables – employment, inflation rate, GDP, etc. – is used to assess the effectiveness of central bank's monetary policy. The relationship between the inflation rate and the evolution of individual monetary aggregates is probably one of the most frequently discussed topics regarding the existence of a dependency, but the conclusions of such discussions can certainly not be regarded as clear-cut.

The basic idea of the relationship between the evolution of monetary aggregates (which represent the money supply) and the evolution of prices (the inflation rate) is based on the quantity theory of money, which defines a direct relationship between the money supply and inflation.[5] According to this theory, an increase in the amount of money in the economy causes prices to rise (Friedman and Schwartz, 1963) and the amount of money in circulation affects prices through its impact on demand. This theory then formed the basis of the practical monetary policies applied by central banks (after WWII), whereby these institutions tried to predict and influence prices by restricting or increasing the money supply. However, this tool has been gradually proven to be ineffective and unreliable (especially in the short run) and central banks switched to direct inflation targeting. Guéné (2001) comments that strictly monetarist policies had already (i.e., by 2001) been virtually abandoned.

Questioning the direct relationship between the evolution of monetary aggregates and inflation has also resulted in analysts' efforts to confirm or refute this basic postulate of monetarism. Various models of temporal and spatial analysis have been applied to this end.

Using U.S. data, Halsag (1990) analysed the relationship between the monetary base (aggregate M0), aggregates M1 and M2, and price evolution. He concluded that the M0 and M2 aggregates, but not the M1 aggregate, appear to be useful for predicting the inflation rate. Guéné (2001), based on a detailed analysis of Eurozone data, concludes that price changes are (in the short run) only insignificantly explained by changes in the volume of monetary aggregates. He also argues that the quality of the predictive model used could be improved by incorporating asset price changes into the inflation rate.[6] Mischkin (2001) analyses the evolution of monetary policy in developed countries[7] in the context of inflation targeting. He concludes that monetary inflation targeting has proved successful in Germany and Switzerland, but not in other countries. The same conclusions for the case of Switzerland can be found in Baltensperger (2001), or Kirchgassner and Wolters (2010); Jordan and Peytrignet (2001) consider that the aggregate M3 (compared to M1 and M2) has been shown to have a better predictive power. A study by Černohorská and Maléř (2019) is based on an analysis of data from Switzerland, the Czech Republic and Israel to prove or disprove the hypothesis of the predictive ability of the M3 aggregate with regard to the inflation rate. The authors' choice of this trio of countries was driven by the central banks' decisions to introduce foreign exchange interventions, which naturally led to an increase in the value of the M3 monetary aggregate. Using co-integration analysis, they concluded that a long-term relationship between the evolution of the M3 aggregate and the inflation rate was not demonstrated in any of the countries studied. The impact of foreign exchange interventions as a monetary policy instrument on the evolution

[5] In the case of the relationship between money supply and inflation, we refer to the so-called equation of exchange derived by J. S. Mill in 1948. It holds that $M \cdot V = P \cdot Q$, where M is the money supply, V is the quantity of money, P is the price level, and Q is the quantity of goods and services.

[6] The problem of the absence of assets (houses and apartments purchased by households) in the consumer price index basket has become a subject of debate, especially in the context of their prices rising faster than those of short- and long-term consumption items after the 2008–2009 crisis. As a result, inflation rates in a number of countries now also take housing price developments into account.

[7] The U.S.A., Canada, the U.K., Germany, Switzerland, New Zealand, and Australia.

of the inflation rate was also examined by Fratzscher et al. (2019) on a sample of 33 countries. The authors conclude that money supply growth due to foreign exchange intervention does not significantly affect the inflation rate.

De Gregorio (2002) uses the example of twenty countries to show that even a very rapid growth in monetary aggregates is not necessarily associated with an increase in the inflation rate and that the time-series relationship between the inflation rate and monetary aggregates (specifically M1 and M2) appears to be significant only in years of high inflation. When the inflation rate is low, the dependence turns out to be statistically insignificant. In this context, King (2001) argues that the dependence of changes in monetary aggregates and inflation rates observed over a long time horizon becomes insignificant as the period under evaluation becomes shorter. On the other hand, he is concerned about the denial of monetarist principles and the neglect of the role of monetary aggregates in central banks' monetary policy models. Hale and Jorda (2007), based on an analysis of historical time series of monetary aggregates and inflation rates in the U.S. and the Eurozone, showed that, in the case of the U.S., monetary aggregates have virtually zero predictive power for forecasting the inflation rates; in the case of the Eurozone, their results were inconclusive. Woodford (2002) reached similar conclusions regarding the situation in the U.S.

