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A Small Quarterly Projection Model for a Selected Group of CEE Economies

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Abstract

The monetary policy decision process is fundamental to achieving price stability and sustainable economic growth over the medium term. In recent years, given the multitude of unprecedented shocks that hit the global economy, many complex models still need to estimate accurately the magnitude of these shocks and their impact on economic activity. This paper proposes a small quarterly projection model to assess the economic outlook for a selected group of Central Eastern European countries with similar economic characteristics. Therefore, we present a comparable analysis between Hungary, Poland and Romania for 2005Q4-2023Q4. Our results suggest a relatively good performance regarding the assessment of the economic downturn from 2020 and a similar recovery pattern in Hungary and Poland, while the recovery in Romania was only partial. A real-time forecasting exercise ensures that the trajectory of macroeconomic indicators is close to the actual data, especially during regular times.

Keywords: quarterly projection model, output gap, core inflation, Phillips curve

JEL Classification: C52, E12, E52, E58

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1 Introduction

In the decision process, monetary policy authorities' ability to assess the evolution of inflation represents an essential component of the medium-term objective of price stability. The monetary policy transmission mechanism is complex, depending on different transmission channels, transmission lags, interdependence, and data availability; therefore, providing a framework to sustain the optimal control of forward-looking monetary policy decisions is imperative. After years of low and stable inflation, following the outbreak of the COVID-19 pandemic, the global economy started to be hit by a high level of uncertainty and a multitude of adverse shocks (energy crisis, increase in commodities and oil prices, supply chain disruptions, war in Ukraine and the recently geopolitical tensions in the Middle East). These were the key drivers of the surge in inflation and had negative spillover and persistent effects. The heightened uncertainty predominantly affects economies such as emerging markets with higher degrees of trade of financial openness, vulnerabilities in the financial system or weak institutions (Bonciani and Ricci, 2020; Gupta et al., 2020).

Thus, the scope of our study is to develop a relatively small quarterly projection model (QPM) for short- and medium-term inflation analysis that could provide support for understanding the process of forward-looking monetary policy decisions and analyse possible paths of macroeconomic variables in different countries. Our contribution to the existing literature is a model that incorporates both core inflation and energy and food prices, given that they were key drivers for further accelerated inflation in 2021 and 2022, after the invasion of Russia in Ukraine that accelerated the process of energy diversification and decoupling from Russian fossil fuels. Moreover, we extend the classical four blocks model with an external block to underline the effects of foreign shocks on three small open economies (e.g., Hungary, Poland and Romania) given the importance of external shock spillovers in these countries. We provide in-sample forecast to assess forecasting performance and goodness-of-fit, ensuring a comprehensive analysis. Our findings suggest that the model provides good performance in terms of predicted values of the output gap during the economic downturn at the outbreak of the pandemic, and the recovery follows a similar pattern in case of Hungary and Poland, while for Romania it was only partial. Moreover, the real-time in-sample forecasting exercise provides the accuracy of the model in normal times, while in times marked by uncertainty such as financial international crisis and pandemic crisis, the results underestimate the true data and highlight the inherent challenges in forecasting during turbulent periods.

One of the main advantages of this reduced form of a new Keynesian model is that its structural form can offer an economic interpretation and assessment of the monetary policy transmission mechanism, while parameters are estimated or calibrated outside the model. Due to data availability, a precise model with a small number of equations, transmission channels and estimated parameters might be more appropriated for developing countries with a relatively small dataset and less experience of inflation-targeting regime. Additionally, in empirical studies simple models are relevant for simplicity, tractability especially in a comparison analysis because they can be presented and be adapted to the new dataset by a simple manner. For monetary policy transmission mechanism, a simple model offers benefits for the central bank communication with the public, in order to improve the monetary policy decisions process.

We particularize the analysis over a group of three Central Eastern European economies with similar characteristics: Hungary, Poland and Romania. First, we motivate our choice by the fact that these countries are small-open economies, classified as emerging and developing markets (IMF, 2023) that have inflation-targeting and floating exchange rate regimes. Hungary adopted the inflation-targeting regime in June 2001 and since 2015 the inflation target is set at 3% +/- 1 percentage point variation band, Poland adopted this regime in 2004 having the inflation target at 2.5% +/- 1 percentage point and Romania adopted inflation targeting regime in August 2005 and the inflation target is the same as Poland. These targets are in line with the practice of the central banks of developing economies. Moreover, empirical studies demonstrate similarities of monetary policy mechanism. For example, Jarociński (2010) provides impulse responses of monetary policy in Hungary and Poland that have similar effects on economic activity (i.e., an increase in interest rate decreases output and inflation). Sevchuck (2020) use a vector autoregressive model and finds that monetary policy responses to inflation are significant and uniform across Central Eastern European countries including Hungary, Poland and Romania. However, in this analysis, the effects on the output gap and real exchange rate are quite heterogeneous.

Second, these economies are European Union nations that are not Eurozone members yet. Candidates to join the euro area, they must accomplish convergence criteria to ensure that a member state is ready to introduce the euro. There are several structural challenges facing these countries such as political instabilities, demographic crisis (migration, fastest aging population and projections of declining the working age population), digitalization and innovation and economic uncertainty. According to DESI 2022 (The Digital Economy and Society Index) Hungary, Poland and Romania are among the six worst performing economies. The most recent coronavirus posed additional challenges; therefore, economic downturns might affect the achievement of price stability and the euro area convergence criteria.

The inflation targeting monetary policy strategy, also used by many countries, is considered by the theory and empirical studies of monetary policy analysis as a tool that allows a central bank to exercise a "constrained discretion" where the nominal anchor becomes the inflation target. At the same time, given the direct inflation strategy, monetary policy is connected to the medium and long term without affecting the capacity to react to short-term developments. Thus, this regime reconciles the discipline and responsibility imposed by rigid rules, and the flexibility allowed by the discretionary approach. In a general way, the primary functions performed by this strategy are: (i) improving communication between monetary policy decision-makers and (ii) ensuring discipline and responsibility in the development of monetary policy. Inflation targets are set in terms of headline inflation (i.e., the annual change in the consumer price index). The quarterly projection model of analysis and forecasting in the medium term that the central usually uses is a new Keynesian model having a semi-structural linearized form consistent with microeconomic fundamentals. The conduct of monetary policy is established by both forward- and backward-looking information, respectively. This class of complex models involves equations linking different channels that form monetary policy mechanisms: interest rate channel, exchange rate channel, balance sheet effect, and inflation expectations. Thus, we provide a basic understanding of the channels through which monetary policy intervenes in the economic fluctuations and potential effects of different structural shocks.

The rest of the paper is organized as follows. The second section briefly reviews the literature regarding new Keynesian models and their spread among other central banks. The following section describes the model with the equations and calibrated parameters. Then, we present the data used in this study and the impulse response functions of the shocks. The last part concludes.

2 Literature review

Over the last decades, projection models used by most of the central banks in the monetary policy decision process have proved relatively resilient and have demonstrated to be adequate for policy and scenario analysis. Most of the methods used by the central banks that adopted the inflation targeting regime are semi-structural, which are preferred for their flexibility and characteristics to accommodate alternative non-linear specifications. The quarterly projection model is a forward-looking calibrated gap model introduced for the assessment of the medium–term path of the economic variables (Benes et al., 2017; Coats et al., 2003). In this context, all the variables are defined as deviations from their long-run equilibrium levels (i.e., steady states). Therefore, it represents a relatively simple and transparent way, allowing for the critical features of the economy to be relevant for the monetary policy analysis framework (Berg et al., 2006).

In this process, a key element is the assessments of different assumptions and expert judgments related to the economy's evolution that can influence future perspectives in case of shocks. Moreover, the model determines a baseline forecast scenario as a hybrid approach between a data-driven model and judgmental input and offers risk assessments for different scenarios for the outlook regarding various kinds of shocks. A relevant aspect is that these models are linear, issue that is easy to compute in simulation exercises for scenarios to assess possible future evolutions—changing the sign of the shock or rescaling the magnitude conduct to a symmetrical or approximately proportional effect.

