The Relationship Between Asset Purchases, Monetary Aggregates, and Inflation Between 2007 and 2022 – an Example of the Federal Reserve

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Summary

The large asset purchase programs following the 2008 crisis led to a significant expansion of money aggregates, which led to an appreciation of the relationship between inflation and money supply. In this study, I analysed the changes in monetary aggregates caused by quantitative easing, the framework for the implementation of monetary policy with ample reserves and their impact on price levels using a vector autoregressive (VAR) model between 2007 and 2022 based on data for the United States. The study includes the pandemic after 2020, however, due to the limited length of time available and the uncertainty of the effects, the focus of the study is on pre-pandemic processes. Inflation fears caused by the significant expansion of the money supply during the period were not substantiated due to the increase of excess reserves, the changing monetary policy operational framework and negative output gap. According to the model monetary aggregate shocks are built into inflation expectations, changes in the money aggregates caused by asset purchases help the central bank to reach its medium-term inflation target.

Keywords: monetary policy, asset purchases, monetary aggregates, inflation

JEL codes: E52, E51, E31

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In the wake of the 2008–2009 global financial crisis and its aftermath, many central banks around the world announced large asset purchases (Krekó et al., 2012). Quantitative easing programmes were further expanded to dampen the economic downturn caused by the Covid–19 epidemic. Asset purchases were financed by central banks by increasing the reserves of commercial banks at the central bank, causing a dramatic increase in the monetary base. In addition, the uptrend in the broader monetary aggregate, M2, has intensified in response to the crisis, driven by the portfolio rebalancing effect of the central bank's quantitative easing. According to theories on the quantity of money (quantity theory of money, monetarism), such an increase in the monetary supply must be accompanied by high inflationary pressures. Following the 2008 crisis, inflation fears began to emerge, but the significant increase in money supply aggregates was not accompanied by an intense rise in price levels. Demand monetised through money creation results in an imbalance in the price level when the expansion of demand so created exceeds the rate of adjustment of aggregate supply (Botos, 2016). The reasons for the rise in inflationary pressures from 2021 onwards are not the effects of monetary aggregate changes, but the disruption in aggregate supply and demand caused by the epidemic.

There is no complete consensus in economic theories and empirical studies on the relationship between the price level and the money supply. According to the New Keynesian HANK model (DSGE) used by *Cui and Sterk* (2021), quantitative easing had a strong and positive effect on output and inflation in the United States during the economic crisis and in subsequent years. However, also using a DSGE model, *Boehl et al.* (2020) highlight that, expansive financial shocks can have a disinflationary effect if supply effects dominate demand effects. The research based on vector autoregressive models used in this paper highlights the significant effects of the Federal Reserve's quantitative easing programmes on macroeconomic variables. *Weale and Wieladek* (2015) used a recursive and sign-restriction Bayesian VAR model, *Kim et al.* (2020) a structural VAR model, and *Anzuini* (2022) a non-linear VAR model to examine the FED's quantitative easing programmes typically until 2015, the end of the expansion of quantitative easing programmes.

In this paper, I use a recursive vector autoregressive (VAR) model to analyse quantitative easing processes, but with different variables than previous empirical studies and over a longer time horizon, including the period of the Covid–19 epidemic. Although due to the limited length of the period affected by the epidemic and the uncertainty of the effects, the paper focuses mainly on the pre-epidemic period. In particular, I focus on the effects on price levels using data for the United States of America between 2007 and 2022, rather than the monetary and real economic focus of previous quantitative research. This paper examines the monetary aggregate changes caused by quantitative easing, the framework for the implementation of central bank policy under ample reserves, and their impact on the price level.

THEORETICAL OVERVIEW

In this sub-chapter, I present the transmission channels of non-traditional instruments relevant to this research and the impact of these instruments on the money supply. In the remainder of the sub-chapter, I examine the relationship between inflation and the money supply from a monetary theory perspective, and the operational framework for monetary policy in the post-crisis period.

Transmission of non-traditional instruments

Asset purchases are pre-announced, large-scale purchases of government bonds or securities (Krekó et al., 2012; Felcser et al., 2017), and in this context several transmission channels can be highlighted. However, this paper aims at presenting the perceived and real inflationary effects, and thus only presents the related channels[1]. Central bank asset purchases have an impact on:

- the liquidity of the banking system (which affects the monetary base),
- private sector portfolio decisions (which affect M2),
- and provide an indication of the expected future stance of monetary policy (which affects market expectations).

Through asset purchases along the *bank funding channel*, the central bank creates large amounts of money, thereby improving liquidity in the financial sector (Ábel et al., 2016). Increased liquidity and lower financing costs may encourage banks to expand lending. However, in a crisis period, banks may use the excess liquidity not to expand lending but to purchase other asset classes out of a sense of prudence.

The *portfolio balance channel* is driven by changes in the quantity and structure of assets on the central bank's balance sheet and their impact on the decisions of economic agents (Gagnon et al., 2011). By purchasing long-term assets (government bonds, MBS), the central bank influences the relative supply of these assets, thereby creating a new supply-demand balance in the market, leading to a reallocation of the private sector portfolio (Felcser et al., 2017). Central bank asset purchases targeting long-term assets can lead to rapid changes in the private sector balance sheet, thereby increasing demand for riskier assets or bank deposits (Janus 2016). Private sector portfolio decisions are of particular importance as they have a significant impact on the broader money supply, M2.

In the *signalling, also known as monetary policy signalling, channel* expectations are the main focus. Announcements of large asset purchases provide information to the private sector about the central bank's future commitment to loose monetary conditions, thereby preventing inflation expectations from falling below target (Bhattarai et al., 2015).

The impact of asset purchases on money supply

Commercial banks have typically played an account management role in asset purchases (Joyce et al., 2011). Through asset purchases, the central bank buys financial assets on the secondary market, which it finances by increasing central bank reserves. When the central bank purchases securities, its balance sheet will increase by the amount of the asset purchase. The commercial banks' balance sheet will increase by the amount of the central bank's reserves on the asset side and by the amount of the third party's deposit with the commercial bank on the liability side. The third party (i.e. the seller) undergoes only one asset-side transformation. The stock of securities decreases and the deposits with the commercial bank increase. As a result, not only the monetary base but also the money supply (M2) will increase. Central bank purchases of assets from non-banks in the banking sector create both new reserves and new deposits at the central bank (Joyce et al., 2011). Increased liquidity and lower financing costs may encourage banks to expand lending. However, with a strong credit demand constraint, banks may use the excess liquidity not to expand lending but to purchase other asset classes out of a sense of prudence.

In the surveyed economy, quantitative easing has led to an eightfold increase in the monetary base and a threefold increase in M2 compared to pre-crisis levels. The former was driven by a rise in the central bank reserves of commercial banks, while the latter expansion was driven by the portfolio rebalancing effect of asset purchases. The stock of securities on the FED's balance sheet rose from around USD 700 billion before the crisis to USD 4,000 billion in 2014, before gradually declining from 2018 onwards as the maturity of securities on the balance sheet and reinvestments declined. However, the impact of the pandemic doubled the 2014 level between 2020 and 2022.

Relationship between money supply and inflation

The inflationary impact of monetary policy and changes in the money supply has been a topic of economic thinking since the beginning (Lucas, 1996). The classical dichotomy completely separates monetary processes from real economic processes on the basis of the neutrality of money through the quantity theory of money (Polgár & Novák, 2015). Keynes broke with the orthodox separation between the real and monetary spheres (Farkas, 2021) and rejected the exclusivity of the variables in the quantity equation in determining the price level. According to *Keynes* (1964), the general price level is influenced by other important factors, such as the unemployment rate, in addition to the size of the money supply. Since the unemployment rate is closely related to the output gap, it can be concluded that the general price level of the economy is influenced not only by the money supply but also by the output gap.

Monetarism's thinking on central bank policy is based on a stable relationship between the money supply and inflation. *Friedman* (1968) argues that, under the assumption of adaptive expectations, a different than expected central bank policy cannot keep interest rates low and unemployment below its natural level for a prolonged period of time through the temporary illusion of money. According to the accelerator hypothesis, the role of monetary policy is not to control interest rates, but to increase the money supply in line with real economic needs in a permanent way, which anchors inflation expectations (Bessenyei, 2007; Polgár & Novák, 2015). *Hayek* saw the cause of business cycles as a sudden and unpredictable change in the money supply, a recurrent process along cycles, which upsets market pricing conditions and thus causes output to fluctuate (Kovács et al., 2016).

