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UDC: 336.711:336.748.12
DOI: 10.2478/jcbtp-2025-0023

Journal of Central Banking Theory and Practice, 2025, 3, pp. 53-77
Received: 20 September 2024; accepted: 11 February 2025

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Monetary Policy of the ECB and its Spillover Effects to Central and Eastern Europe. Rolling Window VAR Approach

Abstract: This paper investigates the impact of the monetary policy of the European Central Bank (ECB) on economic activity in the euro area, as measured by industrial production, and price developments, as well as the spillover effects of this policy to three Central and Eastern Europe Countries: Czechia, Hungary, and Poland for the period 2000–2023 (CEE-3). The method of principal component analysis is employed to account for the bank's overall monetary policy stance and to disentangle the main factors driving the macroeconomic situation. In particular, two main factors are identified. The first pertains to the conventional monetary policy of the ECB, and the second represents its non-standard measures. Moreover, the overall monetary conditions index is calculated. Next, the use of the vector autoregression technique shows that the ECB's monetary policy exerted a significant impact on euro area inflation, while the impact on industrial production was less pronounced. The results also indicate that the ECB's monetary policy exerted some significant international spillovers. Nonetheless, they varied with regard to time (as indicated by rolling window analysis), countries, and macroeconomic variables affected.

Keywords: ECB, overall monetary conditions, spillover effects, principal component analysis.

JEL classification: E52, E58, F45.

1. Introduction

For two decades preceding the Global Financial Crisis (GFC), the recipe for effective monetary policy seemed simple: an independent central bank uses a single instrument (the interest rate) to achieve its main policy goal – price stability (cf. Haoudi & Touati, 2023 and literature cited therein). This seemed to work well during the period known as the Great Moderation, which was characterized by disinflation and relative economic stability. This changed abruptly when the GFC caused central banks to initiate a set of extraordinary monetary policy measures, including quantitative easing, and to take on new responsibilities (for example, in the realms of financial stability). Attempts to return to the pre-crisis status quo were interrupted by the COVID-19 pandemic and its unprecedented consequences for the global economy. Monetary authorities worldwide again responded with a series of measures, including unconventional monetary policies (cf. Kozińska, 2022).

The monetary policy actions undertaken by the major central banks are widely followed by emerging market economies (EMEs), as they were found to be recipients of various spillover effects. In this study, we focus on the monetary policy of the ECB conducted in 2000-2023, which encompassed the interest rate adjustments, non-standard tools, and their later phase-out. We aim to investigate these measures' macroeconomic impact on three EMEs from Central and Eastern Europe: Czechia, Hungary, and Poland. These countries are "natural candidates" for being most susceptible to the ECB's actions due to their close ties with the euro area economy (cf. Grabowski, Janus & Stawasz-Grabowska, 2023).

To account for the international macroeconomic transmission of the ECB' policy (i.e. effects on inflation and economic activity), we construct a synthetic measure of the overall monetary conditions in the euro area, in line with Lombardi & Zhu (2014) and Babecká, Claeys & Vašíček (2016). To that end, we employ factor analysis. In the next step, we estimate parameters of the restricted VAR model to evaluate the impact of the overall monetary conditions on inflation and industrial production.

The contribution of the study to literature is threefold. Firstly, the calculations of the monetary policy stance for the euro area are updated. It is shown how this measure evaluates and what is the relation between this indicator and the ECB's reference rate in period encompassing months when inflation fluctuated much more intensively than before 2020. Secondly, the spillover of the monetary policy stance to countries of the Central and Eastern Europe in recent years is shown. This problem is particularly important, since – due to high dependence on im-

ports of raw materials – these economies suffered from the problem of increasing prices of oil, gas etc. Thirdly, the importance of the overall monetary conditions in affecting inflation level and economic activity is compared in rolling windows.

The rest of the paper is structured as follows. The next section discusses the literature on the global effects of monetary policy measures of the major central banks. Section 3 summarizes the monetary policy of the ECB conducted since its inception. Section 4 lays down the methodology (together with the construction of the synthetic measure) and estimation procedures we use in this paper. Section 5 discusses the results of this study. The last section concludes and identifies issues for further research.

2. Literature review

The measures pursued in response to the GFC and the COVID-19-induced crisis and the effects of these were widely followed since the monetary authority's policy announcements convey its intended actions and assessment of the economic outlook (Hou, Khrashchevskyi, Suardi & Xu, 2024). The global effects of monetary policy pursued by the major central banks have been the focus of a strand of the literature. The actions of the United States (U.S.) Federal Reserve (the Fed) has received particular attention due to the central role of the U.S. financial markets and the U.S. dollar in the international monetary system. The literature shows that the Fed's policies during the GFC period had statistically significant effects on global financial markets (cf. Bauer & Neely, 2014; Chen, Griffoli & Sahay, 2014; Chen, Filardo & Zhu, 2016; Kiendrebeogo, 2016; Borrallo, Hernando & Vallés, 2016). Unsurprisingly, U.S. economic news (beyond monetary policy) exerts an impact on financial conditions overseas. As demonstrated by Engler, Piazza & Sher (2023), during the COVID-19 pandemic, news about U.S. employment, economic activity, as well as vaccines meaningfully affected asset prices and financial volatility in EMEs.

Studies show that EMEs are particularly sensitive to spillovers from the monetary policies of major central banks (Cui, Li & Zhang, 2024; Dajčman, Kavkler, Merzlyakov, Pekarski, & Romih, 2022). Monetary authorities of EMEs thus need to take the monetary policy actions of the major economies into account when determining their own. Notably, comparative studies of the cross-border impacts of U.S. and euro area monetary policies point to the more extensive and persistent effects of the actions taken by the Federal Reserve and the more limited regional scope of the ECB's measures (cf. Chen et al., 2016; Apostolou & Beirne, 2019). Zorzi et al. (2020) provide evidence that the Fed's monetary policy exerts

a stronger external influence than that of the ECB, particularly with respect to foreign financial variables, such as corporate bond spreads. They further demonstrate that Fed monetary policy spillover significantly impacts euro-area financial conditions; the ECB monetary policy impact on the U.S. economy is negligible. The vast majority of existing studies on ECB policy spillover focus on the responses of countries from Central and Eastern Europe (CEE), countries with strong trade and financial ties with the euro area.