Berg et al. (2006) introduced the basics of the quarterly projection model (QPM). Even though this is structured as a macroeconomic model, the four main equations are derived explicitly from microeconomic foundations. The central block is represented by consumers who maximize their expected utility, and firms that operate in monopolistic competition and adjust their prices periodically. Therefore, the internal structure of the model allows for a simple but coherent description of the interactions/relationship between primary macroeconomic aggregates and captures the central propagation channel of economic shocks. The Phillips curve is one of the crucial relationships in the model in which nonlinearity can be present given the potentially flattening Phillips curve for the trade-off between inflation and output gap variability. This development was attributed, in part, to the globalization process.

As mentioned, many policy institutions use different complex extensions of quarterly projection models in their modelling strategy. For example, the Bank of England Quarterly model (BEQM), described by Harrison et al. (2006), is the primary tool in a suite of models employed in the forecast process. Thus, the economy's behaviour at the aggregate level is related to the income and expenditures data from the UK National Accounts. The methodology describes the behaviour of domestic agents, policymakers, and the interactions with the external environments and other financial markets. BEQM model incorporates forward-looking representations about inflation and related to disposable income, aggregate demand, or exchange rate. These features are similar to other models, such as the Bank of Canada's Quarterly Projection Model, the US Federal Reserve Board of Governors, or the Reserve Bank of New Zealand's Forecasting and Policy System model.

Many events that happened in recent periods, after the financial crisis in 2008, such as changes in the system of national accounts or structural changes in the economy after the COVID-19 pandemic, request recalibrations of those models at each significant change in the macroeconomic framework. In this sense, the existing literature highlights that after a major adverse event, the transmission mechanism of shocks, the volatility of exogenous shocks and the correlation between these are changing (Koop et al., 2009; Sims and Zha, 2006; Prüser, 2021; Liao et al., 2023). An updated version of the demand-driven model of the Bank of Spain - MTBE (Ortega et al., 2007; Pareja et al., 2017) incorporates new econometric techniques and new estimates for parameters. The results show less response of demand to interest rates but more to credit and, at the same time, less response to GDP to external demand but more to world prices, especially oil price.

To generate forecasts and risk assessment in conducting policy analysis, a QPM model developed for the Indian economy (Benes et al., 2017) incorporates important aspects representative for the economy, such as the contribution of the agricultural sector and food prices in the inflation, an endogenous credibility channel and some specific characteristic for monetary policy transmission. For the last-mentioned aspect, we note the inertia of the long-run market interest rates and a modified version of the risk-adjusted UIP equation (i.e., Uncovered Interest Rate equation) to diminish exchange rate sensitivity to interest rate differential between domestic and external environment.

Central Eastern European countries use different specifications of the QPM model that became publicly available before the global financial crisis. After switching to an inflation-targeting regime, Magyar Nemtzi Bank started to fund its quarterly projection on NEM (Benk et al., 2006). Similar to other QPM models, the NEM model's short-run dynamics are described according to neo-Keynesian models incorporating nominal rigidities and sluggish adjustments. At the same time, the long-run Phillips curve comes from neoclassical theory. As a particularity, the production function is a Constant of the Substitution function with two inputs given by capital and labour. The long-run path is conducted assuming the existence of labour-augmenting technological progress and a non-accelerating inflation rate of unemployment (NAIRU). The projection model for the Polish economy described by Budnik et al. (2009) is partially forward-looking and models consistent inflation expectations. However, the model is distinguished by path-dependent labour market equilibrium, describing high variability in unemployment. The design of the model does not include external demand. The Romanian economy uses a structured forecasting framework for its quarterly macroeconomic projections, as well.

Another model developed for CEE economies is the one of the Central Bank of the Czech Republic that highlights the importance of the exchange rate stabilization objective in the monetary policy loss function by allowing for an exchange rate feedback term (Strasky, 2005). Small open economies display particularities that should be considered to produce accurate forecasts that explain the relationship between variables and the transmission mechanism. For example, the open economy New-Keynesian general equilibrium model for the Croatian economy defines the monetary policy rule by an unconventionally exchange rate reaction function having a slow-moving exchange rate target. In this way, the gap model describes the dynamics of a small open economy with a high degree of credit euroization (Bokan and Ravnik, 2018).

Recent pieces of evidence in the Forecasting and Policy Analysis Systems are brought by Debuque-Gonzalez and Corpus (2023) who developed a new small macroeconometric model for Philippines. The authors aim for a relatively small macroeconomic model that is tractable and easy to present. The model assesses historical turning points for GDP growth and CPI inflation and produces accurate forecasts of important macroeconomic variables. Al-Sharkas et al. (2023) developed another reliable analytical framework for macroeconomic analysis under a pegged regime for Jordan economy. The model incorporates features like fiscal block and adjustments for COVID-19, government stimulus that enhance the ability to make predictions under uncertainty. However, a more complex form with a developed monetary block may better trace the historical evolutions in domestic interest rates. As an essential mention in this context, we have to say that for central banks to anchor the results of the econometric optimization and expert judgments, those models represent a continuous effort of improvements and incorporate additional expert judgment to describe the economy.

3 The model

This study presents the canonical semi-structural Kew-Keynesian model, which starts from the core model underlying the forecasting and policy analysis system. Following the seminal work of Berg et al. (2006) and Galli (2008), this framework was introduced and developed by many central banks as a practical medium-term analysis and projection tool. It is also known as the Quarterly Projection Model (QPM) or the "gap" model, given that all the variables are expressed as deviations from their long-run trends. The model was calibrated rather than estimated for simplicity and comparative analysis between the selected group of CEE countries. Moreover, the approach of estimated parameters is problematic for data subject to structural breaks, small samples, and regime switching. Thus, in that case it might require additional expert judgments. The model structure proposed in this paper consists of four main equations and several identities.

A. Aggregate demand (IS curve) The "aggregate spending" relationship is representative for real economic activity and define the output gap ($\widehat{y}_t$), which is the deviation of the log of the real output from its potential or trend level ($\overline{y}_t$ represents the level of the output that can be produced in the economy without generating inflationary pressures).

$$\widehat{y}_t = b_1 \widehat{y}_{t-1} - b_2 mci_t + b_3 \widehat{y}^*_t + \varepsilon^y_t \tag{1}$$

$$mci_t = b_4 \left(\widehat{r}_t + prem_t\right) + \left(1 - b_4\right)\left(-\widehat{z}_t\right) \tag{2}$$

$$z_t = s_t + p^*_t - p_t \tag{3}$$

where mci_t is the real monetary condition index defined as a weighted average of i) deviations of the real interest rate from its neutral (noninflationary) level ($\widehat{r}_t$) plus a credit premium term and ii) deviation of the real exchange rate (RER) from its trend level ($\widehat{z}_t$). The real exchange rate is described as nominal exchange rate s_t adjusted for difference in foreign CPI (p^*_t, consumer price index) and domestic CPI (p_t). An increase (decrease) in z_t is equivalent to a depreciation (appreciation) of the RER. The foreign output gap is represented by $\widehat{y}^*_t$ (in log terms) and ε^y_t is an aggregate demand shock. The coefficients of these equations b_1 refers to the persistence of the output gap in the autoregressive process; b_2 quantifies the impact of monetary conditions on economic activity and b_3 stands for the effect of the external block.