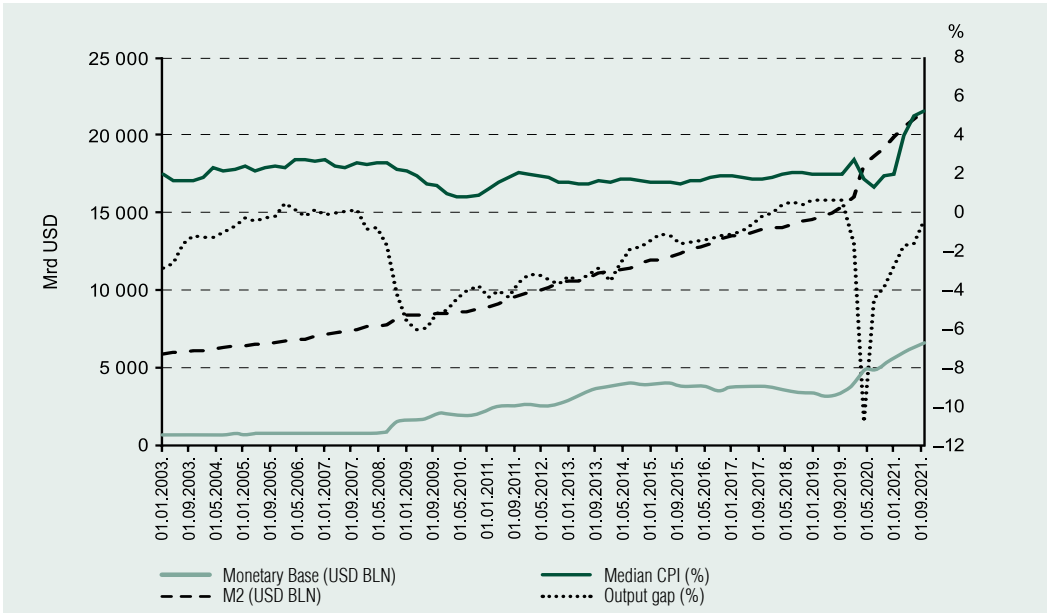
Following the stagflation of the 1970s, inflation in developed countries began to moderate, but its link with the money supply weakened. In the United States, the money supply has risen steadily since the 1990s, but this has not been accompanied by significant inflationary pressures (the phenomenon of cash shortage). *Lucas* (1980) found a positive relationship between annual CPI inflation and M1 growth in the United States for the period 1955–1975. *McCandless and Weber* (1995) analysed data for 110 countries from 1960 to 1990 on a large sample and found a high positive correlation between money growth and inflation. According to *Dwyer and Hafer* (1999), there is a positive correlation between inflation and the rate of money growth in both the short and long run, but this positive relationship is weak in countries with low inflation and stronger in countries with high inflation. *Sargent and Surico* (2010) analysed the annual rate of US money growth and inflation between 1900 and 2005 and found that the correlation weakened between 1984 and 2005 compared to previous periods.

The low inflationary pressures in the global economy over the period 2010–2020 can be explained by the flattening of the Philips curve observed in recent decades, which central banks attribute to well-anchored inflation expectations and credible central bank policies. The loosening of the Phillips-type link helps economic policy, as it can stimulate growth while inducing negligible excess inflation (Szentmihályi – Világi 2015). However, the safe asset shortage literature argues that the explanation for the low inflation puzzle should be seen in the context of weakening global aggregate demand. The theory is that excess demand in the government bond market could push the long-run equilibrium interest rate below the effective interest rate stuck at the effective lower bound. This positive interest rate spread can lead to a negative output gap and hence low inflationary pressures (Beckworth 2021).

After the 2008 crisis, the sharp rise in the monetary base and M2 did not cause high inflationary pressures in the US, with core inflation[2] stabilising around 1–3%. The lessons from *Figure 1* suggest that there is no positive relationship between money supply and inflation over the period under review. Until 2020, with a negative output gap, credit demand and credit supply were subdued, output slowly converged to the long-term natural rate over the period, and a sharp increase in the money supply had little impact on inflation. However, the disruption to aggregate supply and demand caused by the Covid–19 epidemic has led to an increase in inflationary pressures from 2021 onwards.

Figure 1

TRENDS IN THE MONETARY BASE (USD BLN), M2 (USD BLN), INFLATION (%, RIGHT AXIS) AND OUTPUT GAP (%, RIGHT AXIS) BETWEEN 2003 AND 2022



Source: own editing based on FED FRED database

Relationship between asset purchases, inflation and the monetary framework

The operation of quantitative easing has a fundamental impact on the evolution of the money supply. A sharp rise in central bank reserves can have an inflationary impact if, during the recovery phase, large central bank reserves lead to an excessive increase in commercial bank lending activity, which leads to further increases in the money supply and ultimately to a rise in the price level.

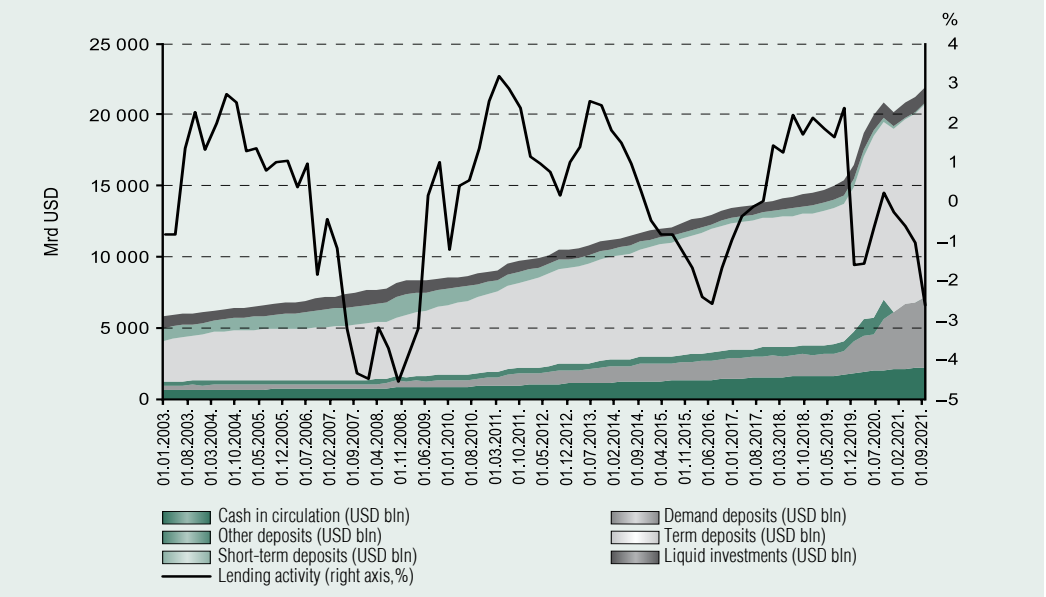
The private sector's portfolio decisions determine the size of monetary aggregates (e.g. M2), as households and firms decide how much of their financial wealth to hold in non-monetary assets (e.g. shares, government securities) and how much in assets that have a money function (Komáromi 2008). In a 'normal' period, monetary policy can have only an indirect, small impact on the broader money stock. However, in 'critical' periods, the central bank influences private sector portfolio decisions through the portfolio balance channel in asset purchases. The shift away from the risk-free government bond market and certain sub-markets (MBS) is driving the private sector towards bank deposits or riskier assets (corporate bonds, shares). Over the period under review, the inflationary impact of a change in M2 driven by an increase in bank deposits due to portfolio decisions may be lower than the same monetary aggregate-increasing impact of a change in bank deposits due to an increase in lending activity. Looking at the percentage deviation of lending activity from the HP-filtered trend, the evolution of credit expansion over the period remained low relative to supply-side lending opportunities *(Figure 2)*.

Along the asset purchases, the framework for the implementation of monetary policy has undergone a significant change. In the calm years before the 2008 crisis, with *limited banking system reserves*, the FED relied on open market operations to achieve the operational objective of monetary policy (Bindseil, 2004). In the market of reserves, the demand for capital and liquidity reserves of commercial banks and the supply of reserves by the central bank determine the benchmark interest rate (federal funds rate) at which commercial banks lend overnight to each other in the interbank market. In the conduct of monetary policy, given the limited availability of reserves, a small change in the supply of reserves, influenced by open market operations, can affect the policy rate, bringing it closer to the target.