Ramos-Francia, Noriega and Rodriguez-Perez (2017), on the basis of an extensive econometric analysis of data for Mexico from 2001–2014, show that money supply affects the price level only in the long run, but does not affect short-term deviations from that level. The predictive power of monetary aggregates is thus minimal for short-term forecasts of inflation rates. The problem of the inflation rate's volatility in relation to the evolution of monetary aggregates was addressed by Papadia and Cadamuro (2021). They confirmed the logical conclusion that, if the inflation rate is more or less stable (i.e., around the 2% target), the predictive ability of monetary aggregates is zero, and the variables under consideration appear to be independent of each other. They thus quite rightly called into question the general validity of the monetarist thesis of a "functional" relationship between monetary aggregates and the inflation rate. Monetary aggregates can help predict inflation rates only in the context of an unstable economy, unstable from the monetary and inflation-rate viewpoints (e.g., Italy in the 1970s and 1980s). A study by Csiki (2022) conducted on data for the U.S. over the period 2007 through 2022, looked at monetary expansion in the context of asset purchases after the 2008 crisis and partly during the COVID-19 pandemic. Money supply growth due to the asset purchase program and non-realised demand during the pandemic raised concerns about price increases. Using a vector autoregression model, the author showed that significant changes in monetary aggregates are built into inflation expectations and that asset purchase programs helped the central bank achieve its medium-term inflation target.

The specific situation of developing countries in terms of monetary inflation targeting was described and analysed by Abango, Yusif and Issifu (2019). Using data for Ghana in the period 1970 through 2015 and using an autoregressive distributed lag (ARDL) model, they showed that monetary inflation targeting implied keeping inflation rates in the lower band only in the short run. In contrast, direct inflation targeting proved to be more effective in keeping inflation rates lower in the long run. At the same time, they pointed out that it was difficult to stably keep the inflation rate within the target band in Ghana.

The view we mention in the introduction, namely, that the inflation rate may be an explanatory rather than the response variable in the relationship between the evolution of monetary aggregates and the inflation rate is, for example, held by Murayama (2017). Using Japan as an example, he shows that money supply growth is not a cause but a result of price growth. He therefore finds the excessive quantitative release by the Bank of Japan, which did not lead to the expected price increases, problematic and disruptive to a well-functioning financial system. The ambiguity of the real relationship between money supply growth and the inflation rate was summarised by Mandelman (2021). Referring to the period during and after WWII, he showed that a jump in the money supply may not cause a jump in prices. This is due to the existence of a number of factors affecting the behaviour of banks, households, the government and companies. During WWII, the U.S. money supply was doubled, but shortages of consumer goods limited the demand and the subsequent price increases. After the end of the war (1946–1947), the annual inflation rate reached 20%, but became stable in two years. The COVID-19 pandemic severely curtailed household and business demand, and meant an increase by 25% in the money supply in 2020. However, this growth did not lead to sudden inflationary pressures.

An analysis of the relationship between the monetary aggregate M3 and the inflation rate in the U.S., Japan[8] and the Czech Republic in the period 1960–2007 was conducted by Jílek (2015). Using annual data, he showed a strong correlation[9] between lagged aggregate M3 (or M2 for Japan) and the inflation rate for all countries studied. An obvious problem in this analysis was that it was only based on annual data (while both quarterly and monthly data were available) and the sole outcome of the analysis was the correlation coefficient. A high value of the correlation coefficient in the case of time series may reflect only an apparent correlation. Moreover, even with a high degree of correlation, the question is whether such a dependence can always be modelled and then factually justified.

The situation in the Czech Republic and in the Eurozone was, from the point of view of the conditions for monetary policy implementation, discussed by Kapounek (2010). By analysing data from the period 2002–2010 for the Czech Republic and from the period 1999–2010 for the Eurozone, he showed that there is no long-term stable relationship between the money supply and the expected inflation rate, or between the money supply and the interest rate.

A detailed analysis of the relationship between monetary aggregates and inflation rates using the U.S. as an example can be found in Michl (2019). Using quarterly data for the period 1959 through 2018, the author concludes that there is no close relationship between the money supply (aggregates M1, M2 and M3) and the inflation rate. He sees the reasons for this phenomenon in the long-run low inflation and in the declining velocity of money. If the inflation rate is low or its changes are insignificant within a certain range, it is clear that it is practically impossible to find a suitable explanatory variable in such a situation.