Two main lines of research can be distinguished in this literature. The first includes event studies that focus on the financial market impact of policy announcements. The second line of research concentrates on the economic effects of policy actions, and studies usually employ vector autoregression (VAR) estimation techniques. In the first body of research, the general conclusion is that the ECB's unconventional monetary policy and its asset-purchase-program announcements during the euro area sovereign debt crisis led to an appreciation of local currencies and a reduction in sovereign bond yields, with inconclusive impacts on equity markets (cf. Falagiarda, McQuade & Tirpák, 2015; Fratzscher, Lo Duca & Straub, 2016; Ciarlone & Colabella, 2016; Varghese & Zhang, 2018). By contrast, in a study focused solely on the Polish economy, Janus (2019) finds time-varying and diversified but typically modest volatility spillover from the ECB's non-standard policies.

As regards the second line of research, Horvath & Voslarova (2016) show that the stabilization measures undertaken by the ECB benefitted the CEE-3 countries (Czechia, Hungary, and Poland); these experienced temporary increases in GDP growth and inflationary pressures. Moder (2019) comes to a similar conclusion. Potjagailo (2017) shows that an expansionary ECB monetary policy had a positive impact on industrial production in all EU countries outside the euro area (especially small open economies with fixed exchange rate regimes). Furthermore, most countries that allowed their currencies to fluctuate against the euro saw their currency appreciate, and most of the countries under consideration experienced declines in interest rates and increased uncertainty. In contrast, Angelovska-Bezhoska, Mitreska & Bojcheva-Terzijan (2018) are unable to identify any positive effects of the expansion of the ECB's balance sheet on capital flows in the region.

Finally, several studies compare the strength of global monetary-policy transmission before and after the GFC; the period prior to the GFC is mostly associated with conventional measures, and the post-GFC period with quantitative easing. Within this strand of research, the post-crisis period shows a strengthening of U.S. policy spillover (cf. Li, Curcuru, Kamin & Rodriguez, 2018 and the literature

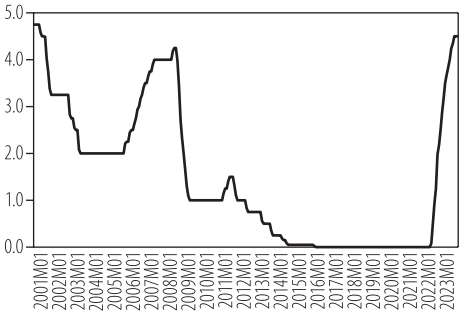
cited therein). In the context of the ECB's actions, Hajek & Horvath (2018) show that the effects of conventional measures are stronger than those of unconventional ones. Babecká et al. (2016) come to a similar conclusion, finding important spillover effects of conventional measures on macroeconomic developments in six non-euro area EU economies; the impact of unconventional measures proved generally weak and differed across the countries of interest. By contrast, in the specific case of the Swiss stock market, Fausch & Sutter (2022) find a statistically significant impact of the ECB's conventional and unconventional monetary policies, with the former's influence being limited to the pre-GFC period.

3. Evolution of the ECB's monetary policy

It seems highly unlikely that when the ECB started in 1999, anyone would have predicted that in its first two decades of operations, it would have to face the extraordinary events of the GFC and the COVID-19-induced shock. Both required quick and bold actions, with little time for consideration of the fact that, indeed, the ECB was entering unchartered waters.

In its early response to the GFC, the ECB acted in two ways. First, it pursued a conventional monetary policy, lowering its key interest rate, the main refinancing operations (MRO) rate, from 4.25% in September 2008 to 1.00% in May 2009 (Figure 1). Second, the bank offered enhanced credit support to the euro area banking sector in its provision of credit. This enhanced credit support consisted of five elements: liquidity management measures, relaxation of collateral standards, extending the maturities of refinancing operations, providing liquidity in foreign currencies (particularly in U.S. dollars), and outright purchases of covered bonds (Trichet, 2009). As the crisis spread, becoming a sovereign debt crisis for some euro area members, the ECB announced two programs allowing it to buy these countries' sovereign bonds in the secondary market – the Securities Markets Programme (SMP) and Outright Monetary Transactions (OMT).

Figure 1: ECB Main Refinancing Operations Rate (%)



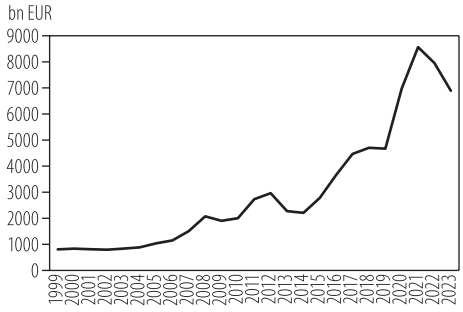
Source: Refinitiv Eikon

The SMP, launched in May 2010, saw the ECB acquire around EUR 220 billion of Greek, Irish, Italian, Portuguese, and Spanish government bonds. The program was terminated in September 2012 with the announcement of the OMT; although never applied, the OMT allowed for unlimited purchases of government bonds and was widely identified as the ECB taking on the role of lender of last resort for euro area sovereigns (cf. De Grauwe & Ji, 2014).

In the post-GFC years, countries in the euro area struggled with subdued economic activity and deflation. Against that background, in March 2016, the ECB, over a series of rate cuts, reduced its MRO rate to 0.00%, where it remained until the first half of 2022. It also initiated a package of measures in mid-2014 with the objective of supporting the monetary policy transmission mechanism, facilitating credit provision to the real economy, and supporting the euro area's recovery. The package included the Targeted Longer-Term Refinancing Operations (TLTROs) and the Asset Purchase Programme (APP), consisting of a Corporate Sector Purchase Programme, Public Sector Purchase Programme, Asset-Backed Securities Purchase Programme, and Third Covered Bond Purchase Programme. The asset purchase initiative expired in December 2018; however, the ECB decided to restart net purchases in September 2019 against the background of muted inflationary pressure and downward revisions to the outlook for the euro area economic growth.