The asset purchases financed by reserve increases have led to a significant increase in the reserve holdings of the banking system. With *ample reserves*, the FED was no longer able to influence the benchmark interest rate by changing the supply of reserves through open market operations. In parallel with the increase in reserves, interest on excess reserves (IOER) was introduced as a new instrument in the FED's toolset, completely transforming the operational framework, while the implicit tax on the formerly required reserves was eliminated with the introduction of interest on required reserves (IORR)[3]. By exploiting market arbitrage opportunities, the evolution of the benchmark interest rate converges towards the IOER set by the central bank, as banks would borrow from each other at the benchmark interest rate and would achieve a higher level of return in the form of excess reserves if the two rates were to diverge[4]. The lower bound on the interest rate is provided by the interest rate on another central bank instrument, the overnight reverse repo (ON RRP), which is not a passive repo instrument for banking agents in the traditional sense (e.g. investment banks, state-funded institutions). Due to the close link between the IOER and the FFR, the central bank does not need to

Figure 2

TRENDS IN M2 COMPONENTS (LEFT AXIS, USD BLN) AND PERCENTAGE DEVIATION OF LENDING ACTIVITY FROM THE TREND (RIGHT AXIS, %) BETWEEN 2003 AND 2022



Source: own editing based on FED FRED

conduct daily open market operations to keep the benchmark interest rate within the target range as it did under the pre-crisis framework (Ireland, 2019). On the one hand, the IOER is an effective tool for keeping the benchmark interest rate in the target range with ample reserves and for influencing short-term interbank interest rates (Ihrig et al., 2020). On the other hand, it is a sterilisation tool for asset purchases.

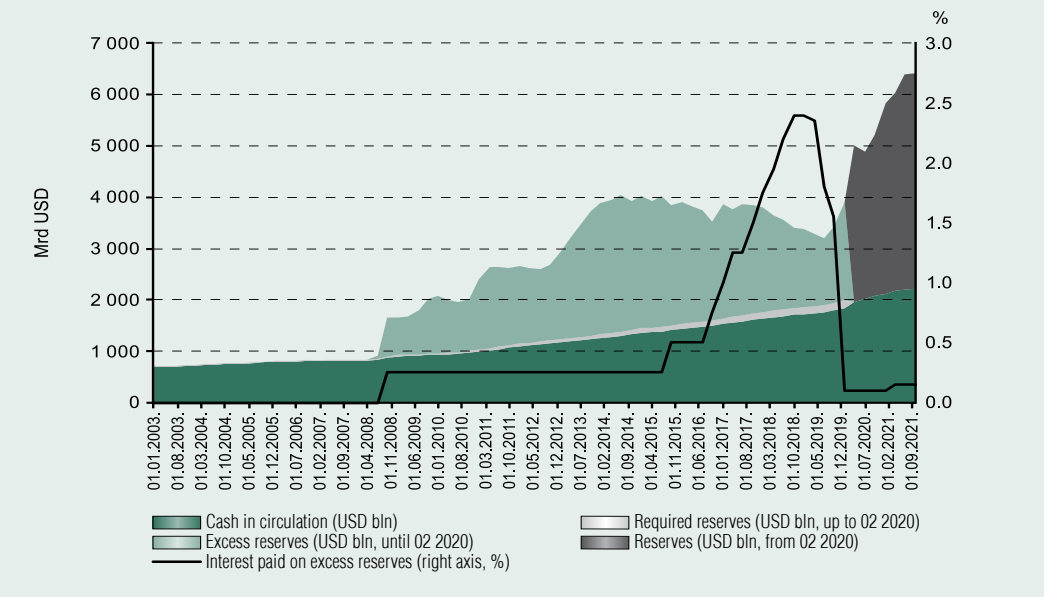
Following the crisis, the monetary policy importance of the liquidity market has been further enhanced by the transformation of the central bank's toolset (Kolozsi – Horváth, 2020). *Reis* (2016) and *Ennis* (2018), analysing the US reserve market, concluded that quantitative easing has shifted the reserve market to a region where the reserve demand function is horizontal in addition to the vertical supply function. The studies point out that from the saturation point of the reserve demand function, further reserve expansion is likely to have little impact on inflation. However, the saturation of the reserve market allows the central bank to use interest paid on reserves to manage inflation and asset purchases for real economic purposes. *(Figure 3)*

METHODOLOGY AND APPLIED MODEL

In my work I applied a vector autoregressive (VAR) model to answer the research questions. A vector autoregressive (VAR) is a linear model with *n* equations and *n* variables, in which the variables are explained by their past (lagged) values and the past values of the other variables plus an error term. The VAR model framework can capture the dynamics

Figure 3

TRENDS IN MONETARY BASE COMPONENTS (USD BLN) AND IOER (%, RIGHT AXIS) BETWEEN 2003 AND 2022



Comment: With the abolition of the reserve requirement ratio in the second quarter of 2020, required reserves were merged into excess reserves as reserves.

Source: own editing based on FED FRED database

of multivariate time series. A general p order VAR(p) model with n variables is constructed as follows (Hansen 2020):

$$y_t = c + R_1 y_{t-1} + R_2 y_{t-2} + \ldots + R_p y_{t-p} + u_t, \qquad (1)$$

where, y_t is the ($nx1$) vector of endogenous variables constituting the model, c is the ($nx1$) vector of constants, R_j is the (nxn) matrix of autoregression coefficients (j=1,2,...p) for the lagged values of the endogenous variables, and u_t is a vector of ($nx1$) normally distributed error terms. The error terms are assumed to be non-autocorrelated. Ω is the (nxn) variance-covariance (symmetric positive semidefinite) matrix of the error terms.

The error terms represent the random, shock-like movements of the variables. The model includes interacting variables, and therefore the simultaneous response of variables to the same shock is given, which makes causal analysis impossible (Ács, 2014). One way to address this problem is to use a recursive VAR model, where the error terms in each equation are uncorrelated with the error terms in the other equations because the equations use the simultaneous values of the variables as explanatory variables. One possible solution to the problem of simultaneity is the Cholesky decomposition of the variance-covariance matrix Ω of the VAR error terms. The Cholesky decomposition results in a transformation of the matrix Ω into a lower and upper triangular matrix with the standard errors of the error terms on the main diagonal (Ács, 2014). In the recursive VAR model, the order of the variables plays a prominent role. By sequencing the elements of the y_t vector, we assume the simultaneous order of the variables (Vincze, 2018).

Applied model and variables

The study covers the period from Q4 2007 to Q4 2021 with quarterly data[5]. The time span includes the acute phase of the 2008 crisis, the recovery from the crisis and the situation caused by the Covid–19 epidemic.

In my work, I tested the VAR model constructed as follows under 4 lags[6]:

$$y_t = c + R_1 y_{t-1} + R_2 y_{t-2} + R_3 y_{t-3} + R_4 y_{t-4} + R_5 y_{t-5} + R_6 y_{t-6} + R_7 y_{t-7} + B_t rec_t + B_t cvd_t + u_t, \quad (2)$$

where is the vector of endogenous variables, which can be written in matrix form:

$$y_t = \begin{pmatrix} og \\ p \\ lqe \\ ler \\ ldep \\ ioer \\ pv \end{pmatrix}, \quad (3)$$

where *og* represents the output gap, i.e. the difference between actual and potential output. *p* is the trend in core inflation. *lqe* is the proxy variable of quantitative easing, i.e. the logarithmic value of the quantity of securities on the central bank balance sheet. *ler* is the logarithmic value of the excess reserves, a component of the monetary base. *ldep* is the logarithmic value of one of the components of M2, term deposits. *ioer* is the interest paid by the central bank on excess reserves. *pv* is the 5-year forward-looking inflation expectation. *Cvd* is the dummy variable for the situation caused by the Covid–19 epidemic, *rec* is the dummy variable for the acute phase of the crisis based on the NBER recession database.

The order of the variables is of paramount importance (Bernanke & Blinder, 1992), so it is assumed that the output gap is not affected simultaneously by the other variables; inflation is affected simultaneously by the change in the output gap (demand shock), but only with a lag for the other variables. The central bank makes its quantitative easing decisions on the basis of the output gap and inflation, but can only react to them with a lag due to monetary policy lags. Reserve decisions by commercial banks are influenced by the output gap (credit demand), inflation and quantitative easing. Deposit decisions are also influenced by reserve trends in addition to the above variables. In determining the interest rate paid on excess reserves, the monetary authority takes into account the state of the economy (output gap, inflation) and the changes caused by quantitative easing (excess reserves, deposits), but there is a lag in the feedback on these. All the above variables are immediately incorporated into inflation expectations.