The review presented above shows that the theoretical monetarist concept of the inflation rate's dependence on the evolution of monetary aggregates is questionable and probably cannot be relied upon much in practical economic decision-making. If this relationship were generally valid, it would have to hold in both the short and long runs, at both low and high inflation rates, in both advanced and emerging economies. Economic theory establishes relationships between concepts and formulates them into formulae that give the impression of functional dependence.[10] In economics, however, functional dependences never hold; we are only able to model loose dependence, since the evolution of the variables under study is always influenced by a number of external factors that distort the "would-be-functional" relationship. In the case of the relationship between monetary aggregates and the inflation rate, these factors can undoubtedly include government spending, the changing tax system, the political situation affecting the behaviour of businesses and households, etc. It is therefore a very diverse combination of various causes for the behaviour of monetary aggregates and inflation rates, which are, moreover, time-varying and effectively non-repeatable. It is therefore practically impossible to find a model relationship that is a satisfactory and plausible summation of all these diverse and highly unstable causes over time. Moreover, a separate problem is whether we are able to substantively defend statistical free dependence at all. The explanation is simple: inflation is highly sensitive to its causal roots, and these roots may differ significantly from one another in different time periods. Therefore, the evolution of the inflation rate cannot be described by a lump-sum statistical dependence or a lump-sum econometric model.

[8] In Japan, the respective aggregate was M2.
[9] But not causality, as the author himself stressed in many instances in that article.
[10] Inclusive of the "equation of exchange".

The validity of the relationships (concepts) defined by economic theory can only be demonstrated with the aid of data.[11] We must therefore work with statistical indicators and their values. In addition, here is another problem that disturbs the validity of the "functional" relationship – this is the discrepancy between the content of the concept and its quantifiable form, i.e. the indicator.[12] Unless a strong and valid dependence has been established between the variables under consideration, it is inappropriate to use such relationships to guide economic policy and to make major decisions on the policy. Such an instrument is bound to fail over time (as economic conditions change). And even if, despite all the problems mentioned above, the statistical data eventually prove that a dependency does exist, the causal character of this dependence is not proven.[13] It also goes without saying that two variables may only apparently be statistically dependent since they are both influenced by a third variable (sometimes overt, sometimes very well hidden). All this is a problem not only with respect to the relationships between monetary aggregates and inflation rates analysed here, but also to other relationships presented by economic theory, such as those given by the Phillips curve (see, e.g., Atkeson and Ohanian, 2001; Lansing 2002; Hindls and Hronová, 2015).

The controversial nature of the relationships between the evolution of monetary aggregates and the inflation rate has led us to the idea of checking whether it is possible to model their dependence in the case of long-run time series for the Czech Republic and to verify the direction of this dependence. Is it true that an increase in money in circulation leads to price increases, or is the price growth the cause of money supply growth? Or is the relationship between these variables insignificant? Or even the observed time series may indicate a certain level of formal correlation, but their relationship can in fact not be modelled and is therefore useless for the purposes of predictions?

2 BASIS OF ANALYSIS

In order to test the validity of the respective hypothesis, it is first necessary to identify and define the content and periodic nature of the indicators so that they, as closely as possible, to the theoretical economic assumptions and their values are capable of reflecting the changing situation during the years under evaluation. At the same time, it is necessary to decide how long a time series period should be chosen in order to satisfy not only the formal requirements for the use of time series analysis methods but also the substantive requirements, i.e., the requirements of adequate demonstrability and justifiability of the economic cycle phase.[14] The final task of this analysis will be to find (if any) the time lead or lag reflecting the response of the inflation rate to the evolution of monetary aggregates or vice versa. The definition of the indicators and their subsequent analysis will be based on data for the Czech Republic available on the websites of the Czech Statistical Office (see: <*www.czso.cz*>) and the Czech National Bank (see: <*www.cnb.cz*>); these indicators are methodologically internationally comparable.

The indicators initial for our analysis are the inflation rate and monetary aggregates, whose values will be monitored on a monthly basis. The inflation rate is defined as the relative increase corresponding to the consumer price index. The monthly inflation rate provides information on the percentage change in the price level (of consumer goods) in the month under review compared to the immediately preceding month. It is determined as the ratio of the underlying consumer price index in the month under review

[11] Lord Kelvin's (1824–1907) quote is certainly worth mentioning here: "When you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind".

[12] This is the so-called adequacy problem. Its striking example is the relationship between the economic concept of inflation and the statistical indicator of the inflation rate, which only characterises the development of consumer prices.

[13] This is a well-known problem in medicine – the statistical dependence may exist, but doctors are, at the current level of knowledge, often unable to reveal causal dependence.

[14] However, this requirement already contains a hidden seed of a "correlation" trap: the causes of changes in the inflation rate will be so different over the period under review that it will be virtually impossible to find a unifying view of these multiple causes.

and the underlying consumer price index in the preceding month, with the base being the same in both cases (in the Czech Republic, the base is the 2015 average).