B. Aggregate supply (Phillips curve) The forward-looking "Phillips curve" block for a small open economy consists by a set of equations, namely Phillips curves for headline inflation, core inflation and its components.

$$\pi_t^{core} = a_1 \pi_{t-1}^{core} + (1 - a_1) E_t \pi_{t+1}^{core} + a_2 rmc_t + \varepsilon_t^{core} \tag{4}$$

$$rmc_t = a_3 \widehat{y}_t + (1 - a_3)(\widehat{z}_t - \widehat{rp}_t^{core}) \tag{5}$$

$$\pi_t^{food} = a_{21} \pi_{t-1}^{food} + (1 - a_{21}) E_t \pi_{t+1}^{food} + a_{22} rmc_t^f + \varepsilon_t^{food} \tag{6}$$

$$rmc_t^f = a_{23} \left(\widehat{rp}_t^{WFOOD} + \widehat{z}_t - \widehat{rp}_t^{food} \right) + (1 - a_{23}) \widehat{y}_t \tag{7}$$

$$\pi_t^{energy} = a_{31} \pi_{t-1}^{energy} + (1 - a_{31}) E_t \pi_{t+1}^{energy} + a_{32} rmc_t^{energy} + \varepsilon_t^{energy} \tag{8}$$

$$rmc_t^{energy} = a_{33} \left(\widehat{rp}_t^{WOIL} + \widehat{z}_t - \widehat{rp}_t^{energy} \right) + (1 - a_{33}) \widehat{y}_t \tag{9}$$

$$\pi_t = w^{energy} \pi_t^{energy} + w^{food} \pi_t^{food} + \left(1 - w^{energy} - w^{food}\right) \pi_t^{core} \tag{10}$$

We define π_t^{core} a measure of core inflation, equivalent to CPI excluding food and oil components that cannot be directly influenced by the monetary policy stance. This measure depends on core inflation π_{t-1}^{core} from the previous period, a forward-looking component for rational expectations, namely expected core inflation $(E_t \pi_{t+1}^{core})$ and real marginal costs (rmc_t). The last is a weighted average of the output gap and RER gap, being related to domestic producers and importers. The influence of the real cost on inflation is the slope of the Phillips curve equivalent to a "sacrifice ratio", i.e., the amount of output that is lost for diminishing inflation by one percentage point. The equations (6) and (8) are Phillips curves representative for food prices and energy prices. They are also dependent by their own lagged values and a forward – looking component, which adds to current value to real marginal costs. The pass-through from the output gap to food prices is usually limited, thus, the value for a_{23} is close to one. In equation (10) we compute headline inflation π_t by using core, food and energy inflation and their relevant weights in the CPI basket.

C. Monetary policy rule Monetary policy follows a well-known Taylor (1993) interest rate reaction function for a floating regime and focuses on stabilization the inflation (i.e. bring inflation close to target).

$$i_t = g_1 i_{t-1} + (1 - g_1) \left(i_t^n + g_2 \left(\pi_{t+3}^e - \pi_{t+3}^T \right) + g_2 \widehat{y}_t \right) + \varepsilon_t^i \tag{11}$$

$$i_t^n = \overline{r}_t + \pi_{t+4}^e \tag{12}$$

The nominal interest rate (i_t) is a function that reflects inertia through its own lagged value, assuring the effect of smoothing the policy rate. Woodford (2003) mentions that interest rate smoothing reflects a policy signal that monetary authority will not change policy variable with large increments. The policy stance is forward-looking while incorporating model-consistent inflation expectations. A neutral interest rate (i_t^n) defines the level of nominal interest rate that prevails if inflation equalize the target, and the output gap is zero.

D. Uncovered Interest rate parity condition (UIP)

$$s_t = E_t s_{t+1} + \frac{(i_t^* - i_t + prem_t)}{4} + \varepsilon_t^s \tag{13}$$

The nominal exchange rate (s_t) measured by units of domestic currency per one unit of foreign currency has also a model-consistent expectation of nominal exchange rate ($E_t s_{t+1}$). We note with i_t^* the foreign nominal interest rate (per annum), $prem_t$ is the risk premium (also per annum), and the residual term ε_t^s is exchange rate shock. Given this forward-looking behaviour, the exchange rate exhibits no persistence, which creates difficulties to match the evolution of the economy. According to equation (13), the current exchange rate needs to adjust immediately to the sum of all expected interest rate differentials and changes in risk premium. To incorporate a backward-looking component for persistence, which project the exchange rate as an extrapolation between the past values adjusted for the rate of growth in the long-run and the average inflation differential we refer to the modified version of UIP

$$s_t = (1 - e_1) E_t s_{t+1} + e_1 \left(s_{t-1} + \frac{2}{4} \left(\overline{\pi}_t - \overline{\pi}_t^* + \Delta \overline{z}_t \right) \right) + \frac{(i_t^* - i_t + prem_t)}{4} + \varepsilon_t^s \tag{14}$$

4 Calibration

The calibration of this small QPM model is based on a wide variety of literature and empirical evidence for this group of CEE countries: Hungary, Poland, and Romania. These countries have similar economic characteristics, so we propose a calibration for parameters that might be appropriate for all (Table 1). In this way, we assure comparability of the overall behaviour of the economy in response to shocks, which we will present in the subsequent sections.

We use the IRIS toolbox in MATLAB to obtain model solutions and the simulations based on the first-order approximation (around the steady-state). The steps to solve it are: i) linearization of the model around the steady-state, ii) solving the forward-looking variables, and iii) introduce the equations in a state-space representation.

5 Data set

The data set introduced to estimate the gap and trend components from the QPM model comprises 16 nominal and real variables. For a detailed description and data sources, see Table 2. Given the limited data availability and the adoption of the inflation-targeting regime in these countries, we estimate the model between 2005Q4 and 2023Q4.

Table 1: Calibrated parameter values and description

Parameter	Value	Description
$\mathbf{b_1}$	0.75	Output gap persistence that usually varies between 0.1 (very low persistence) to 0.95 (highly persistent). Consistent with Lindquist (2023).
$\mathbf{b_2}$	0.15	Pass-through from monetary condition to the real economy. It is set between -0.1 to -0.5; the higher the parameter, the more responsive is the output gap to changes in monetary policy. Consistent with Bokan (2013).
$\mathbf{b_3}$	0.3	Impact of foreign demand on the output gap, between 0.1 and 0.5 and it is based on the calibration on the export-to-GDP ratio. Consistent with Jackson (2024).
$\mathbf{b_4}$	0.6	The relative weight of the real interest rate and real exchange rate in real monetary conditions. The values are usually between 0.3 for an open economy and 0.8 for a closed economy. Consistent with Lindquist (2023).
$\mathbf{a_1}$	0.4	Inflation persistence denotes the share of backward-looking agents, and its values are between 0.4 (low persistent) and 0.9 (high persistent). The linear convention for homogeneity is $0 < \mathbf{a_1} < 1$ to bring inflation into target with zero gaps. Consistent with Jackson (2024).
$\mathbf{a_2}$	0.35	The impact of real marginal cost on inflation (policy pass-through). The value varies between 0.1 (low impact and high sacrifice ratio) and 0.5 (strong impact and low sacrifice ratio), with 0.25 to 0.35 a reasonable range for most countries. Consistent with Lindquist (2023).
$\mathbf{a_3}$	0.75	The relative weight of output gap in firms' real marginal costs. The value typically varies between 0.9 (relatively closed economy) and 0.6 (open economy). Consistent with Lindquist (2023) and Jackson (2024).
$\mathbf{a_{21}}$	0.2	Persistence of world food prices.
$\mathbf{a_{22}}$	0.6	Pass-through from the world food prices and business on food prices.
$\mathbf{a_{23}}$	0.3	The impact of the world food prices and business cycle on real marginal cost. Consistent with Jackson (2024).
$\mathbf{a_{31}}$	0.1	Persistence of energy prices.
$\mathbf{a_{32}}$	0.1	Pass-through from world oil prices and the exchange rate on domestic oil prices.
$\mathbf{a_{33}}$	1.0	The impact of the world oil prices and business cycle on real marginal cost.

Table 1: Calibrated parameter values and description, cont.

Parameter	Value	Description
$\mathbf{g_1}$	0.75	Policy rate persistence in the Taylor rule. For convergence, the parameter is set $0 < \mathbf{g_1} < 1$ and a value of zero means no persistence in policy setting, while a value around 0.8 is for a *"wait-and-see"* policy. Consistent with Lindquist (2023) and Jackson (2024).
$\mathbf{g_2}$	2	Weight put in the policy rule on the deviation of inflation from the target. The Taylor principle says that $\mathbf{g_2} > 0$ for a stable economy. Given the last periods marked by high inflation we assume a stronger policy reactiveness to inflation compared with Lindquist (2023) that assumes $\mathbf{g_2}= 1.1$ or Jackson (2024) that assumes $\mathbf{g_2}= 1.2$.
$\mathbf{g_3}$	0.5	Weight put in the policy rule on the output gap. The values vary from 0.3 to 1. The linear homogeneity condition $\mathbf{g_3} > 0$ is necessary for convergence. Consistent with Lindquist (2023).
$\mathbf{e_1}$	0.2	Policy maker's control of the domestic money market and its short-term nominal interest rate. A value of zero represents complete control of the short-term rates, and one means no control and the central bank uses nominal exchange rate to stabilize inflation with interventions in the FOREX market. Consistent with Jackson (2024).