The stationarity condition is not fulfilled for all variables, but according to *Brooks* (2014), if the VAR model is not used for hypothesis testing or for testing the statistical significance of coefficients, stationarity need not be fulfilled and thus dynamic relationships between variables can be more efficiently investigated. The p-value of the LM test (0.7011), at a 5% significance level, indicates that there is no autocorrelation between the residuals at a lag of 4. Based on the Lütkepohl normality test with a p-value of 0.7845, the error terms follow a normal distribution at 5% significance level.

RESULTS

In this sub-chapter, I investigate the dynamic relationships between the key variables using cumulative impulse response functions and variance functions.

Impulse response functions

Asset purchases can affect price level developments through changes in monetary aggregates,

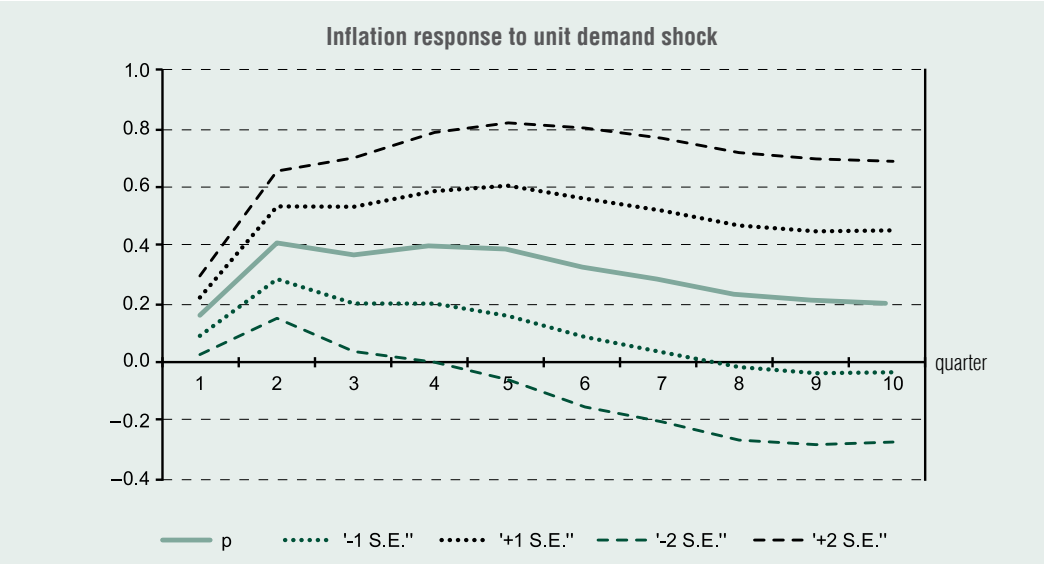
but the data show that the abundance of money caused by quantitative easing has been captured in the form of bank deposits as a result of over-reserving by commercial banks and portfolio decisions by the private sector. Looking at inflation responses, the impact of demand shocks *(Figure 4.a)* and supply shocks *(Figure 4.b)* has a significant impact on inflation developments in both the short and long run. A gradual closing of the negative output gap on the demand side from the bottom up to 2020, followed by supply-side effects from 2020 onwards in an epidemic situation, lead to higher inflationary pressures.

The inflation response to central bank asset purchases, i.e. balance sheet shocks *(Figure 5.a)*, and reserve management decisions *(Figure 5.b)* is not significant in the model. Over the period, M2 growth was driven by quantitative easing through an increase in bank deposits. In the model, positive shocks to bank deposits, i.e. the rise in M2, do not cause a significant shift in the price level *(Figure 5.c)*. The disruption in the money supply-inflation relationship in the pre-epidemic period can certainly be explained by the failure of economic output to reach a long-run equilibrium level, and in the epidemic period by the damage to production capacity. Low aggregate demand in the first half of the period and falling aggregate supply and demand in the epidemic period may explain the credit demand constraints, and these credit demand constraints and the increasing excess reserves at the central bank may explain the subdued credit supply.

In the period 2007–2022, the driving force behind the significant increase in the monetary base was the growth of commercial banks' excess reserves with the central bank.

Figure 4.a

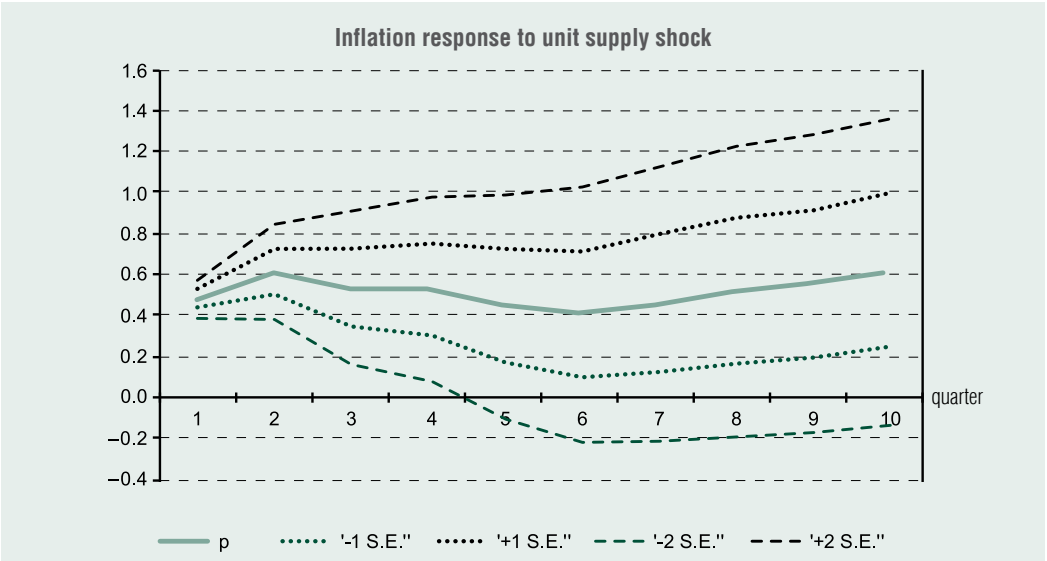
CUMULATIVE RESPONSE OF INFLATION TO VARIOUS REAL ECONOMIC SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 4.b

CUMULATIVE RESPONSE OF INFLATION TO VARIOUS REAL ECONOMIC SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
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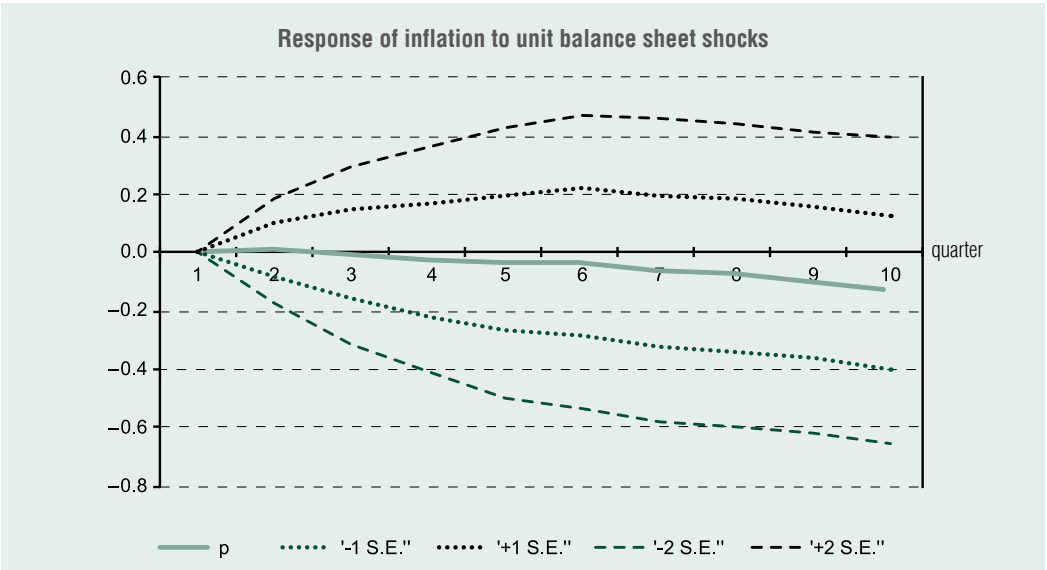
Figure 5.a