Monetary aggregates represent the money supply in an economy. In general, a narrow (M1), medium (M2) and broad (M3) aggregates are defined. The M1 aggregate includes the currency in circulation, i.e., banknotes and coins, as well as balances that can be immediately converted into currency or used for non-cash payments, e.g., overnight deposits. The M2 aggregate includes M1 plus deposits with a maturity of up to two years and deposits with a notice period of up to three months. Depending on liquidity, these deposits can be converted into M1 components, but in some cases, there may be restrictions, such as the need to give notice, default, penalties or fees. The M3 aggregate includes M2 and negotiable instruments issued by the MFI subsector. This aggregate includes certain financial-market instruments, in particular financial market fund shares and units as well as repo operations. The high degree of liquidity and price certainty ensure that these instruments are close to deposits. Their inclusion and the cascading architecture of the aggregates mean that M3 is less affected by substitution between different categories of liquid assets, making it more stable. In our analysis, we have used both the month-on-month growth rates of the aggregates M1, M2 and M3, as well as their end-of-month balances (in CZK million).

We have faced certain formal problems when choosing the length of the monthly time series; the Czech monetary statistics do not provide such a long time series of the aggregates as encountered in most Western countries; and the Czech economy underwent an extensive transformation of ownership relations and economic management instruments in the early 1990s. These considerations have finally led us to choose the period of 2002 through 2022 (more than 240 observations are thus available when choosing a monthly periodicity).

This length is not only suitable for stochastic time series modelling tools; it is also sufficient to capture the phases of the business cycle as they manifested themselves in the Czech economy during this period. These phases, for example, include the accelerated dynamics of the Czech economy at the beginning of the millennium (with a peak around 2005–2007), the effects of the global crises in 2008–2009, and the recession in 2011–2013, then the recovery lasting until 2017, and the subsequent gradual slowdown in the performance of the Czech economy (noticeable since the beginning of 2018), and last but not least the economic downturn due to the global pandemic.

The uneven evolution of the average annual inflation rate in the Czech Republic between 2002 and 2021[15] (see Figure 1) requires a substantive analysis of the causes for this evolution in individual phases of the economic cycle.

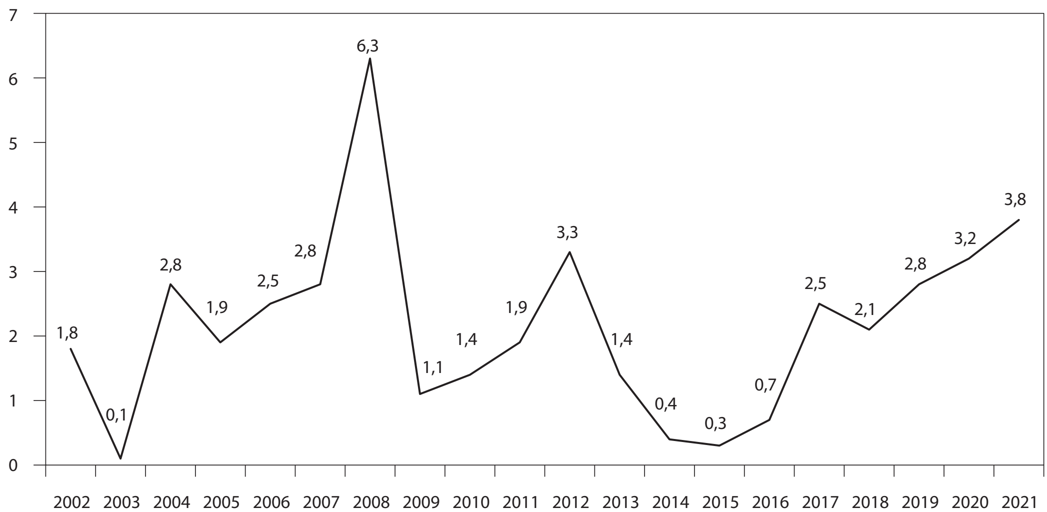
In the early years of this millennium, the inflation rate was kept around the inflation target (2%), the money supply did not show any significant trajectory, central bank and retail bank interest rates were kept low, and household consumption was also stable. All these parameters were rather indicators of positive expectations in the economy and stimuli for further gradual growth. Fiscal parameters were also in line with the potential of the Czech economy and were a harbinger of a rather upward trajectory. This was indeed evident in 2004–2007, when the performance of the economy started to increase and was still at the limit of its potential.

At that time, a sudden dramatic reversal occurred (beginning in 2008), caused by the global economic crisis. The U.S. mortgage crisis was the primary cause of that turning point, which gradually escalated into a global financial crisis. The high oil prices in early 2008 also played a significant role, leading to a fall in real GDP values worldwide and a sharp rise in consumer prices. The world oil price was fostered not only by speculative trades (pension and hedge funds buying commodities to reduce portfolio risk stemming from equity markets), but also by the weak dollar and growing demand from China prior

[15] The 2022 inflation rate was not yet available at the time of writing this text, but its real value will be extremely high, at least around 15%.

to the upcoming Olympics. Moreover, when the financial crisis hit in its full force in autumn 2008, it swept away not only the world's leading banks and stock markets, but also the oil prices. From a peak of USD 147 per barrel in July, it fell by a third in two months and continued to fall until it broke the USD 40 per barrel mark at the end of 2008.