The ECB's response to the COVID-19-induced crisis seems to have been bolder than its reaction to the GFC; in the former case, the bank initiated various non-standard measures in an extremely quick fashion. More specifically, in March and April 2020, soon after the WHO's declaration of the global COVID-19 pandemic (March 11, 2020), the ECB announced additional long-term refinancing operations (LTROs), more favorable terms in a third series of targeted LTROs (TLTRO III), enhanced U.S. dollar liquidity provision (in coordination with the Fed and other major central banks), additional net asset purchases, collateral easing, and the Pandemic Emergency Longer-Term Refinancing Operations. In addition, the ECB launched the Pandemic Emergency Purchase Programme of EUR 750 bn, covering private and public sector securities, which was later expanded to

Figure 2: ECB total assets



Source: ECB

a total of EUR 1,850 bn. As a result, the ECB's balance sheet reached its highs in 2021 (Figure 2).

After years of inflation running well below central bank targets (or even falling into negative territory), 2022 turned out to be a year of "brutal inflation" (The Economist, 2022). Prices in advanced and emerging economies soared, with the global inflation rate reaching an estimated 9.0%. In the euro area, inflation reached double digits in September 2022, a level not seen since the inception of the currency union. Initially, price pressures, which had been mounting since the second half of 2021, were seen as reflecting transitory factors (Lane, 2021). Hence, with a view to supporting post-pandemic recovery, the bank maintained an extra loose monetary policy stance. A reassessment of inflation developments caused the ECB to reverse course and tighten its policy. In particular, since July 2022, the ECB increased its MRO rate ten times to reach 4.50% in September 2023. The bank also began reducing its balance sheet. More specifically, it discontinued net asset purchases under the Pandemic Emergency Purchase Programme in March 2022. Reinvestments under the programme were scheduled to cease at the end of 2024. Net purchases under APP were discontinued in July 2022 and reinvestments in July 2023.

4. Data and methodology

As demonstrated above, since the onset of the GFC, the ECB has employed both conventional and unconventional monetary policy measures, and the policy interest rate cannot be used as a proper measure of its monetary policy stance. Therefore, we calculate a synthetic measure of overall monetary conditions – a monetary conditions index (MCI), following the logic of Babecká et al. (2016). The index is based on 14 variables, reflecting the monetary policy stance in the euro area. They can be classified under one of the following categories: interest rates, monetary aggregates, selected balance sheet items from the ECB's balance sheet, and exchange rate. Table 1 sets out the definitions and sources for all variables employed.

Table 1: Variables used in the study

Name	Description	Source
MRO	Main refinancing operations rate (%)	ECB
Rate3M	Money market interest rates, 3-month rate (%)	Eurostat
Rate12M	Money market interest rates, 12-month rate (%)	Eurostat
Yields	10-year government bond yields (synthetic measure for the euro area, %)	Eurostat
OIS	Overnight index swap (%)	Refinitiv Eikon
M1	Monetary aggregate M1 (millions of EUR)	ECB
M2	Monetary aggregate M2 (millions of EUR)	ECB
M3	Monetary aggregate M3 (millions of EUR)	ECB
Assets	Total assets of the Eurosystem (millions of EUR)	ECB
Securities	Securities held for monetary policy purposes – Eurosystem	ECB
LTRO	Longer-term refinancing operations – Eurosystem (millions of EUR)	ECB
Currency	Currency in circulation reported by the Eurosystem (millions of EUR)	ECB
Liabilities_CI	Liabilities to euro-area credit institutions related to monetary policy operations denominated in euro (millions of EUR)	ECB
FX	Nominal exchange rate USD/EUR	Refinitiv Eikon

In the study, we analyze the period 2000-2023. The data follow a monthly frequency, and related time series data were obtained from the ECB, Eurostat, and Refinitiv Eikon databases.

Following the methodology proposed by Babecká et al. (2016), all variables, except for interest rates, are transformed into year-on-year changes. The other categories are introduced with a negative sign to maintain coherence with interest rates, an increase in which reflects monetary policy tightening.

Factor analysis is an appropriate method to identify unobservable features using observable categories. The factor analysis model has the following form (Harman, 1976):

$$\boldsymbol{x} = \boldsymbol{\mu} + \boldsymbol{\Lambda f} + \boldsymbol{u}, \tag{1}$$

where $\boldsymbol{x}$ is the vector of observed responses, $\boldsymbol{f}$ denotes a vector of common factors, and $\boldsymbol{u}$ is the vector of unique factors. The matrix $\boldsymbol{\Lambda}$ comprises factor loadings. It is assumed that vectors $\boldsymbol{f}$ and $\boldsymbol{u}$ have a zero mean and are uncorrelated. The vector $\boldsymbol{\mu}$ contains the means of $\boldsymbol{x}$.

After identifying factors summarizing the information contained in the original set of 14 variables, the overall monetary policy conditions in the euro area are identified with the MCI. The index is created by weighing the identified factors by their share in the explanation of variability of the original data series.

Finally, we check the impact of overall monetary conditions, as expressed by the MCI, on the macroeconomic situation of the CEE-3 countries to account for the ECB's spillover effects. More specifically, we investigate the response of prices and economic activity, as measured by industrial production. To that end, we estimate the parameters of the VAR model and conduct an impulse response analysis.

Apart from the impulse response analysis for the whole period 2000-2023, impulse response analyses are conducted in rolling windows for 9-years periods. We start with the impulse response analysis on the basis of data covering years 2000-2008 and later do it for years 2001-2009, 2002-2010,…,2015-2023. Such analysis enables comparing reaction of macroeconomic variables on monetary policy of the ECB (domestic reactions and spillovers) in different sub-periods.

5. Empirical results

Table 2 presents the eigenvalues of subsequent components. Using the eigenvalue criteria proposed by Kim and Mueller (1978), it seems that the choice of two factors is optimal (two eigenvalues are larger than 1).

Table 2: Variances of subsequent factors

Component	1	2	3	4	5	6	7
Variance	8.28	2.62	0.99	0.87	0.60	0.30	0.13
Component	8	9	10	11	12	13	14
Variance	0.08	0.02	0.02	0.02	0.01	0.01	0.00

Table 3 presents the results of factor analysis in the two-factors case using Varimax rotation.