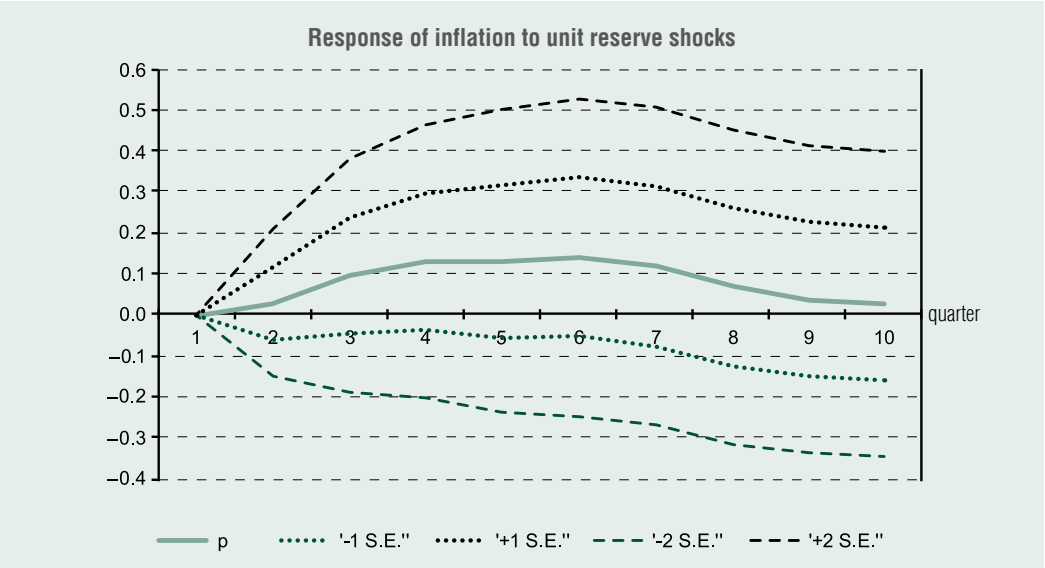
CUMULATIVE RESPONSE OF INFLATION TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 5.b

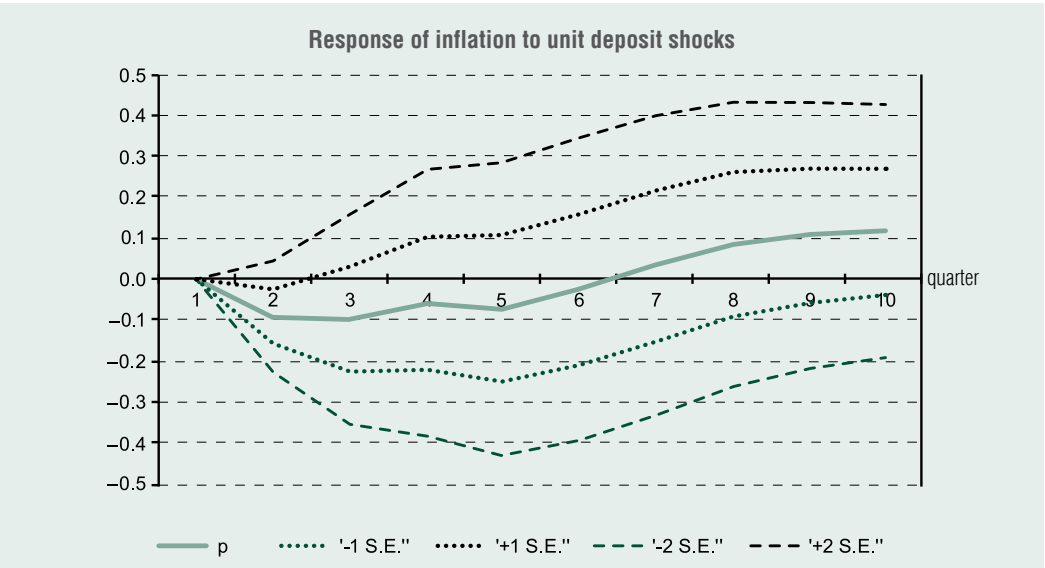
CUMULATIVE RESPONSE OF INFLATION TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 5.c

CUMULATIVE RESPONSE OF INFLATION TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

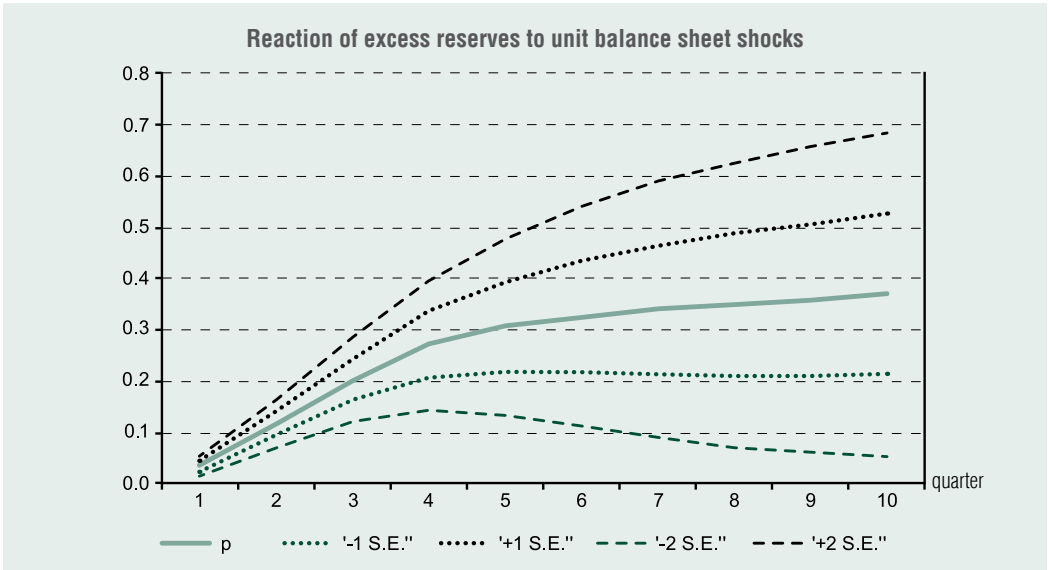
Positive asset purchase shocks lead to a steeper increase in the level of excess reserves in both the short and long-term *(Figure 6.a)*. The liquidity surplus caused by quantitative easing was sterilised by the central bank through the interest on the required and then excess reserves (IOER). According to the model, increasing asset purchases cause the interest rate paid on excess reserves to rise over the entire time horizon *(Figure 6.b)*.

The effects of quantitative easing have not led to high inflationary pressures in the period typically described by negative output gaps, but an important question is how these factors may affect future inflation developments. Long-term inflation effects are of particular concern in the context of the epidemic situation due to the tightening of the supply side (production, supply chain problems). The response of the 5-year forward-looking inflation expectations to demand shocks is significant for at least 3 quarters with a 68% confidence interval, i.e. demand shocks affect not only current inflation but also future expected inflation *(Figure 7.a)*. Whilst epidemic supply shocks drive inflation expectations more strongly and over the entire time horizon *(Figure 7.b)*. The supply-side effects may have a stronger impact on the medium- to long-term path of inflation than the demand-side effects.

However, no direct significant effect of quantitative easing can be detected for inflation expectations *(Figure 8.a)*. However, the direction of the cumulative impulse response functions suggests that economic agents have settled in for a longer period of lower inflation along asset purchases, which may indicate a signalling channel for quantitative easing and the impact of monetary policy commitment. Increasing excess reserves did not have a

Figure 6.a

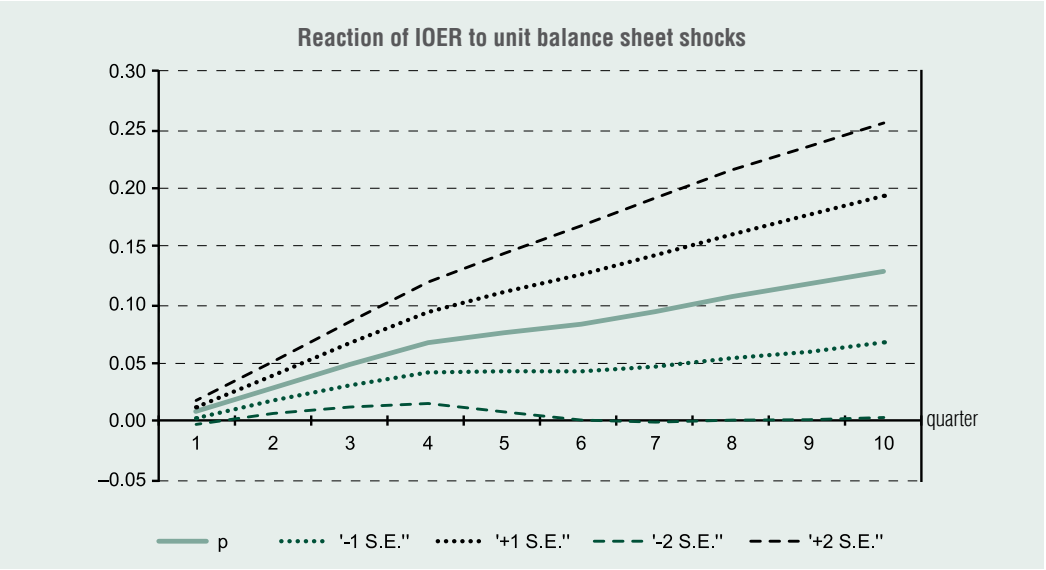
CUMULATIVE RESPONSE OF EXCESS RESERVES AND IOER TO UNIT BALANCE SHEET SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 6.b