6 Results

In this section, we present the most relevant results from this multivariate filter. Figure 1 to Figure 3 describe the output gap decomposition for each selected country. Compared with the predicted values, the model performed quite well regarding the output gap. Some differences can be observed in the crisis periods due to unprecedented shocks. The predicted values were very close to the magnitude of the economic downturn from the outbreak of the COVID-19 pandemic in all three countries (Hungary, Poland, and Romania). The pattern of the recovery from the pandemic in 2021 is very similar in Hungary and Poland, given the high demand and the actual output that is higher than the potential output. However, in Romania's case, the recovery was only partial and volatile, reflecting the actual data of GDP that was also volatile.
According to our results, the evolution of the output gap was mainly driven by domestic factors that prove a high degree of persistence of the output gap to which

Table 2: Data and source for the variables of the model

Data	Source
Real GDP	Eurostat
Consumer Price Index (CPI) - total	Eurostat
CPI (food)	Eurostat
CPI (energy)	Eurostat
CPI (excluding food and energy)	Eurostat
Nominal exchange rate (EUR/PLN, EUR/HUF, EUR/RON)	Eurostat
Monetary policy rate	National Bank of Hungary/ National Bank of Poland/ National Bank of Romania
Euro area GDP	Eurostat
Euro area inflation	Eurostat
Euro area nominal interest rate	European Central Bank
Target inflation	National Bank of Hungary/ National Bank of Poland/ National Bank of Romania
Brent spot price	US. Energy Information Administration
World food price	Food and Agriculture Organization
Nominal exchange rate EUR/USD	Eurostat
CPI - food weight	Eurostat
CPI - energy weight	Eurostat

adds relatively small contributions of the real interest gap and real exchange gap. At the same time, the impact of the foreign factors is limited. However, immediately after the outbreak of the COVID-19 pandemic, in 2020Q2, the foreign output gap exhibits a comparatively greater impact for all these countries, accounting for more than a quarter of the large negative drop. Lindquist (2023) estimates similar results for the Polish economy. Some potential explanations for this evidence are related to the stringency of the lockdown measures imposed by the authorities, in industries that highly affected trade flows. The recovery was mainly driven by domestic demand. In recent periods, the impact of the foreign gap has significantly diminished. The emerging economies continue to be affected by supply chain bottlenecks and energy crises, but domestic measures such as energy price capping schemes and energy transition process might help these countries to mitigate negative spillover effects.

At the same time, in the last quarters, the real exchange rate gap and real interest rate gap have exerted a restrictive impact. The exchange rate influences the real economy via the net export channel and the effects on agents' wealth and balance

Figure 1: Output gap decomposition (Hungary)

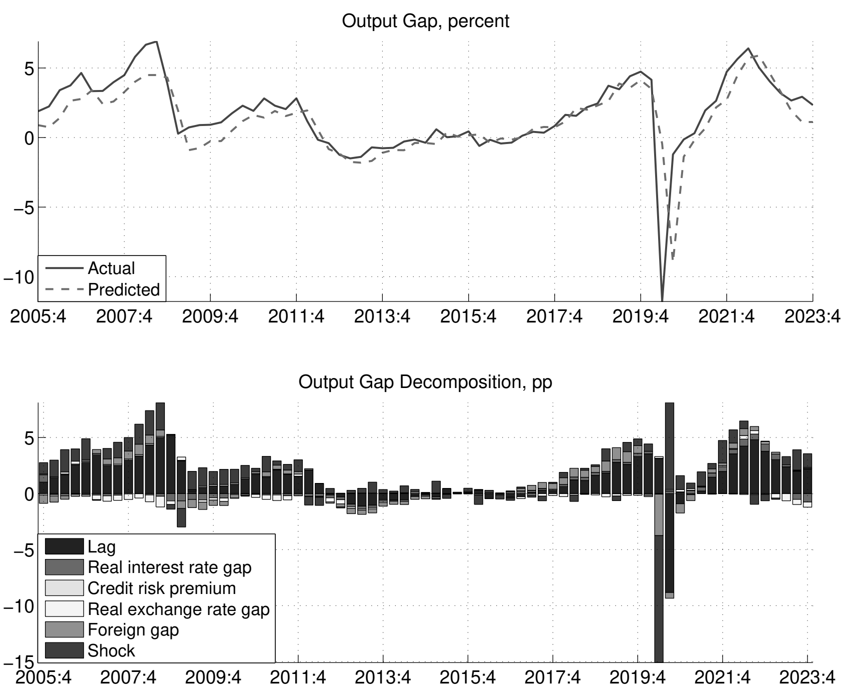


Figure 2: Output gap decomposition (Poland)

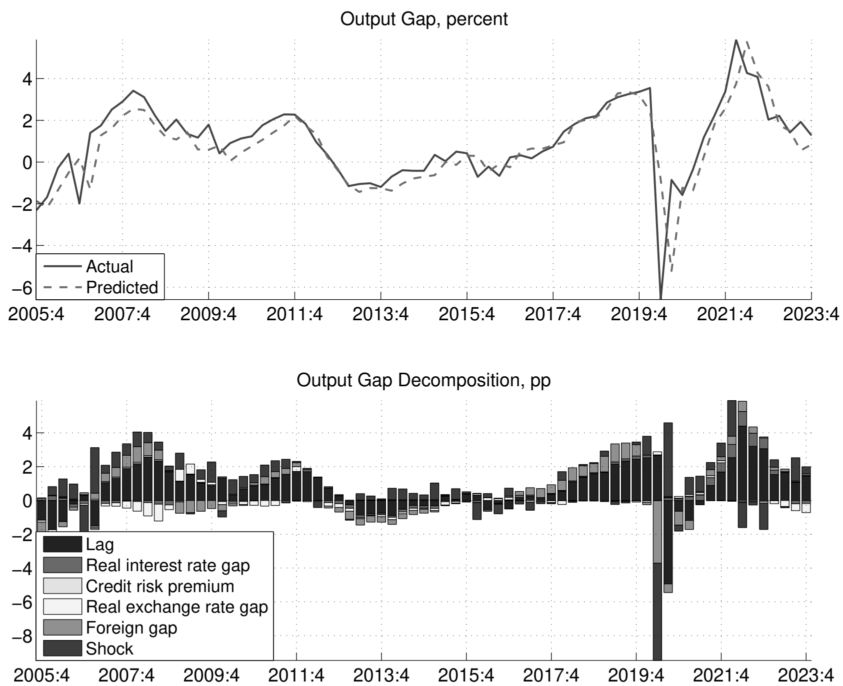
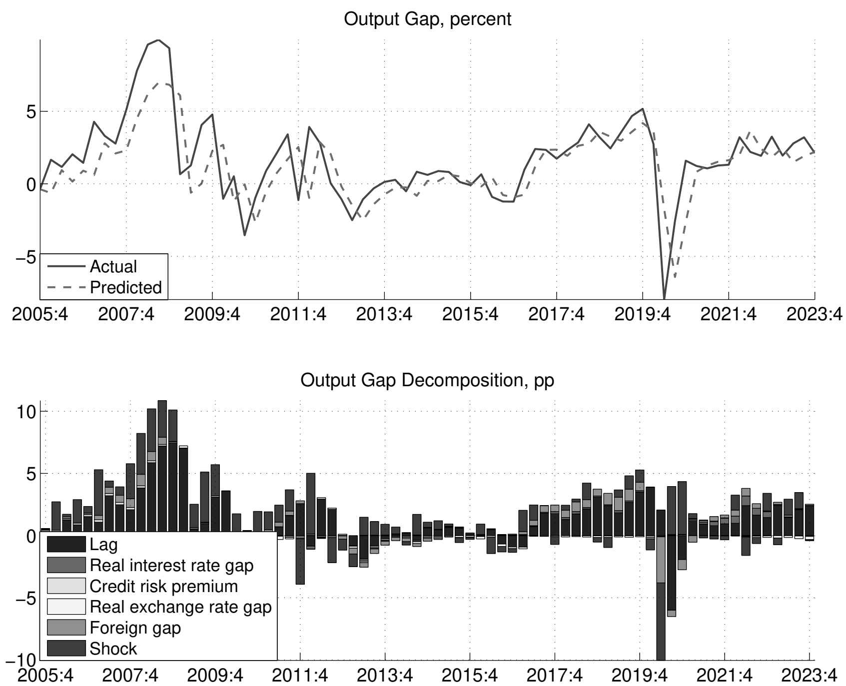


Figure 3: Output gap decomposition (Romania)



sheet. Similar contributions are expected for the output gap in Poland. For Romania, the restrictiveness of real monetary conditions over the recent quarters is estimated to be lower amid a slower and gradual pass-through of the central bank's monetary policy decisions that aim to bring inflation into target interval. The contribution of credit risk premium exerts a quasi-neutral effect.