Table 3: Results of factor analysis in the two-factor case

Variable	Factor 1	Factor 2	Uniqueness
MRO	0.215	0.967	0.019
Rate3M	0.198	0.981	0.002
Rate12M	0.230	0.971	0.003
Yields	0.395	0.752	0.279
OIS	0.211	0.959	0.036
M1	0.741	0.527	0.174
M2	0.883	0.188	0.184
M3	0.855	0.000	0.268
Assets	0.914	0.273	0.091
Securities	0.671	0.473	0.325
LTRO	0.794	0.138	0.351
Currency	0.635	0.375	0.456
Liabilities_CI	0.855	0.264	0.199
FX	0.000	-0.125	0.984
SS loadings	5.450	5.181	
Proportion explained	0.389	0.370	
Cumulative proportion	0.389	0.759	

The identified factors explain about 76% of the variability in the original series. The proportion of variability explained by each factor is similar (39% for the first factor and 37% for the second factor). Given the standardized loadings presented in Table 3, the first factor is mainly associated with developments in the ECB's balance sheet and monetary aggregates. The second factor is largely driven by interest rates, thus representing the conventional monetary policy stance.

In the last column of Table 3 the uniqueness of each variable is presented. It can be interpreted as the proportion of variance of each variable that is not shared with the other variables. The largest value of uniqueness is identified for *FX* and is equal to 0.984. This result indicates that the linkages between this variable and the other categories are not strong.

After multiplying values of each factor by relative proportion of explained variability (proportions of variability explained by both factors are divided by sum of proportions), multiplying by standard deviation of MRO and adding sample mean of MRO[1] value of the MCI index is calculated. Figure 3 presents the MCI

[1] Due to the use of standardization procedure in the factor analysis, multiplying by standard deviation of the MRO rate and adding the sample mean of this variable enables comparison of the MRO and the MCI in time.

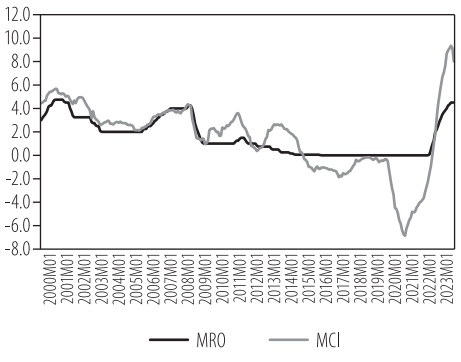
index against the MRO rate. It follows that two subperiods can be distinguished: a pre-GFC crisis and a post-GFC ones. In particular, up to 2009, the MCI tracked closely the actual MRO rate. It does not come as a surprise given that the ECB resorted to no additional measures affecting the size and composition of its balance sheet and the monetary transmission mechanism worked smoothly. Some deviations in the MCI identified at the beginning of this period are attributable to the increase in the growth rate of monetary aggregates due to the euro cash changeover in 2002 (Babecká et al., 2016).

The second subperiod is marked by the episodes of substantial deviations of the MCI from the MRO rate. In particular, at the hight of the euro area crisis, the ECB launched two 3Y LTRO-s (in December 2011 and March 2012) and the SMP (with largest purchases conducted in the second half of 2011 and at the beginning of 2012), which translated into the MCI falling below the MRO rate in the first half of 2012. With a decrease in the ECB's balance sheet, resulting from early repayments of LTROs and maturing of securities purchased under the Covered Bond Purchase Programme and the SMP, the MCI increased above the MRO rate again.

A substantial monetary policy easing of monetary policy conditions, initiated with a launch of TLTROs in the mid-2014 is reflected in a drop in the MCI. The index fell below the MRO rate at the beginning of 2015, i.e. soon after the ECB embarked on quantitative easing. Its deviations from the MRO rate seem to illustrate the changing targets set under the APP: from an increase in net purchases in April 2016 – via three decreases – to only reinvestments of redemptions, from January to October 2019.

A package of unconventional measures introduced by the ECB as a response to the COVID-19-induced shock pushed the MCI again into the negative territory, well below the MRO rate. The index reached its lowest level at the beginning of 2021 when the size of the ECB's balance sheet expanded to its record highs. Conversely, the aggressive monetary tightening, including quantitative tightening, drove the MCI above the MRO rate at the beginning of 2023, with the largest difference between the two in October 2023.

Figure 3: The MCI and the MRO rate (%)



In order to analyse the impact of the MCI on macroeconomic categories in the euro area and the CEE-3 countries, parameters of VAR models will be estimated. Since VAR models are estimated for stationary variables, the order of integration of the macroeconomic categories should be tested. Table 4 presents the results for the order of integration of the two response variables considered in the empirical investigation for the euro area, Czechia, Hungary, and Poland using unit root tests proposed by Dickey & Fuller (1979, 1981), as well as Kwiatkowski, Phillips, Schmidt & Shin (1992).

Table 4: Testing order of integration of macroeconomic variables

Euro area					
Variable	Level		First difference		Decision
	ADF-statistic	KPSS-statistic	ADF-statistic	KPSS-statistic	
Inflation	-2.08 (i,1)	0.40	-12.65 (n,0)	0.09	I(1)
Industrial production	-3.57 (i,1)	0.08	-	-	I(0)
Czechia					
Variable	Level		First difference		Decision
	ADF-statistic	KPSS-statistic	ADF-statistic	KPSS-statistic	
Inflation	-1.11 (n,1)	0.46	-12.96 (n,0)	0.07	I(1)
Industrial production	-1.80 (i,0)	0.22	-16.92 (n,0)	0.06	I(1)
Hungary					
Variable	Level		First difference		Decision
	ADF-statistic	KPSS-statistic	ADF-statistic	KPSS-statistic	
Inflation	-3.43 (i,2)	0.12	-	-	I(0)
Industrial production	-1.67 (i,0)	0.24	-16.56 (n,0)	0.03	I(1)
Poland					
Variable	Level		First difference		Decision
	ADF-statistic	KPSS-statistic	ADF-statistic	KPSS-statistic	
Inflation	-1.96 (n,1)	0.59	-	0.11	I(0) or I(1)
Industrial production	2.56 (n,0)	4.66	-15.53 (n,0)	0.09	I(1)