Figure 1 Average annual inflation rate in the Czech Republic (%)



Source: Czech Statistical Office <*www.czso.cz*>

This situation naturally had a devastating effect on the small and open Czech economy. The annual inflation rate rose sharply (2008, see Figure 1), while the value of the monetary aggregate M3 rose by 13.6% year-on-year (December 2008 with respect to December 2007). The effect known as consumption smoothing also played a significant role, as Czech households gradually moderated their consumption. This led to a rapid decline in the inflation rate (2009), but monetary aggregates stagnated. This can be easily explained by the fact that Czech households' real income has naturally been falling since 2008, so there was not much to put aside into monetary aggregates. In the 2011–2013 period, which was characterised by a deterioration of fiscal parameters in the Czech economy (and not only in the Czech Republic), the inflation rate was below the inflation target; however, the money supply grew.[16] So did government spending.

By contrast, a different trajectory can be observed from the end of 2020 to the present day. As noted above, the COVID-19 epidemic knocked down household and business demand, and logically implied an increase in the money supply (by 10.0%) in 2020. Households and businesses were forced to postpone their consumption, only to subsequently plunge funds into purchases and consumption when pandemic restrictions were loosened. This turn of events, together with the injection of money into the economy, affected the inflation rate only about a year later; the latter began to rise more significantly from as late as autumn 2021, and was accompanied by an annual increase in monetary aggregates of about 6%.

Similarly, since the first months of 2022, when the "Czech" inflation rate started to pick up at an unusual pace,[17] the M1 aggregate has logically shown a certain decline[18] (this is about currency and also

[16] The annual monthly inflation rate amounted to 12.7% in March 2022, 17.2% in June 2022 and 18.0% in September 2022.
[17] The annual monthly inflation rate amounted to 12.7% in March 2022, 17.2% in June 2022 and 18.0% in September 2022.
[18] In July 2022, the value of the M1 aggregate M1 fell by 4.3% as compared to July 2021.

about balances that can immediately be converted into currency or used for non-cash payments), but the other aggregates, which are characterised by a more limited availability of liquidity, grew despite high commodity prices.[19] Households therefore postponed consumption, perhaps because of the extremely high prices during that period, or because they were "waiting" for a return to price stability, especially for medium- and long-term consumption items. It is therefore a slowdown in the velocity of money circulation that must logically have obscured the relationship between the movement of monetary aggregates and the evolution of the inflation rate. Therefore, the model's capture of this relationship (using the relevant correlation statistics) is, in fact, not sufficiently convincing.

It follows logically that the examined relationship between the evolution of the inflation rate and the evolution of monetary aggregates must be very loose. The substantive justification is also manifested in the model (see below), using stochastic techniques.

3 METHODOLOGY OF ANALYSIS

The cross correlation function (CCF) has been used to test the hypothesis whether there is a relationship between monetary aggregates and the inflation rate in the Czech economy and a certain time shift that needs to be found and confirmed by appropriate tests. See Box, Jenkins and Reinsel (1994), Pankratz (1991) or Wei (2006) for more details.

The CCF is defined as:

$$\rho_{XY}(k) = \frac{\gamma_{XY}(k)}{\sigma_X \sigma_Y}\,, \tag{1}$$

where X_t and Y_t are the time series to be analysed. The CCF's value at k is then defined as the covariance between X_t and Y_{t+k} for $k = 0, \pm 1, \pm 2, \ldots$, divided by a product of the standard deviation values of both series, where σ_X and σ_Y are the standard deviation values for the series X_t and Y_t (respectively). It is clear that, for the CCF relationship, the following formula holds true:

$$\rho_{XY}(k) = \rho_{YX}(-k)\,. \tag{2}$$

The CCF is defined for stationary time series and its advantage is that it measures not only the strength of the linear dependence between two time series, but also the direction of this dependence. From its values we can thus determine the time shift of the dependence between the analysed series.