In terms of core inflation, this small quarterly projection model performs similarly as in case of output. Figure 4 to Figure 6 show a relatively high accuracy in regular times (period 2011 – 2019). However, for the pandemic's outbreak, the predicted values signal deflation, while actual data exerted only a temporary disinflation in Hungary and Poland. The real marginal costs indicator represents an essential driver for inflation in the Phillips curve. The output gap significantly contributes to the real marginal costs, even if we calibrated the coefficient for the policy pass-through, equivalent to a medium impact. The real exchange rate gap has had a restrictive impact over the last quarters on firms' real marginal costs amid imported prices, which is more pronounced in Poland compared with Hungary and Romania.

Figure 4: Core inflation decomposition (Hungary)

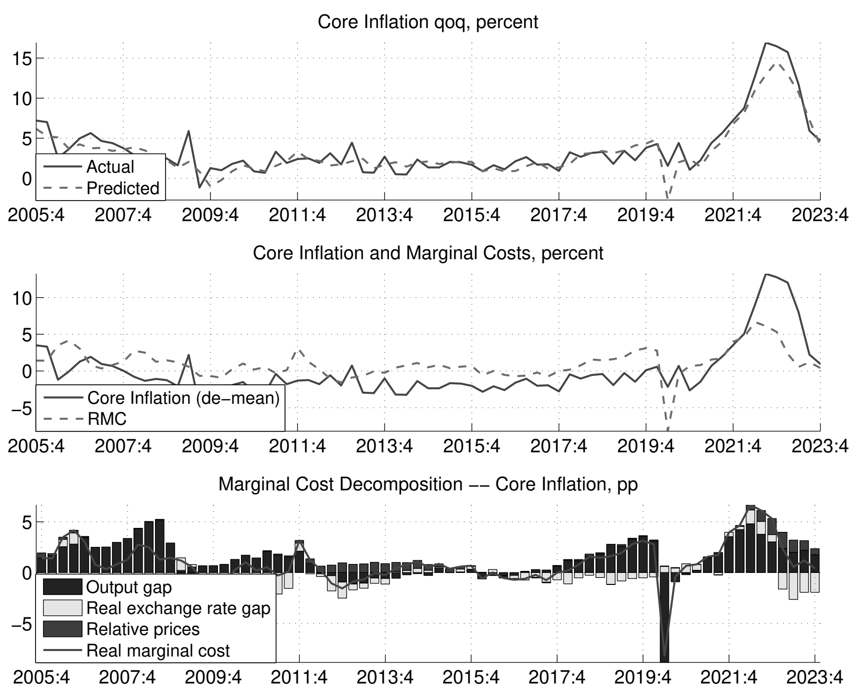


Figure 5: Core inflation decomposition (Poland)

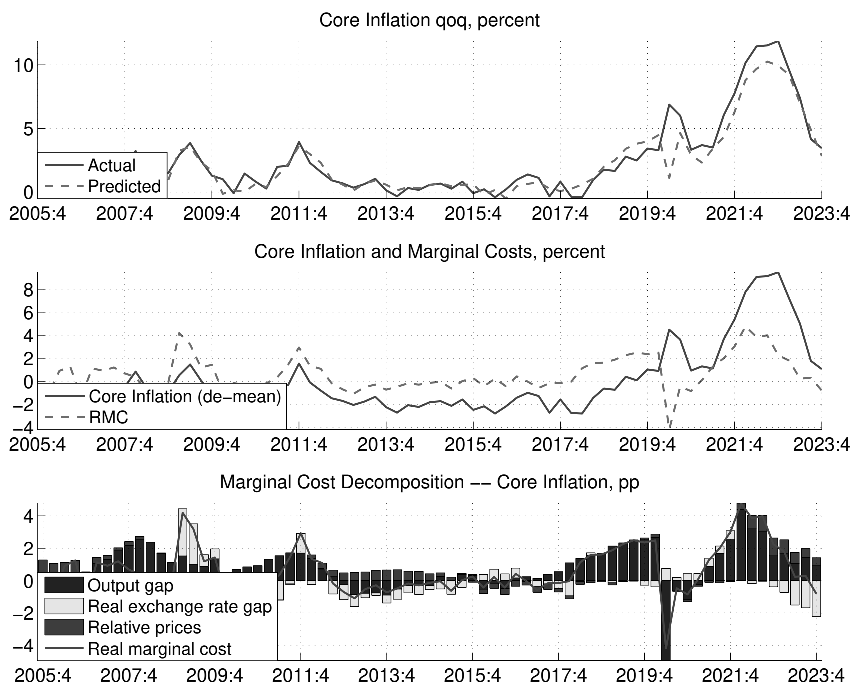
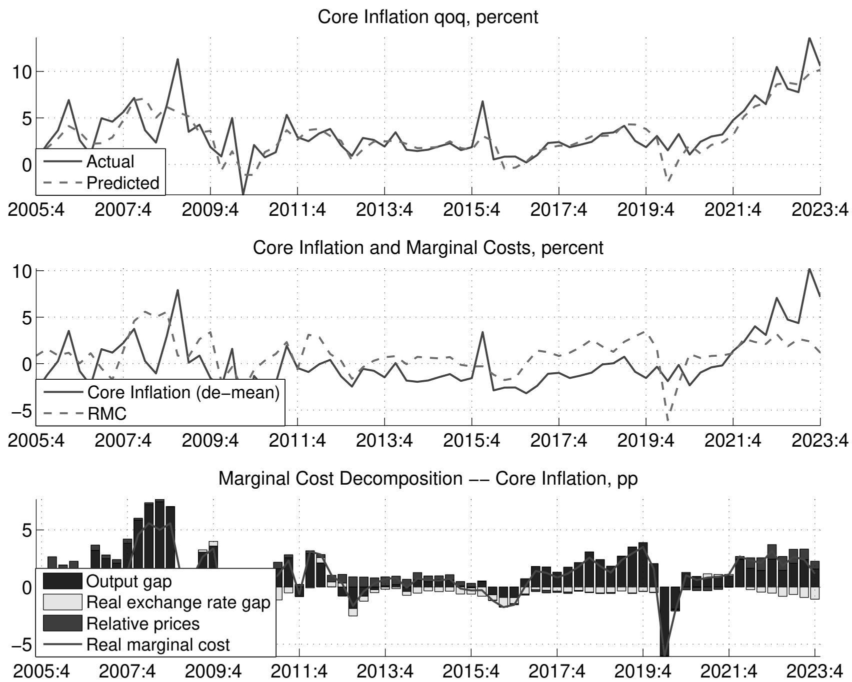


Figure 6: Core inflation decomposition (Romania)



In Figure 7 to Figure 9, we plot the interest rate path and the indicator's decomposition. The predicted values are slightly more volatile for all cases than the actual data. The evolution of the interest rate displays a high degree of inertia that plays the most significant role in case of Hungary in recent periods, which adds to the contribution of the neutral interest rate. One should mention that the monetary policy tightening was more pronounced in Hungary compared to Poland and Romania in response to the significant inflationary pressures and depreciation in forint in 2022. However, the high degree of interest rate inertia can be related to the characteristics of these three developing countries that are susceptible to external spillover shocks. Thus, monetary authorities are more cautious regarding monetary policy decisions and their lagged effects on the real economic activity. In recent periods, given the experience of the global financial crisis and the increased uncertainty during pandemic period and after that, the European countries tended to adopt a "wait-and-see" monetary policy reaction, which justifies the assumption of a high degree of inertia.
In the Phillips curve, besides the backward-looking component, two important channels explain short-term inflation dynamics. On one side, since the seminal work of Gali and Gertler (1999), real marginal cost played a significant and quantitatively

important contribution to the inflation dynamics. According to the economic theory, there is a positive relationship between inflation and real marginal costs, i.e., higher inflation is associated with higher marginal costs, which tend to rise in expansion due to high demand, tightened labour market and wage pressure. Moreover, standard microeconomic theory confirms that short-run marginal costs should be procyclical (Rotemberg and Woodford, 1999). High production levels relative to potential output increase the competition for the production factors, which leads to increase in real costs (i.e., the production costs increase more that rises in prices).