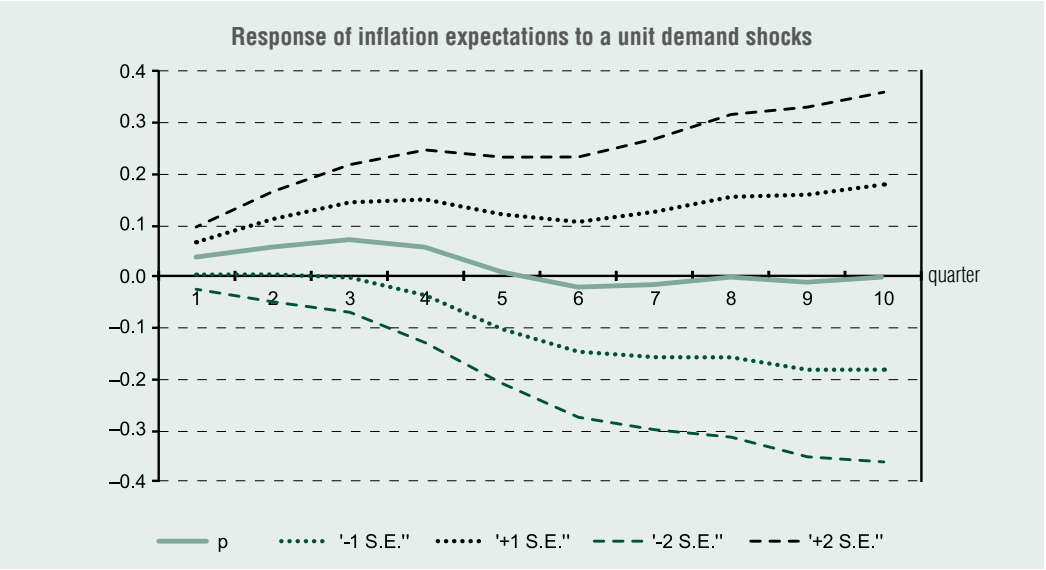
CUMULATIVE RESPONSE OF EXCESS RESERVES AND IOER TO UNIT BALANCE SHEET SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 7.a

CUMULATIVE RESPONSE OF INFLATION EXPECTATIONS TO DIFFERENT REAL ECONOMIC SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
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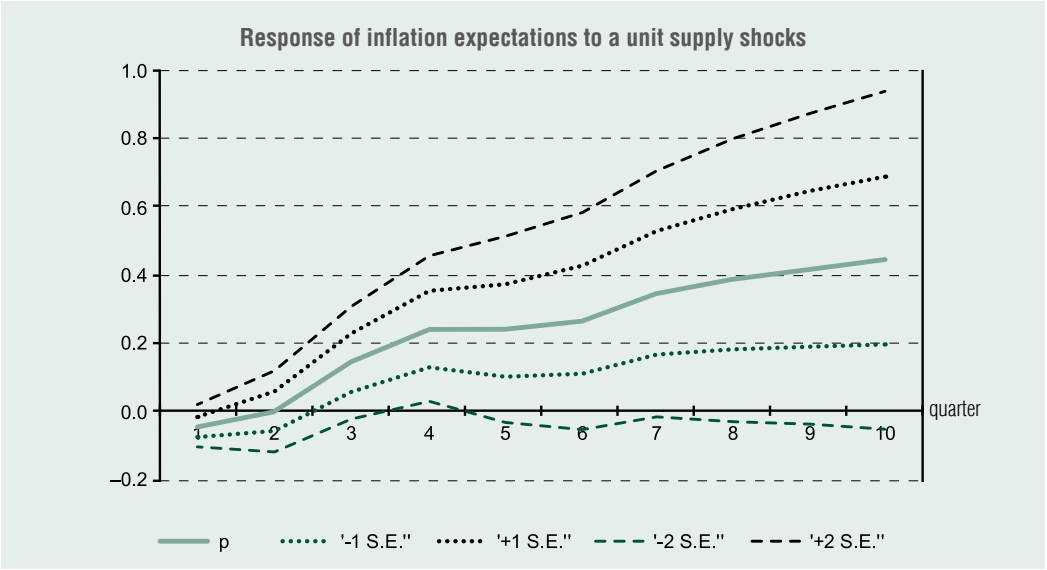
Figure 7.b

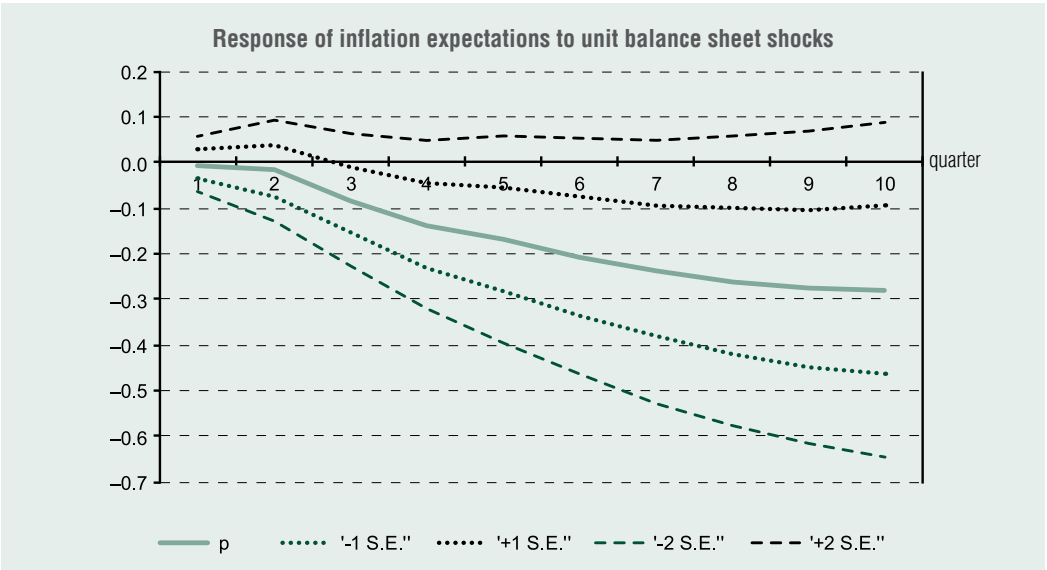
CUMULATIVE RESPONSE OF INFLATION EXPECTATIONS TO DIFFERENT REAL ECONOMIC SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 8.a

CUMULATIVE RESPONSE OF INFLATION EXPECTATIONS TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

statistically significant effect on inflation in the model, but it did have a statistically significant effect on inflation expectations at the 68% confidence interval, meaning that credit supply restraint tends to affect the longer-term path of the price level *(Figure 8.b)*. At the same time, the evolution of term deposits had no significant effect on either inflation or inflation expectations *(Figure 8.c)*.