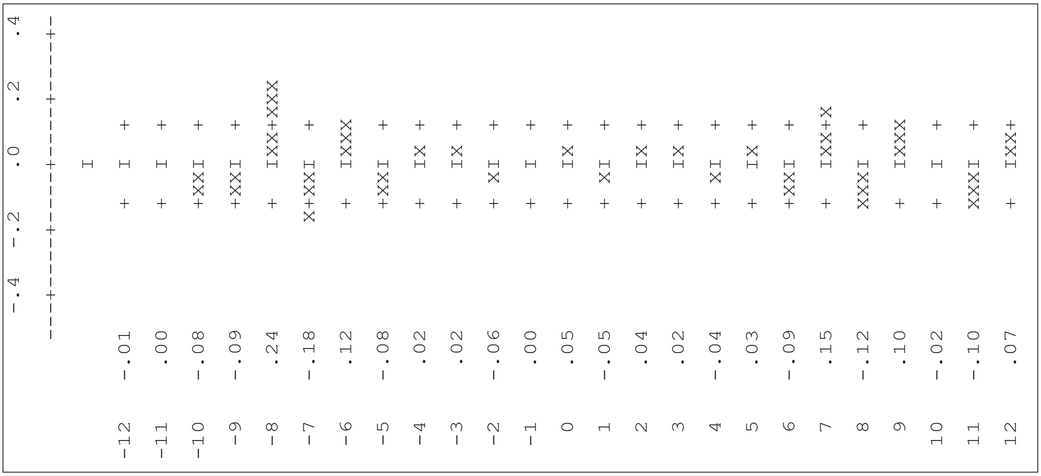
In order to apply the CCF, we first need to adjust the time series to be stationary; and to achieve stationarity, we use normal and seasonal differencing. Only then can we calculate the CCF values and decide whether there is a linear dependence between the series under analysis. This linear dependence will be examined not only at the same-time points t; we will also look for dependence including time shift to both sides, i.e., at times t, $t\pm1$, $t\pm2$, etc. For the purpose of this analysis, we will consider the time series of monetary aggregates M1, M2 and M3 in two forms. First, in the form of month-on-month relative growth rates (series labelled M1, M2 and M3), and second, in monetary balance values at the ends of the months (series labelled M1state, M2state and M3state).

First of all, we will study the time series correlograms of the inflation rate in relation to the aggregate M3, or M3state. Ordinary differencing (of order 1) and seasonal differencing (of order 12) have already been applied to all series. Let us look at the graphical progression of the CCF first for the M3 series

[19] In July 2022, the value of the M2 aggregate increased by 4.9% compared with July 2021; in the case of the M3 aggregate, the increase amounted to 5.9%.

(relative increments) and the inflation rate series (see Figure 2). We do not assume that the dependence either way from time point t might have a lag (or lead) longer than 1 year.

Figure 2 CCF between inflation rate and M3



Source: Authors' own calculations

We can clearly see in Figure 2 that a very strong linear dependence can be observed at time points t and t−8. In addition, there seems to be a weak linear dependence with lead times −8 and +7. Let us therefore try to construct a linear dynamic model to describe this dependence. The entire theory of linear dynamic models is described in detail in Box, Jenkins and Reinsel (1994), Pankratz (1991) or Wei (2006). The general model can be written as follows:

$$Y_t = c + \nu_0 X_t + \nu_1 X_{t-1} + \nu_2 X_{t-2} + \ldots + \nu_K X_{t-K} + \frac{1}{(1-\phi_1(B))(1-\Phi_1(B^L))}\,\varepsilon_t\,, \tag{3}$$

where Y_t is the output series, X_t is the input series, c is constant, ν_i are unknown parameters for $i = 0, \ldots, K$, $\phi_1(B)$ is the autoregressive operator of order 1, $\Phi_1(B)$ is the seasonal autoregressive operator of order 1, ε_t is the random variable (white noise), B is the shift operator ($BY_t = Y_{t-1}$), and L is the length of the season.

Let us now estimate the model parameters. All calculations are performed in SCA software. We consider the dependence at time point t and then with lags 1, 2, ..., 10. The variables $\nu0$, $\nu1$, ..., $\nu10$ represent time lags of 0, 1, ..., 10. The output (cf. Table 1) shows that in none of these instances did the coefficient on the time lagged variable turn out to be significant, despite the coefficient of determination being almost equal to 1. It can be concluded that the occurrences of the significant CCF values at different time points are only accidental and cannot be described by the model.

Let us now have a look at the situation for the M3state time series (the M3 aggregate in monetary terms, i.e., the balances at the ends of the months). Figure 3 shows the CCF values for the inflation rate series and the M3state aggregate.

In none of these instances was the CCF value statistically significantly different from 0. The entire analysis is performed at a significance level of $\alpha = 0.05$; Figure 3 thus shows the 95% confidence interval from which the CCF value did not deviate in any of these cases.