On the other side, from a theoretical point of view, new-Keynesian Phillips's curve should be consistent with rational expectations. This framework has expectations that are "well-anchored" in the medium-term and economic agents' inflation expectations are align with a credible inflation objective. However, when inflation is persistently high, there is an increasing risk of expectation de-anchoring, given that households' inflation expectations are more sensitive to price increases than price cuts (Baqaee, 2020). Thus, in a high-inflation regime, inflation and inflation expectations may be much more persistent. However, recent studies found that inflation expectations are less well-anchored in emerging than in advances economies (Moessner and Takáts, 2020; Kose et al., 2019).

According to our results, before the pandemic outbreak, these three economies (Hungary, Poland and Romania) were characterised by excess demand and very low core inflation, even slightly disinflation. In the pre-pandemic period, real marginal costs increased, playing a critical role. Higher marginal costs are related to the position of the economy in the business cycle. Thus, real marginal costs tend to rise in expansion when aggregate demand is high, the labour market is tight and wages pressure increases. After the pandemic, during 2021-2023, the increase in the real marginal costs was significantly lower than the surge in inflation, while short-term inflation expectations have widened on the back of the adapting learning in forming expectations, especially in the case of households because the consumers revise their beliefs in response to past forecast errors that they have made. Additionally, increased uncertainty regarding the evolution of inflation and the high level of disagreement of the forecasts could lead to an inflation de-anchoring.

As mentioned, the policy stance is forward-looking while incorporating model-consistent inflation expectations. In the period between the financial crisis and the outbreak of the pandemic, which was a stable period, the contribution of the inflation expectations was negative. After the pandemic, the impact started to become positive, i.e., inflation expectations contributed to tightening in interest rates given the high level of inflation and, consequently, the process of monetary policy normalization.

Figure 7: Interest rate decomposition (Hungary)

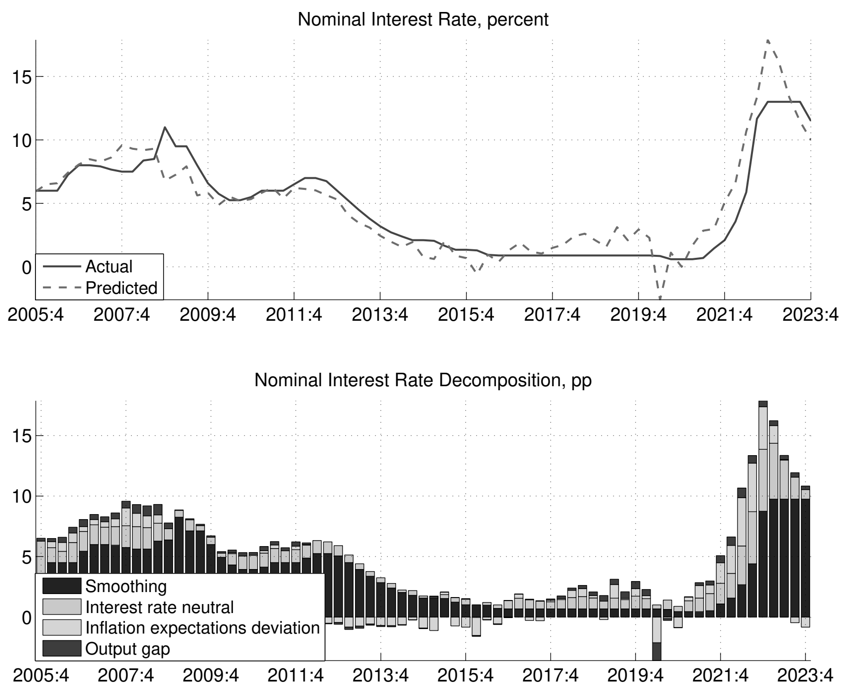


Figure 8: Interest rate decomposition (Poland)

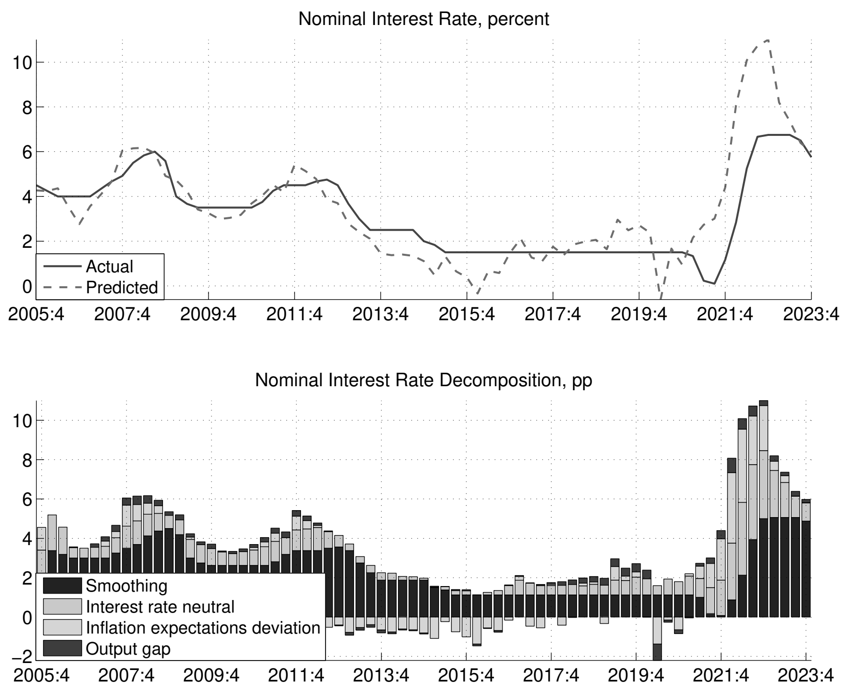
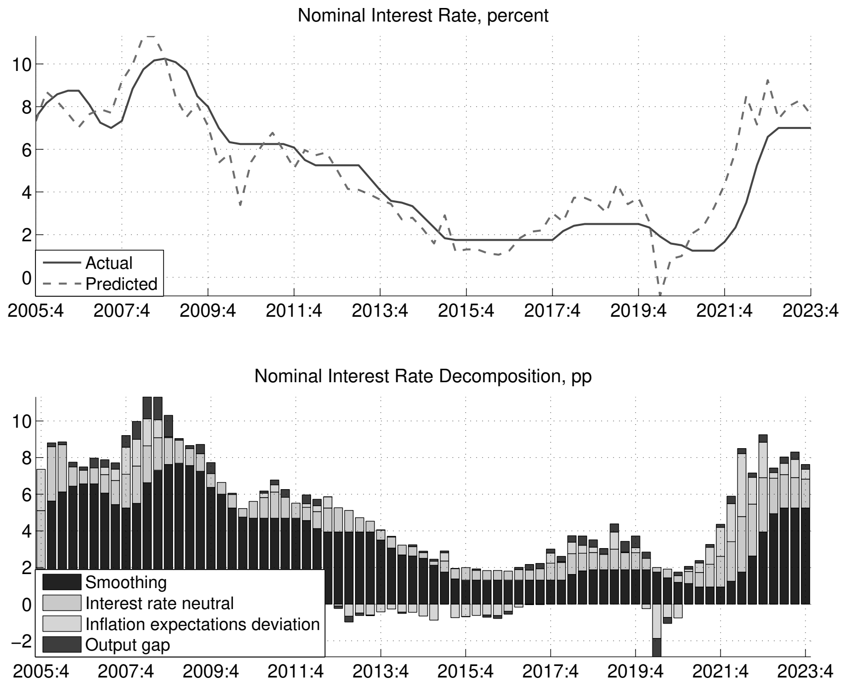