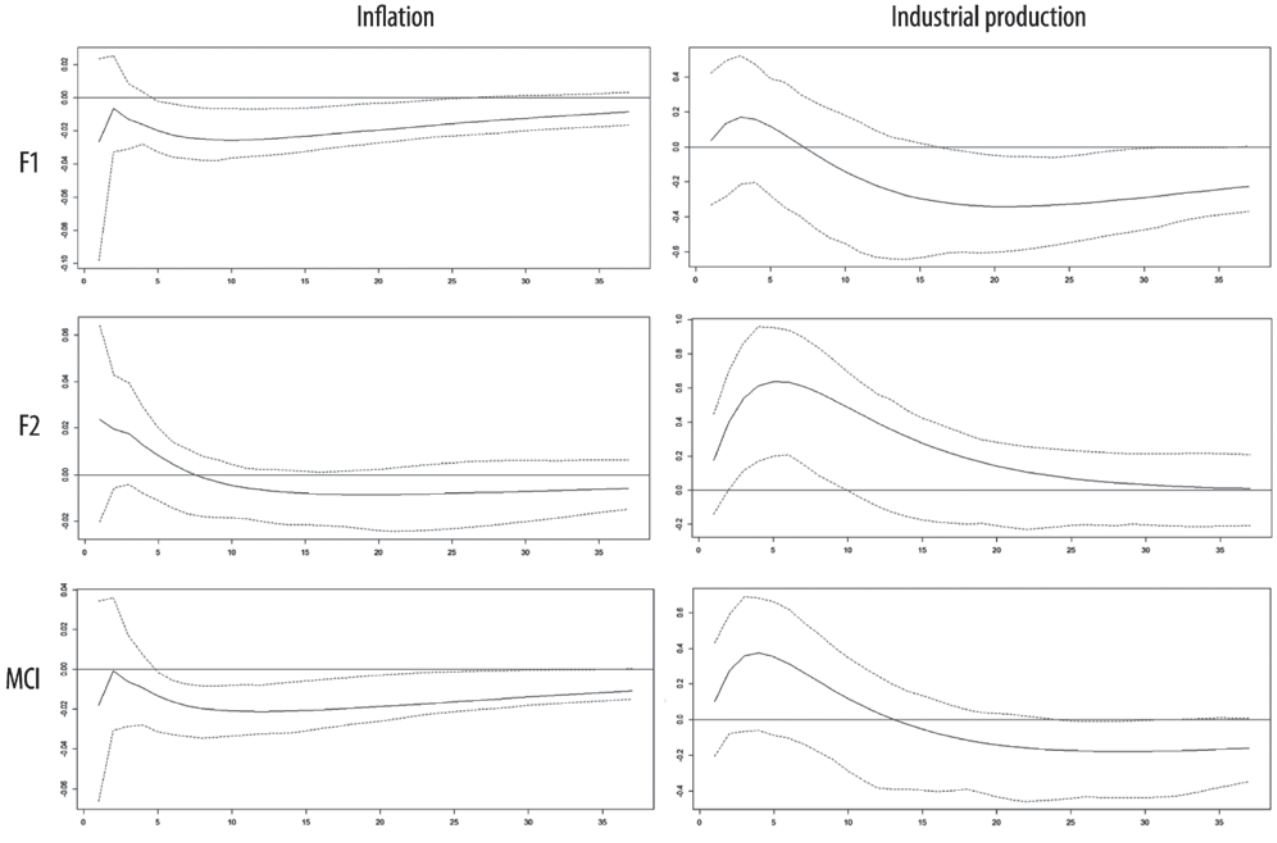
Note: In brackets n means that statistic is based on regression without intercept while i means that the statistic is based on regression with intercept. Number in bracket denotes lag length for the ADF test.

The results from Table 4 indicate that in the case of the euro area, industrial production index is stationary (trend-stationarity is identified), while in the case of Czechia, Hungary, and Poland it is I(1). Therefore, in the VAR model deterministic trend will be eliminated from the series of industrial production for the euro area and in the case of this variable for Czechia, Hungary and Poland first differences of industrial production will be calculated and used in VAR model. Inflation turned out to be trend-stationary for Hungary and integrated of order one in the case of the euro area and Czechia. Inconclusive results of the ADF and KPSS test are found in the case of Poland. However, the use of the joint ADF-KPSS test (Charemza & Syczewska, 1998) indicates that this variable should be treated as I(1).

In order to evaluate the impact of the MCI on the macroeconomic variables in the euro area and the CEE-3 countries, two variants of VAR models for Czechia, the euro area, Hungary, and Poland were estimated. In both variants the variables *Inflation* and *Industrial production* were included in VAR models. In the first variant, the two identified factors (F1 and F2) are included in VAR, while in the second variant the MCI is included. Moreover, restrictions assuming that economic variables for the CEE-3 countries do not have an impact on monetary policy of the ECB were imposed.

Figures 4-7 present the results of the impulse response analysis, showing the impact of F1, F2, and the MCI on the analysed macroeconomic variables (*Inflation* and *Industrial production*).

Figure 4: Impulse response functions – the impact of the ECB monetary policy on macroeconomic variables: euro area