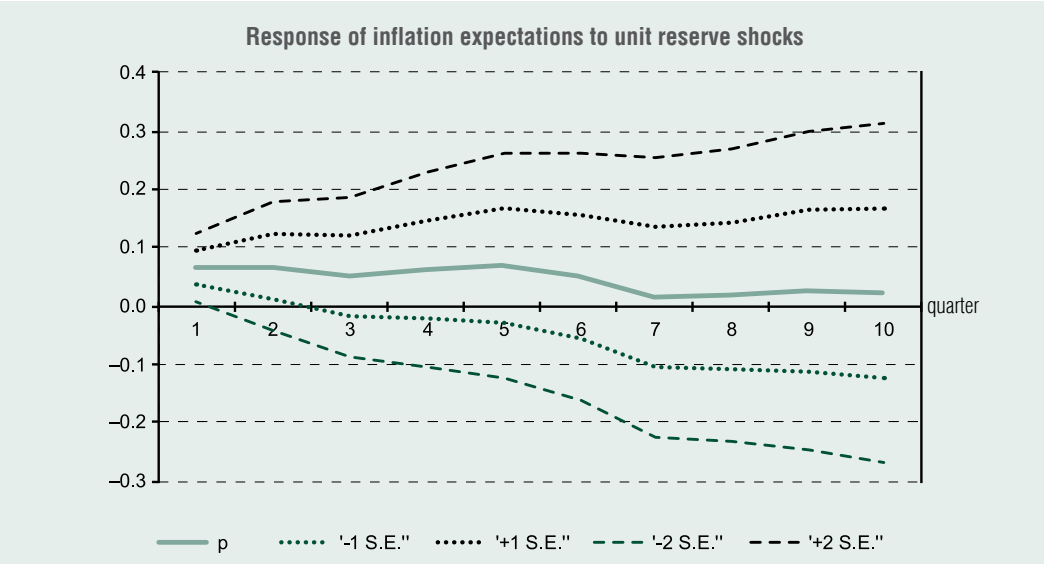
Variance decomposition

The variance decomposition of the relevant variables allows to determine which shocks are determinant for the short and long-term evolution of the variables under study. In the model, it is observed that the negative supply (cost) shock and the demand shock had the largest impact on the evolution of inflation, while changes in the money aggregates had only a small impact on the change in the price level over the period *(Figure 9.a)*. In contrast, the evolution of inflation expectations is influenced by several monetary factors in addition to macroeconomic variables. Changes in excess reserves are most likely to affect inflation expectations in the short-term, while a shock to asset purchases is likely to drive inflation expectations in the long-term *(Figure 9.b)*. Shocks to monetary aggregates are not incorporated into inflation but are incorporated into inflation expectations. The monetary aggregates induced by quantitative easing may help to achieve the medium-term inflation target for the central bank under study.

According to the variance composition of the change in the quantity of securities on the central bank balance sheet, aggregate demand

Figure 8.b

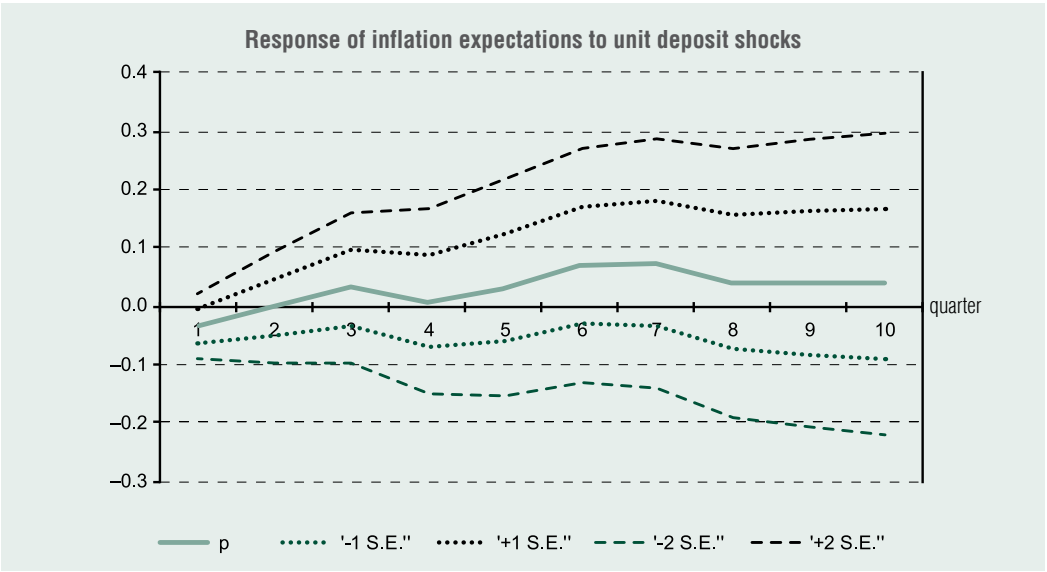
CUMULATIVE RESPONSE OF INFLATION EXPECTATIONS TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 8.c

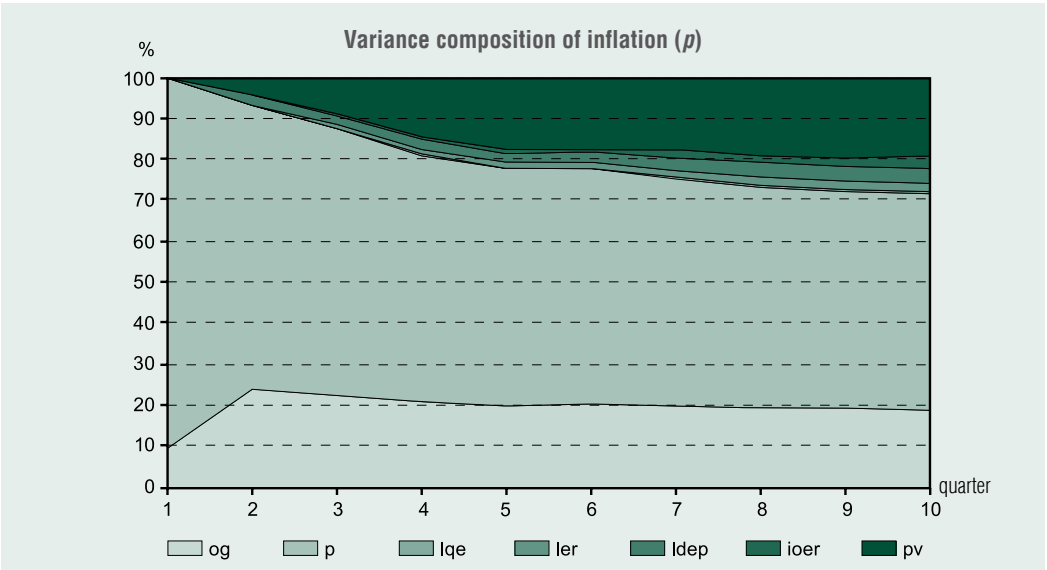
CUMULATIVE RESPONSE OF INFLATION EXPECTATIONS TO DIFFERENT MONETARY SHOCKS



Comment: Solid lines indicate cumulative impulse response functions at 68% (+/–1 S.E.) and 95% (+/–2 S.E.) confidence intervals.
Source: own editing

Figure 9.a

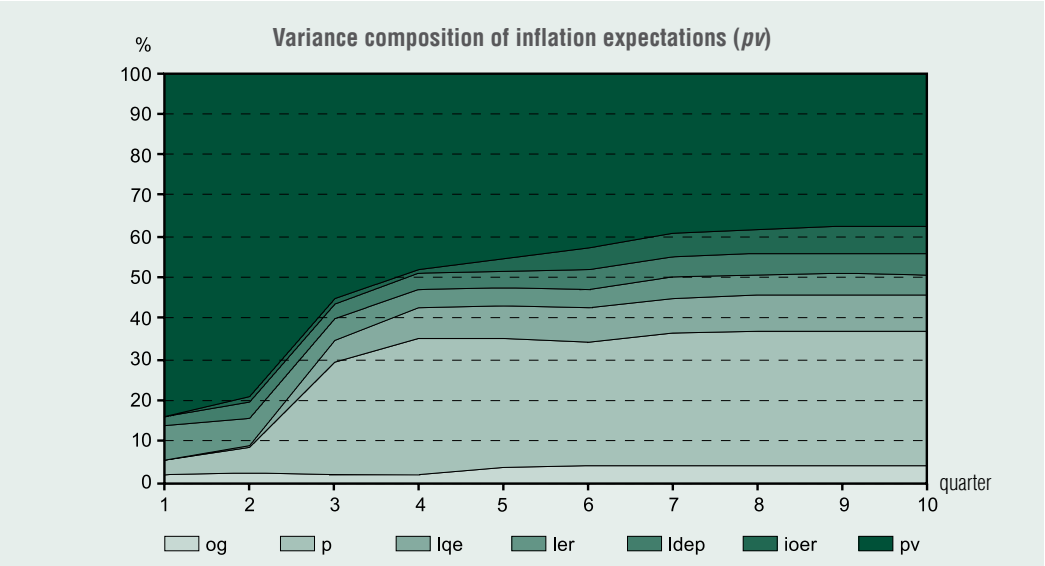
VARIANCE DECOMPOSITION OF INFLATION AND INFLATION EXPECTATIONS



Comment: Og is the output gap, p is the trend in core inflation, lqe is the proxy for quantitative easing, ler is the amount of excess reserves, ldep is the amount of term deposits, ioer is the central bank interest paid on excess reserves, pv is the 5-year forward-looking inflation expectation.
Source: own editing