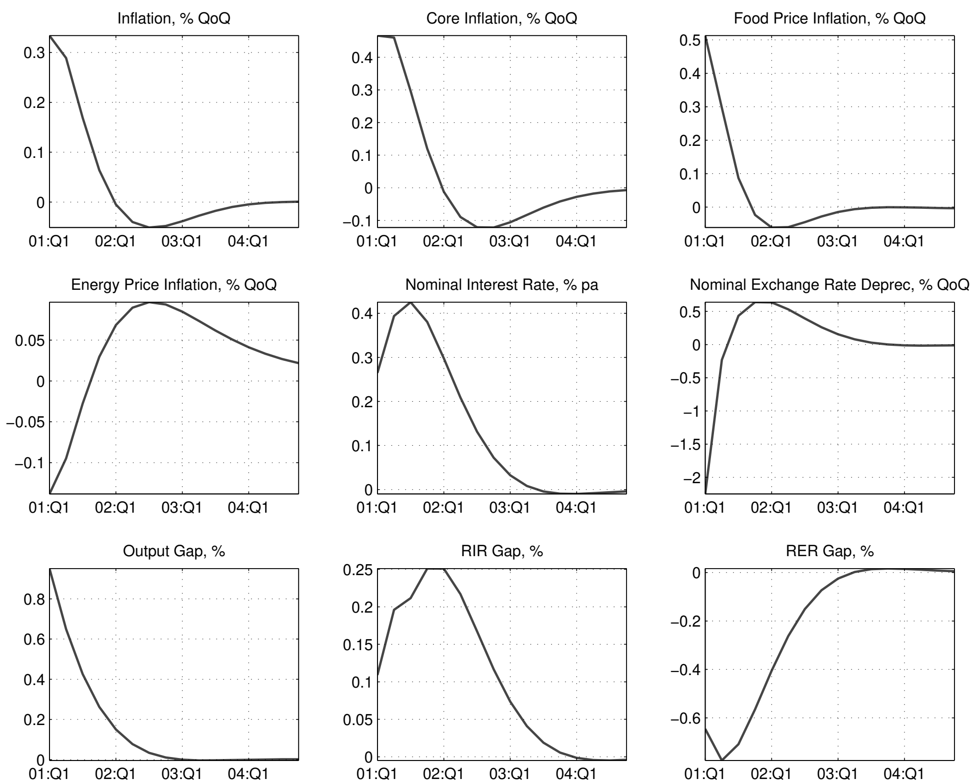
Figure 9: Interest rate decomposition (Romania)



In Figure 10 to Figure 13, we present the impulse response functions for an aggregate demand shock, a core inflation shock, a monetary policy shock and exchange rate shock under this calibrated model. This consists in illustrating the trajectory of variables of interest, following isolated simulations of these macroeconomic shocks. However, these isolated simulations involve only one shock at a time, with all others assumed to remain constant.

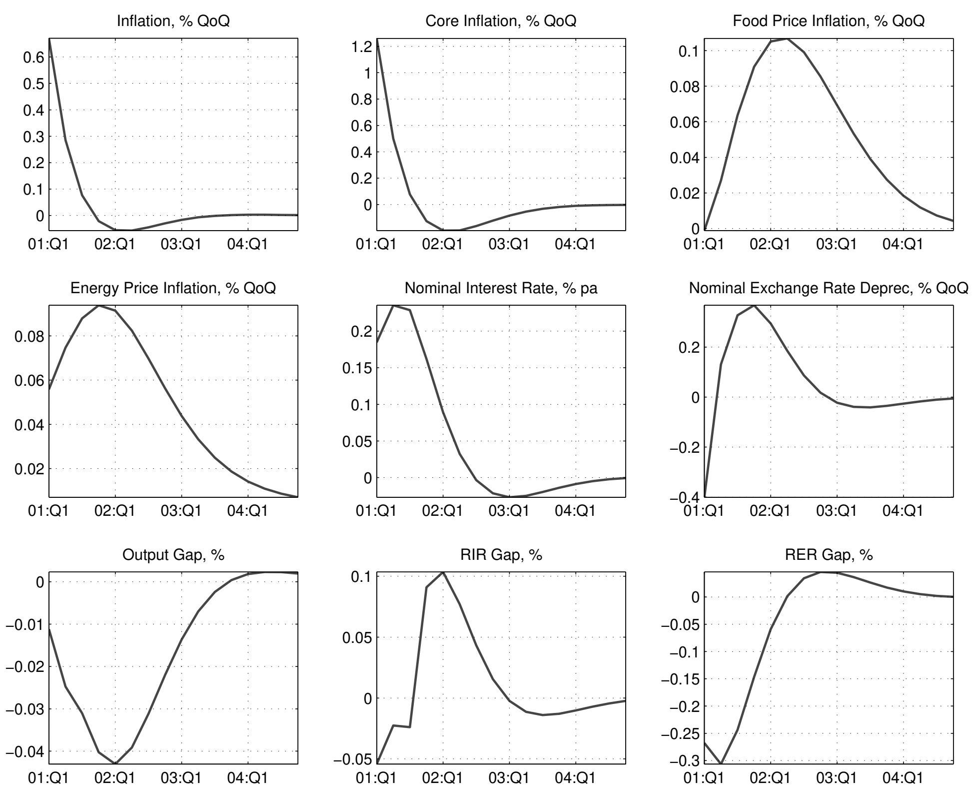
The aggregate demand shock captures the effects of factor other than those included in the aggregate demand equation, e.g., changes in consumption preferences. The excess demand and inflationary pressures induced by the increase of the output gap cause the central bank to immediately react by rising the policy interest rate to diminish the demand and inflation (Figure 10). Moreover, both the increase in the monetary policy interest rate and the appreciation of the exchange rate might impose a restrictive effect on real monetary conditions, the latter acting mainly through the channel of net exports of real exchange rate.

Figure 10: Impulse response functions for an aggregate demand shock



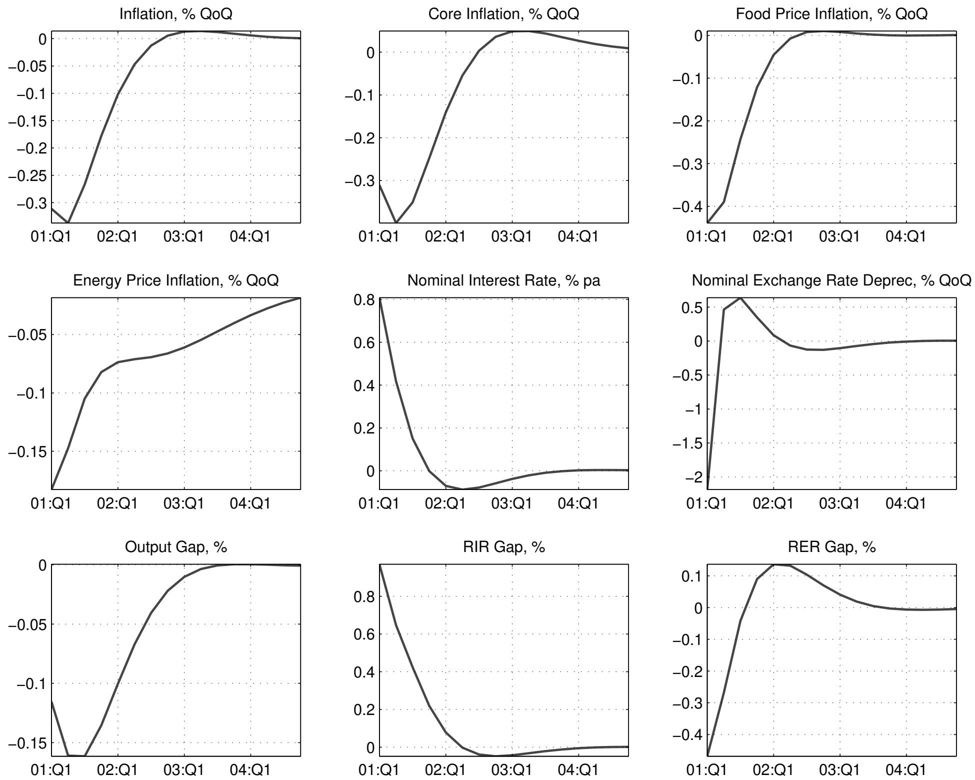
Following an increase in the core inflation, equivalent to a supply shock, the central bank responds by raising the monetary policy rate, which imposes a restrictive effect of the real monetary conditions through the deviations from the trend of interest rates and exchange rates (Figure 11). The output gap turns negative as result of the effect of counteracting the increase in the inflations expectations. Like the aggregate demand shock, the exchange rate acts to stabilize the inflation rate to its restrictive contribution to economic activity. The action of the monetary policy leads to the stabilization of the core inflation after about one year from the moment of the shock.