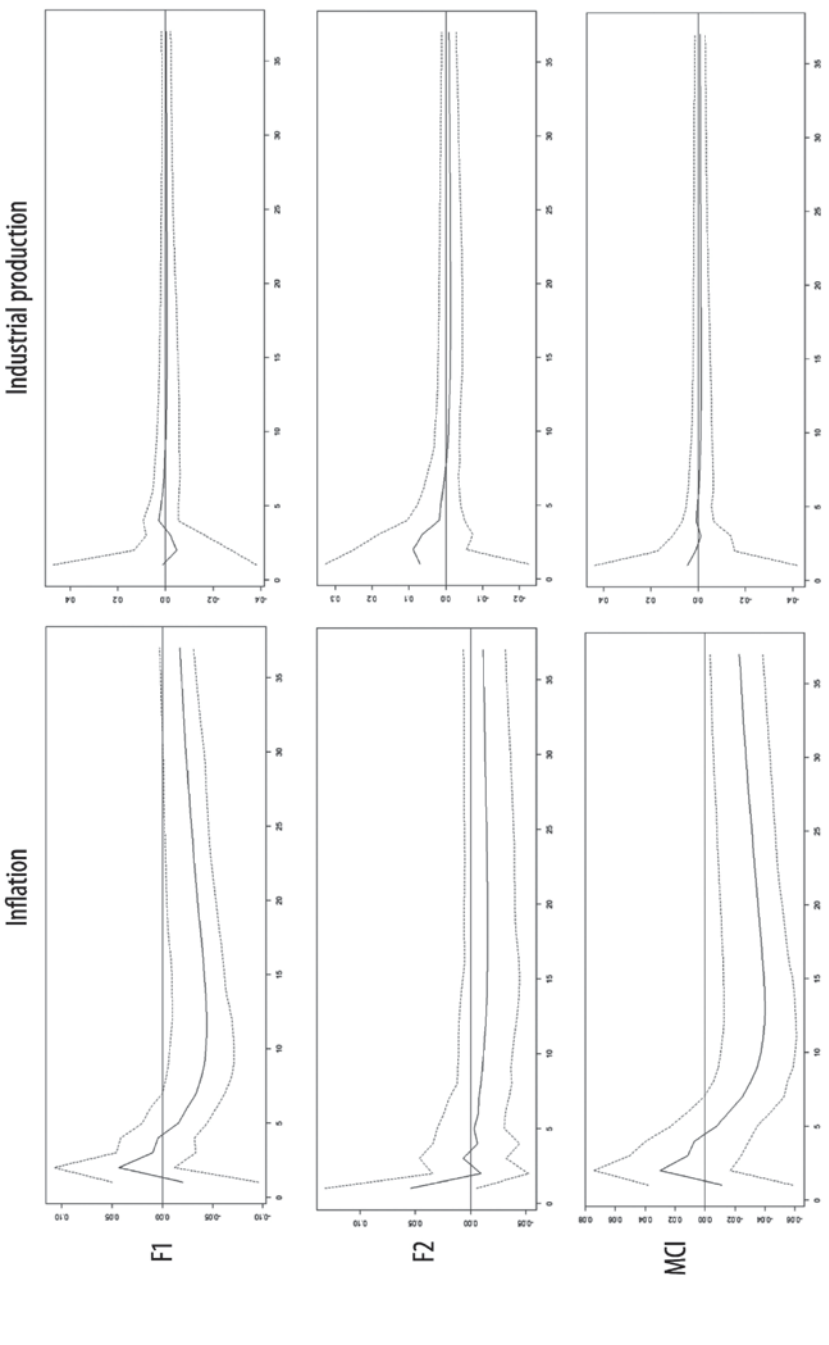
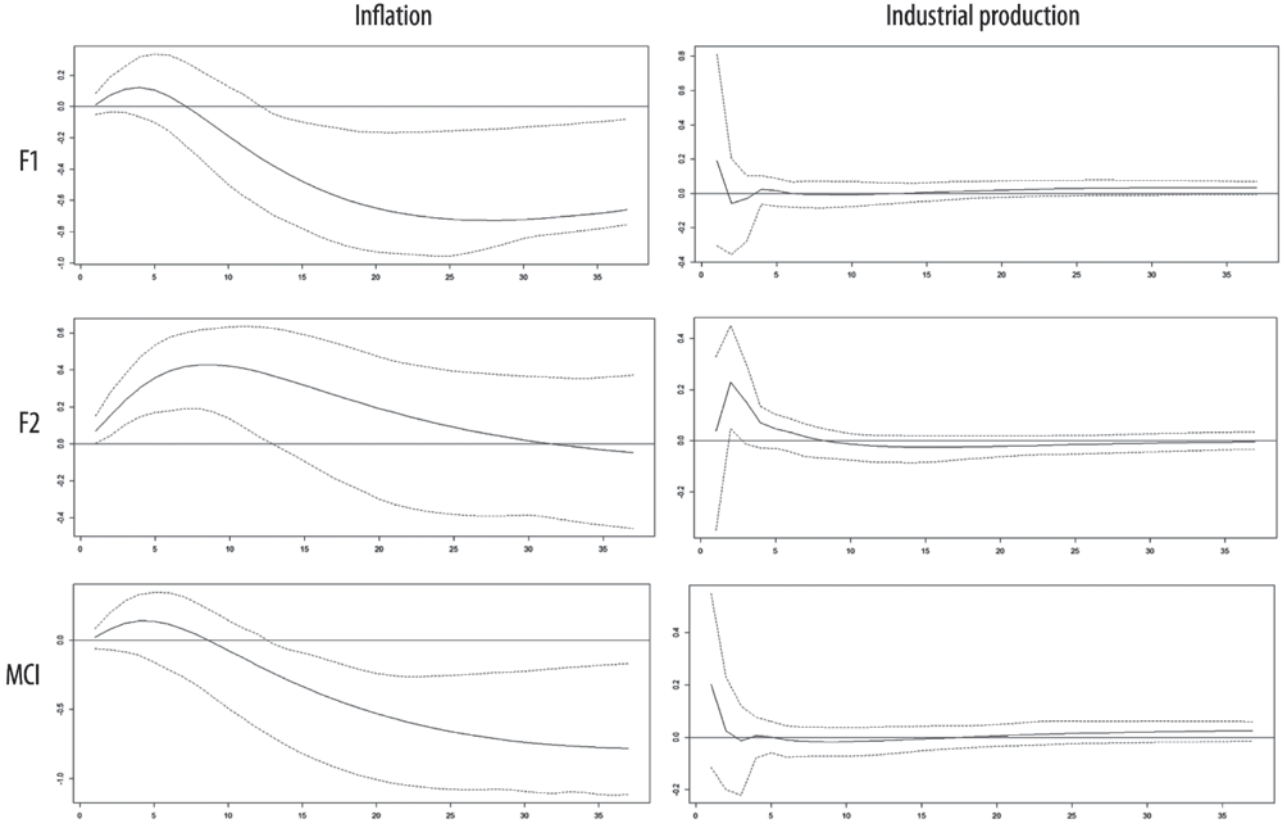


Figure 5: Impulse response functions – the impact of the ECB monetary policy on macroeconomic variables: Czechia

Figure 6: Impulse response functions – the impact of the ECB monetary policy on macroeconomic variables: Hungary