Table 1 SCA software output

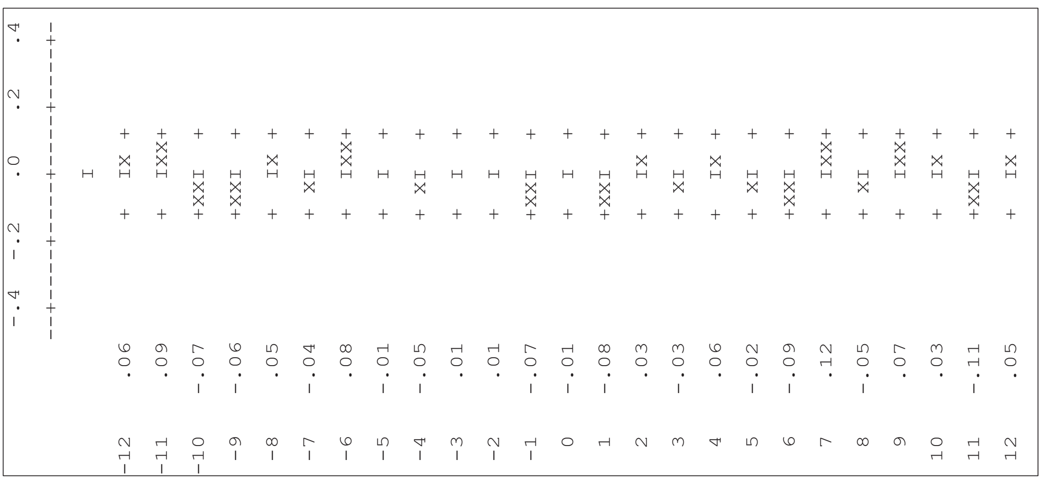
Summary for univariate time series model – INFM3

Variable	Type of variable	Original or centered	Differencing	
M3	Random	Original	(1–B^1)	(1–B^{12})
INF	Random	Original	(1–B^1)	(1–B^{12})

Parameter label		Variable name	Num./denom.	Factor	Order	Constraint	Value	STD error	T value
1	V0	INF	NUM.	1	0	None	–3451.9047	4122.7372	–.84
2	V1	INF	NUM.	1	1	None	–7136.5605	5277.9051	–1.35
3	V2	INF	NUM.	1	2	None	–1434.0809	5836.6937	–.25
4	V3	INF	NUM.	1	3	None	265.2890	6047.2992	.04
5	V4	INF	NUM.	1	4	None	3312.9799	6147.3186	.54
6	V5	INF	NUM.	1	5	None	–347.1029	6192.5495	–.06
7	V6	INF	NUM.	1	6	None	–1466.1811	6199.3914	–.24
8	V7	INF	NUM.	1	7	None	9687.5670	6288.8980	1.54
9	V8	INF	NUM.	1	8	None	7539.9223	6153.4431	1.23
10	V9	INF	NUM.	1	9	None	11365.5169	5635.2959	2.02
11	V10	INF	NUM.	1	10	None	7046.1141	4313.0207	1.63
12	PHI1	M3STATE	MA	1	1	None	–.0993	.0699	–1.42
Effective number of observations						212			
R-square						0.966			
Residual standard error						.262371E+05			

Source: Authors' own calculations

Figure 3 CCF between inflation rate and M3state



Source: Authors' own calculations

We have performed the same type of analysis for all of the time series considered and the relationships between them. In none of these instances is it possible to describe the relationship between the time series of the inflation rate and the variables M1, M2 and M3 with the aid of a suitable model that would properly capture the linear dependence. The same situation occurs when we consider the M1state, M2state, and M3state time series.

In result of our – at this point still just statistical – analysis we can conclude that, in the case of the Czech Republic, either there is no linear relationship between the time series of the inflation rate and the aggregates M1, M2 and M3 (respectively M1state, M2state and M3state), or the dependence is only accidental (including the time shift to both sides, so that the so-called feedback occurs here). In other words, this dependence cannot be truly described by any model. This observation holds true even though our analysis has been carried out on monthly data for a period of 20 years, which is characterised by relatively large fluctuations in the inflation rate in the Czech Republic. And not only in terms of its numerical values, but also in terms of the fundamental causes of these fluctuations.

CONCLUSIONS

The relationship between the inflation rate and monetary aggregates is an important issue in the implementation of the central bank's monetary policy. Is the relationship only one-sided (in terms of money supply), as theory suggests, or two-sided (also in terms of money demand), depending on specific economic realities? And if the latter case occurs, what are the lead/lag directions and magnitudes? A number of studies have attempted to demonstrate the validity of the theoretical relationship that provides the central bank with a tool to influence (and therefore target) inflation. However, central banks have gradually abandoned the targeting of monetary aggregates (especially M3), and hence the monetary influence on the inflation rate, and moved towards inflation targeting. The reason for this move has been the empirically demonstrated invalidity, or significantly limited validity, of the relationship of direct proportionality between money supply and price growth given by the equation of exchange.