Figure 9.b

VARIANCE DECOMPOSITION OF INFLATION AND INFLATION EXPECTATIONS



Comment: Og is the output gap, p is the trend in core inflation, lqe is the proxy for quantitative easing, ler is the amount of excess reserves, ldep is the amount of term deposits, ioer is the central bank interest paid on excess reserves, pv is the 5-year forward-looking inflation expectation.
Source: own editing

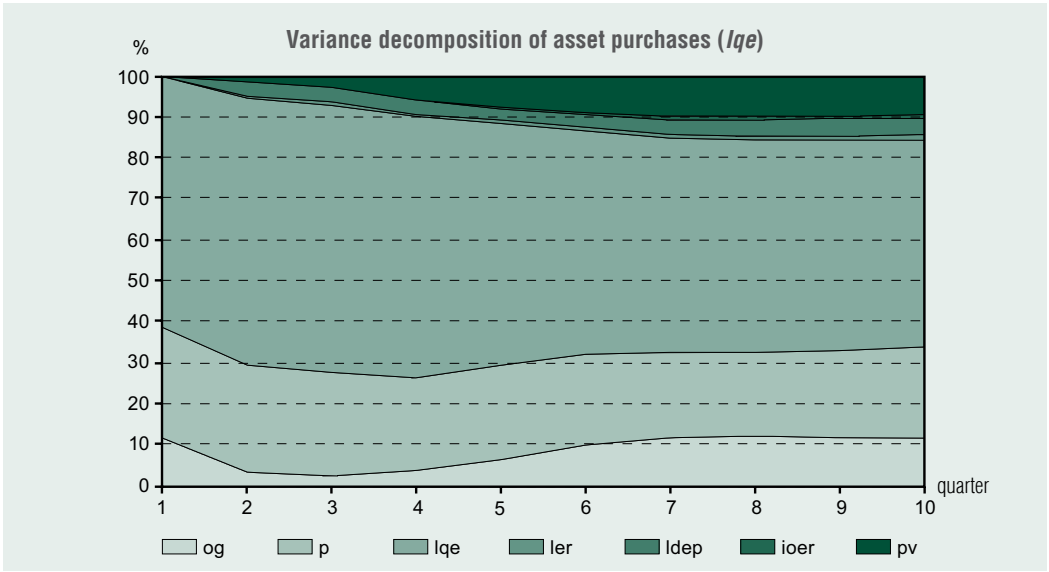
and supply shocks are the main drivers of quantitative easing *(Figure 10.a).* The over-reserving decisions of commercial banks are affected by quantitative easing processes and by the trends of the output gap, i.e. the demand for credit *(Figure 10.b).*

SUMMARY

The large asset purchase programmes following the 2008 crisis and the Covid–19 epidemic in 2020 have led to a significant expansion of money supply aggregates, along which examining the relationship between inflation and money supply was (re)valued. Quantitative easing can have an impact on inflation at a number of points, but the data show that the monetary abundance caused by quantitative easing has been in the form of bank deposits as a result of over-reserving by commercial banks and portfolio decisions by the private sector. In the model, the monetary aggregate shock does not cause a significant shift in the price level. The disruption in the money supply-inflation relationship can certainly be explained by a negative output gap until 2020 due to a demand-side lag and a disruption in aggregate supply and demand between 2020 and 2022. In contrast, inflation expectations are, according to the variance decomposition, driven by balance sheet and monetary aggregate shocks in addition to real economic shocks. Monetary aggregate shocks are embedded in inflation expectations, i.e. the monetary aggregate shocks caused by quantitative easing may help the central bank under review to achieve its medium-term inflation target. In the model, an increasing excess of reserves, i.e. a reduction in the supply of credit, affects expectations for the longer-term path of the price level. By buying assets, economic ope-

Figure 10.a

VARIANCE COMPOSITION OF ASSET PURCHASES AND EXCESS RESERVES

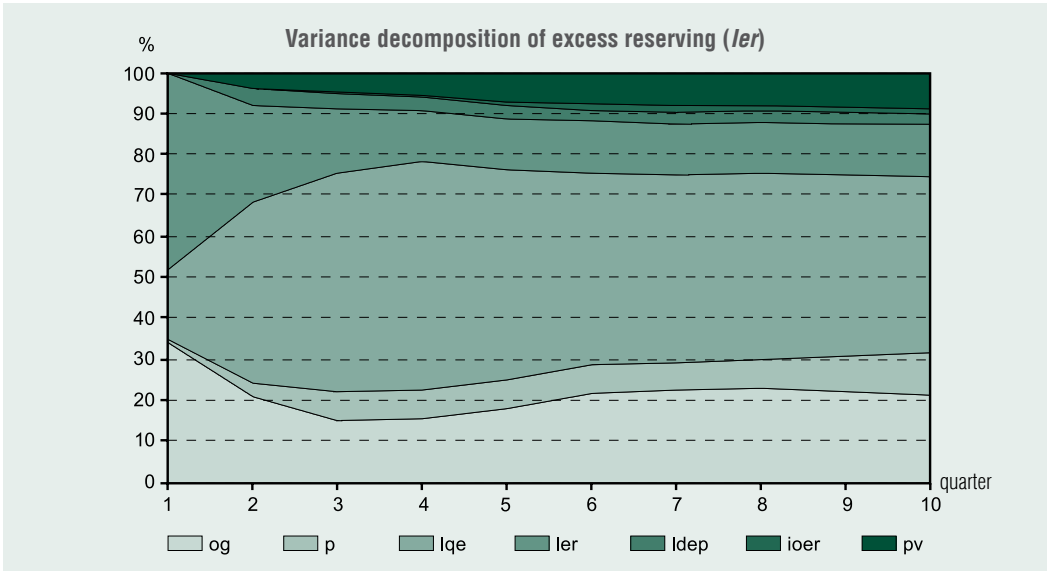


Comment: Og is the output gap, p is the trend in core inflation, lqe is the proxy for quantitative easing, ler is the amount of excess reserves, ldep is the amount of term deposits, ioer is the central bank interest paid on excess reserves, pv is the 5-year forward-looking inflation expectation.

Source: own edited

Figure 10.b

VARIANCE COMPOSITION OF ASSET PURCHASES AND EXCESS RESERVES



Comment: Og is the output gap, p is the trend in core inflation, lqe is the proxy for quantitative easing, ler is the amount of excess reserves, ldep is the amount of term deposits, ioer is the central bank interest paid on excess reserves, pv is the 5-year forward-looking inflation expectation.

Source: own edited

rators are setting themselves up for a longer period of lower inflation, which may indicate a signalling channel for quantitative easing and the impact of monetary policy commitment.

In conclusion, inflation fears caused by the abundance of liquidity due to asset purchases have not materialised. On the one hand, due to the impact on aggregate demand of the 2008 crisis and its aftermath, and of the Covid–19 epidemic in 2020 on both aggregate demand and supply, and on the other hand, due to a limited credit demand and an effective central bank sterilisation environment. With appropriate limitations, the observations of this research should also be instructive for the response of Central and Eastern European countries (notably Hungary, Poland and Croatia) to the epidemic situation and the asset purchase programmes that are likely to emerge in the future. Monetary aggregate shocks, with subdued credit expansion and adequate sterilisation, do not cause a significant shift in the price level, but they do shift inflation expectations, while providing a signalling channel for asset purchases. ■

Notes

[1] Transmission channels are discussed in more detail in Gagnon et al. (2011); Janus (2015); Czeczeli (2016).

[2] I measured inflation using the Median Consumer Price Index (CPI) core inflation indicator, which is able to capture inflation trends.

[3] From March 2020, the interest on required reserves ceased to exist in parallel with the reduction of the required reserve ratio to 0%, and from July 2021, the instrument was renamed interest on reserve balances (IORB).

[4] The benchmark interest rate and the IOER may differ only slightly, as some institutions are entitled to borrow funds on the interbank market but are not entitled to interest income on reserves (e.g. government agencies).

[5] The source of the data is the FED FRED database, and the econometric calculations were performed using Eviews 11 software.

[6] Based on AIC, SC and HQ values.

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