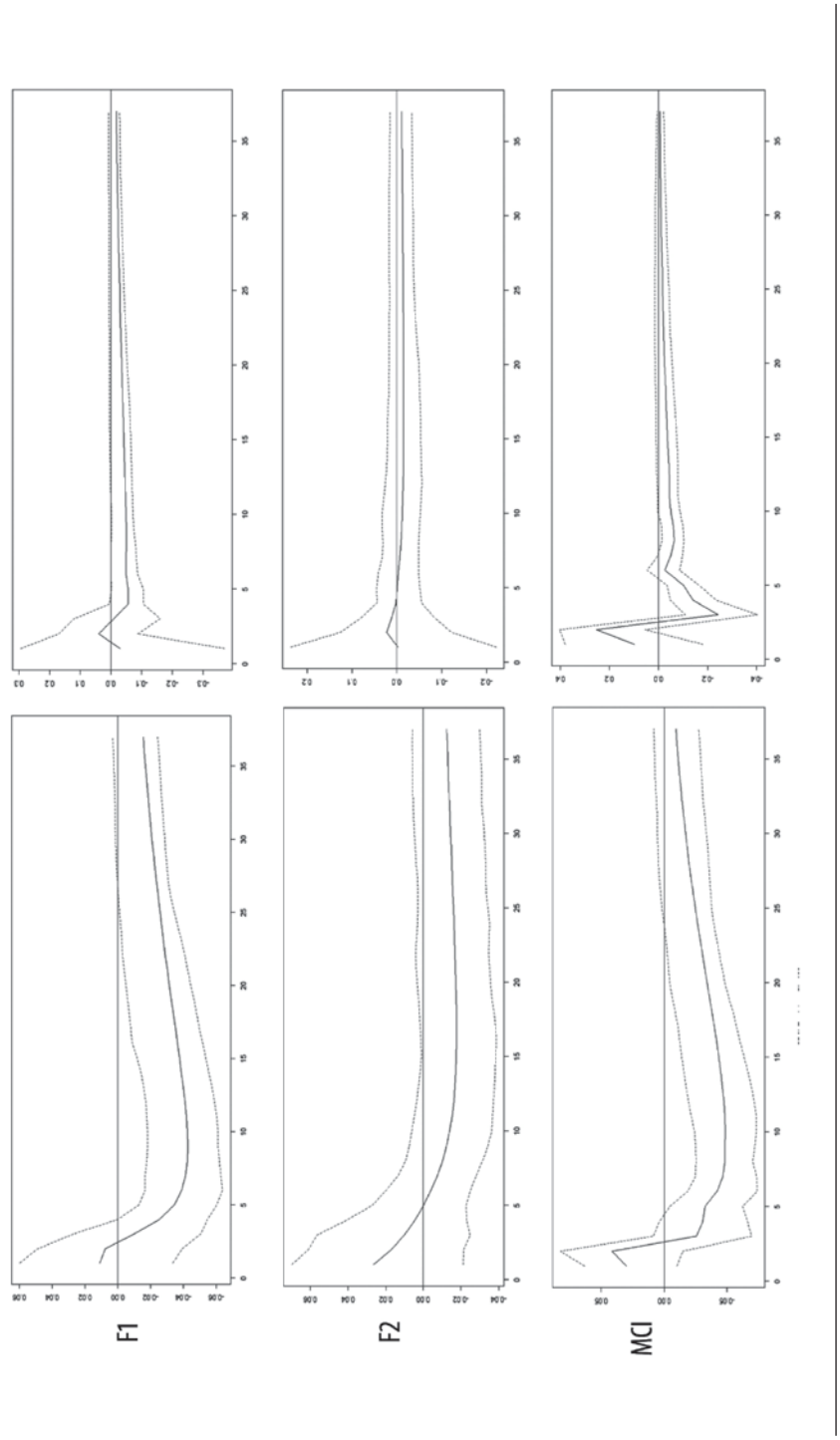


Figure 7: Impulse response functions – the impact of the ECB monetary policy on macroeconomic variables: Poland

Figures 4-7 indicate that, unsurprisingly, the reaction of *Inflation* and *Industrial production* to changes in monetary conditions (as measured by F1, F2, and the MCI) varied between the euro area and the CEE-3 countries. More specifically, the impact on the euro area turned out to be stronger, given that both variables were affected (though *Industrial production* only by F1). The strongest response of *Inflation* came from shocks to F1 and the MCI. In both cases, monetary conditions tightening resulted in a decrease in inflation, with the strongest effects observed after 10 to 20 months.

Referring to the spillover effects from the ECB's monetary policy, a very similar pattern emerged in each of the analysed countries. In particular, economic activity, as measured by industrial production, proved to be unaffected by changes in monetary conditions in the euro area. When it comes to inflation, we identify no response to shocks to F2. In other words, conventional measures introduced by the ECB had no impact on inflation in the CEE-3 countries. On the other hand, inflation in all countries was affected by shocks to F1 and the MCI, accounting for the ECB' s non-standard monetary policy. A tightening of the monetary conditions in the euro area translated into lower inflation in the CEE-3 countries. With regard to the magnitude of influence, the strongest response was identified for Hungary. Also, the effects on Hungarian inflation turned out to be more lasting than in the other two economies. At the same time, they occurred with a lag with regard to the effects found in Czechia and Poland.

In the next step, to check whether the above-discussed effects were stable or differed with regard to time, impulse response analysis was conducted in rolling windows, each consisting of 9 years. That way, estimations were carried out for the following subperiods: 2000-2008, 2001-2009,…, 2015-2023. In Table 5 and Table 6, "+" denotes statistically significant negative impact of an increase in the factors, i.e. tightening of monetary conditions in the euro area, on inflation and industrial production (for some n-step ahead forecasts, 95-percent confidence intervals of IRFs were below 0). "-" denotes insignificance.

Referring to inflation, results from Table 5 show that changes in monetary conditions in the euro area exerted particular impact in periods 2012-2020,..., 2015-2023. It may be due to the fact that these years were marked by unprecedented scale and variety of measures launched by the ECB. First, the bank maintained an ultra-loose monetary policy stance which it later started to aggressively reverse by increasing its policy rate to 4.5%, i.e. the highest level since the GFC, and embarking on quantitative tightening.