When verifying and modelling the relationship between the inflation rate and the money supply (monetary aggregates), it is still necessary to bear in mind that the inflation rate derived from the consumer price index is quite distant from the concept of inflation in economic theory. Proving the validity of the theoretical relationship between the concepts when the quantifiable variable (indicator) expresses something else tends to be quite difficult. This can naturally lead to ambiguous conclusions in terms of the direction and strength of this relationship.

By means of deriving a dynamic linear model, we have been able to show that the dependence between the inflation rate and the money supply (M1, M2 and M3 – monthly relative growth) does exist, but it is accidental (with a time shift to both sides); so it cannot be modelled. The dependence between the inflation rate and the monetary aggregates M1, M2 and M3 expressed in absolute amounts in CZK (states at the ends of the months in CZK million) does not exist at all. The results of our analysis show that the intuitive view of the consequences of the high inflation rate in the Czech Republic at the present time (increasing government spending, i.e., the amount of money in circulation to compensate for the high cost of living of (mainly) households) is not confirmed by the data examined. Thus, the money supply is not growing as a result of the rise in the price level and the increase in government spending. Similarly, the inflation rate is not rising as a result of an increase in the money supply. This analysis has also shown that such a situation is a long-term phenomenon in the case of the Czech Republic and is therefore not simply an outcome of the current – extremely unfavourable – economic situation.

In other words, some dependence between the inflation rate and the monetary aggregates (M1, M2, M3) probably exists, but it is highly random in nature, so it cannot really be described by a model. The practical implication of such a conclusion is the impossibility of using the relationship between monetary aggregates and the inflation rate to make predictions. There may be several reasons based on factual considerations.

One of the reasons for the significant deviations in inflation rates in both directions is implied by very different, in some cases extremely non-standard and dominantly non-economic circumstances (most recently, for example, the COVID-19 pandemic, soon followed by Russian invasion of Ukraine, etc.). This leads to non-standard responses in the structure of the behaviour of economic actors, and such responses dramatically change the existing view of the evolution of monetary aggregates, i.e., the evolution of the values of such indicators as the velocity of money circulation (postponement of consumption, which significantly weakens gross domestic product), the current price level, and the money supply.

Another reason is probably the fact that if the reversals in the development of the analysed phenomena have economic roots (such as the 2008–2009 crisis, 2011–2013 recession, etc.), the magnitude of the changes is rather enormous and provokes unpredictable behaviour of individual economic entities and this behaviour cannot be properly modelled. One of the reasons for this unpredictability may be the phenomenon known as consumption smoothing, whereby households tend to reduce or postpone consumption in bad times. They therefore defer their consumption to other periods to ensure greater stability and predictability. This has been typical since 2008, and it has greatly obscured the relationship between monetary aggregates and the inflation rate.

The third cause is undoubtedly the so-called quantitative release, where global and national financial institutions have repeatedly injected money into economies in recent years; this has also been the case in the Czech economy. This instrument, used in adverse times, may have had some effect in boosting the growth of economies (including efforts to counter deflation), but as a non-standard element, it naturally also provokes non-standard behaviour of economic actors, with consequences for, on the one hand, the level of monetary aggregates, but also, on the other hand, the development of the inflation rate.

A fourth reason for the inadequate conclusiveness of the statistical modelling of the relationship may be the permanently present, so-called adequacy gap. A simple reasoning applies: what we cannot measure perfectly, we cannot model perfectly either. Of course, the consumer price index used as a measure of inflation does not fully correspond to the definition of inflation as an economic category. All these circumstances logically obfuscate the possibility of constructing an effective model for the relationship between monetary aggregates and the inflation rate.

The factual reasoning presented above shows that the relationship between monetary aggregates and inflation rate is in fact too inexplicable to admit a simple formal model from which meaningful implications might be drawn. This effort fails to do so even with variations of different time shifts in the two indicators. Having in mind the time lag that undoubtedly exists between a monetary policy measure and its impact on the real economy, the central bank can only partly be guided by the current situation, while it must also take into account, at least to some extent, the forecast of future economic developments. However, such a forecast is quite difficult to get, especially in the last 15 years.

The behaviour of households, the political establishment, non-standard foreign exchange interventions of the Czech National Bank,[20] and a great variety of the circumstances affecting the economic development do not give much chance of finding a formal model of the relationship that would also have a strong footing in substantive reasoning.

[20] The foreign exchange interventions were launched in 2013 to achieve the inflation target, which is set at 1–3%; therefore, the exchange rate of the koruna was kept above CZK 27 to 1 euro. In contrast, the Czech National Bank is currently intervening to strengthen the koruna to around CZK 24.50 to 1 euro in order to make imports cheaper and thus cool down the sharp rise in prices.

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