The response of industrial production turned out to be time-varying too. As with inflation, the euro area output proved to be affected by shocks to conventional and non-standard shock, which was observed in years at the beginning of the research period (2000-2008,…, 2003-2011) and at its end (2011-2019,…, 2015-2023). It seems that in the case of the impact on inflation the first factor dominates. In the case of the impact on industrial production, the second factor seems to be more important.

When it comes to spillover effects, the results from Table 6 may seem somewhat surprising. Though the analysis of Figures 5-7 indicates that the impact of monetary policy shocks to industrial production in Czechia, Hungary, and Poland in the whole period 2000-2023 was weak, some significant responses can be found when data for 9-year subperiods are considered. In all these countries, statistically significant spillovers were found at the beginning of the research period. Subsequent euro area monetary conditions, especially from the last few subperiods, generated a variety of responses. In particular, no significant impact was identified in Czechia, while industrial production in Hungary and Poland were affected.

When the impact of monetary policy shocks to industrial production in Czechia, Hungary and Poland is considered, it turns out that on the basis of data encompassing initial and final sub-periods, spillovers were statistically significant. It may mean that the impact of the euro area monetary policy shocks on industrial production in middle sub-periods was very insignificant and might have had opposite direction[2]. Spillovers of the ECB monetary policy to inflation in the CEE-3 countries are in line with the results from figures. However, Table 5 shows that the reaction of inflation was significant but not in all sub-periods. The strongest spillover of the ECB monetary policy to inflation in the CEE-3 countries was recorded in sub-periods 2012-2020,…,2015-2023. This finding is in line with expectations, since in the last years, the ECB introduced numerous measures aimed at firstly increasing and later decreasing inflation. The COVID-19 pandemic, as well as the Russian invasion of Ukraine turned out to have very significant impact on changes in prices, and the fact that inflation was not close to the target encouraged the ECB to introduce appropriate measures. Inflation in the CEE-3 countries might have reacted to these measures or might have reacted to domestic measures introduced by national central banks as a reaction to decisions of the ECB.

[2] Results of the calculations confirm this guess. These results are available on request.

Table 5: IRFs in rolling windows – Inflation response to F1, F2, MCI shocks

	Euro area			Czechia			Hungary			Poland		
	F1	F2	MCI	F1	F2	MCI	F1	F2	MCI	F1	F2	MCI
2000-2008	+	-	-	-	-	-	-	-	-	-	-	-
2001-2009	+	-	-	-	-	-	-	-	-	-	-	-
2002-2010	+	+	+	-	-	-	-	-	-	-	-	-
2003-2011	+	+	+	-	-	-	-	-	-	-	-	-
2004-2012	-	-	-	-	-	-	-	-	-	-	-	-
2005-2013	-	-	-	-	-	-	-	-	-	-	-	-
2006-2014	-	-	-	-	-	-	-	-	-	-	-	-
2007-2015	-	-	-	-	-	-	-	-	-	-	-	-
2008-2016	-	-	-	-	-	-	-	-	-	-	-	-
2009-2017	-	-	-	-	-	-	-	-	-	-	-	-
2010-2018	-	-	-	-	-	-	-	-	-	-	-	-
2011-2019	-	-	-	+	-	-	-	-	-	-	-	-
2012-2020	-	+	+	+	-	-	+	-	+	+	-	+
2013-2021	+	+	+	+	-	-	+	+	+	+	-	+
2014-2022	+	+	+	+	-	+	-	+	+	+	-	+
2015-2023	+	+	+	+	-	+	-	+	+	+	-	+

Table 6: IRFs in rolling windows – Industrial production response to F1, F2, MCI shocks

	Euro area			Czechia			Hungary			Poland		
	F1	F2	MCI	F1	F2	MCI	F1	F2	MCI	F1	F2	MCI
2000-2008	+	+	+	-	+	-	-	-	-	-	+	+
2001-2009	+	+	+	-	+	-	-	+	-	-	+	+
2002-2010	+	+	+	-	+	-	-	+	-	-	+	-
2003-2011	+	-	-	-	+	-	+	+	+	-	+	-
2004-2012	-	-	-	-	+	-	+	+	+	-	+	-
2005-2013	-	-	-	-	+	-	-	+	-	-	+	-
2006-2014	-	-	-	-	-	-	-	-	-	-	-	-
2007-2015	-	-	-	-	-	-	-	-	-	-	-	-
2008-2016	-	-	-	-	-	-	-	-	-	-	-	-
2009-2017	-	-	-	-	-	-	-	-	-	-	-	-
2010-2018	-	-	-	-	-	-	-	-	-	-	-	-
2011-2019	-	+	-	-	-	-	-	-	-	+	-	-
2012-2020	-	+	+	-	-	-	+	+	+	+	-	+
2013-2021	+	+	+	-	-	-	+	+	+	+	-	+
2014-2022	+	+	+	-	-	-	+	+	+	+	-	+
2015-2023	+	+	+	-	-	-	-	-	-	+	-	+

6. Conclusion

The aim of this paper was to examine the effects of the overall monetary conditions in the euro area on its key macroeconomic variables (inflation and industrial production) as well as to investigate whether the ECB's monetary policy exerted spillover effects in the CEE-3 economies from 2000 to 2023. Given that this period comprised two unprecedented shocks (GFC and COVID-19-induced crisis), the monetary policy stance in the euro area could not be associated solely with the interest rate policy.

To account for the overall monetary conditions, a synthetic measure – monetary conditions index was calculated. Moreover, the method of principal component analysis allowed to distinguish two key factors, reflecting conventional and unconventional monetary policy measures, respectively.

The use of the vector autoregression technique showed that the ECB's monetary policy exerted a significant impact on the euro area inflation, while the impact on industrial production was less pronounced. The results also indicate that the ECB's monetary policy triggered some significant international spillovers. The CEE-3 countries were affected in the area of price developments, whereas economic activity in these countries exerted no response to the overall monetary conditions in the euro area. At the same time, a rolling-window analysis pointed out to some discrepancies with regard to the significance of spillover effects across time, the impact of individual factors, and responses of the macroeconomic variables included.

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