Figure 11: Impulse response functions for a supply shock (core inflation)



The effects of a monetary policy shock i.e., the increase in the nominal interest rate, are presented in Figure 12. This action induces (through the relationship between monetary policy and the interbank interest rates and uncovered interest rate parity condition) the appreciation of the national currency with disinflation effects through both import prices and the output gap. The negative deviation of the output gap and

Figure 12: Impulse response functions for a monetary policy shock

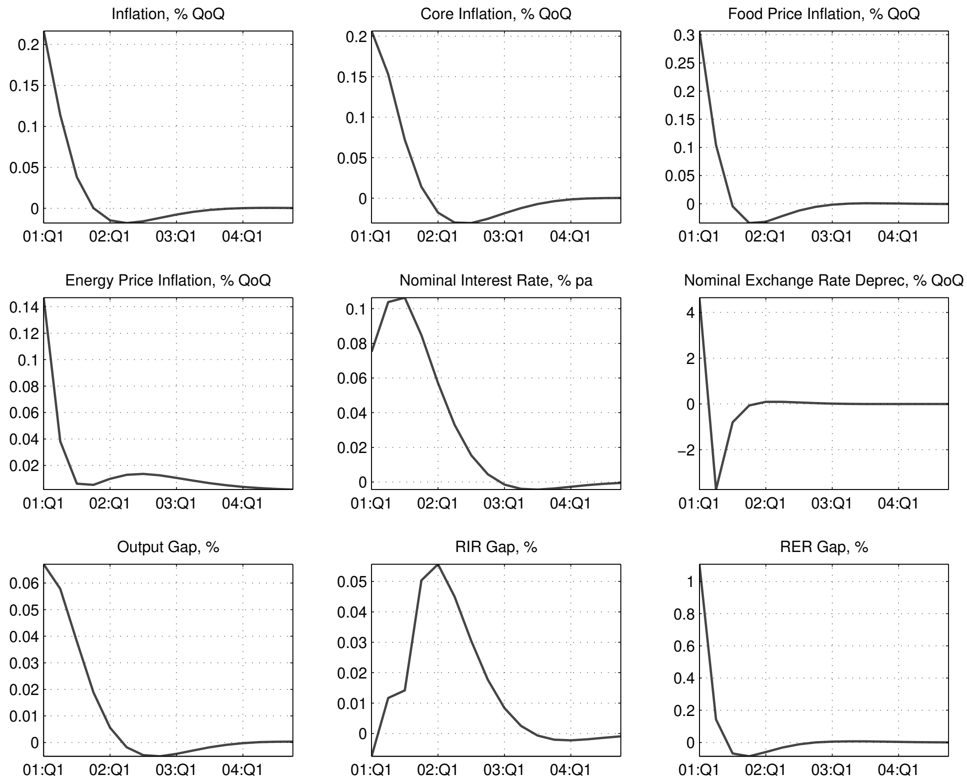


the reduction of import prices exert disinflationary pressure of the headline inflation and core inflation immediately after the shock.
The depreciation of the exchange rate can be generated, for example, by temporary changes of investors in the preferences in the capital markets, thus, is not determined by structural changes in the economy (Figure 13). These exchange rate developments have stimulating effects on the economy through the net export channel. Following the shock, inflationary pressures are created through the channel of import prices, which determine the central bank to increase the interest rate.

7 Forecasting performance and goodness-of-fit

We perform a real-time sample forecasting exercise that implies at each moment of time six period-ahead forecasts from $t+1$ to $t+6$. Thus, we observe the accuracy of the model forecasts for the most relevant indicators. In Figure 14 to Figure 16 we

Figure 13: Impulse response functions for an exchange rate shock



represent the in-sample forecasts for output gap, core inflation, nominal interest rate, and nominal exchange rate, the main four indicators of the model implemented for Hungary, Poland and Romania. According to these representations, the assessment of the future trajectory for these indicators (i.e., dotted lines) is quite close to the actual evolution (i.e., black solid line) estimated in normal times from the model. In times marked by uncertainty, such as the financial international and pandemic crises, the forecasted results underestimate the true data. For example, during the financial crisis, the model predicts a decrease in interest rates much earlier and more pronounced that had happened. However, given the significant shock on financial markets, central banks adopted a precautionary policy approach to manage economic fluctuations and to achieve price stability.

During the COVID-19 pandemic, the model developed in this paper predicts the economic downturn and the subsequent recovery at lower magnitudes than what economies have experienced. All the economies are confronted with these significant issues because none of the models could accurately predict the magnitude of this unprecedented shock and its effects on the economy. However, we observe an interesting result in the case of Poland during the process of tightening the monetary policy to stabilize high levels of inflation in 2022. The nominal interest rate is forecasted to reach 9% in the second quarter of 2022, while the actual data was 6.75%. At the same time, the core inflation in Poland was above 12%, the highest among the analysed countries, signalling a more aggressive normalization of monetary policy, as the results from the model.

Figure 14: In-sample forecast (Hungary)

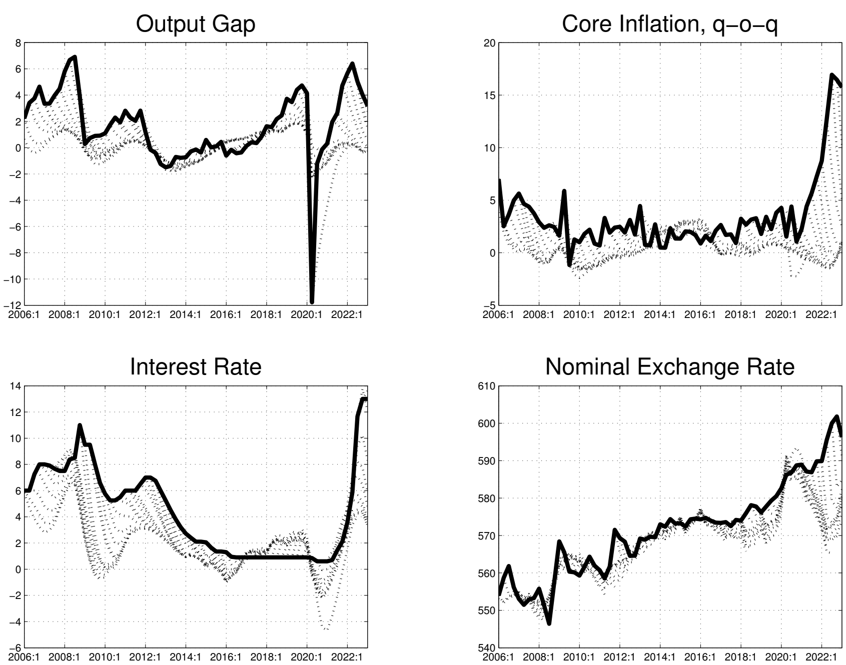


Figure 15: In-sample forecast (Poland)

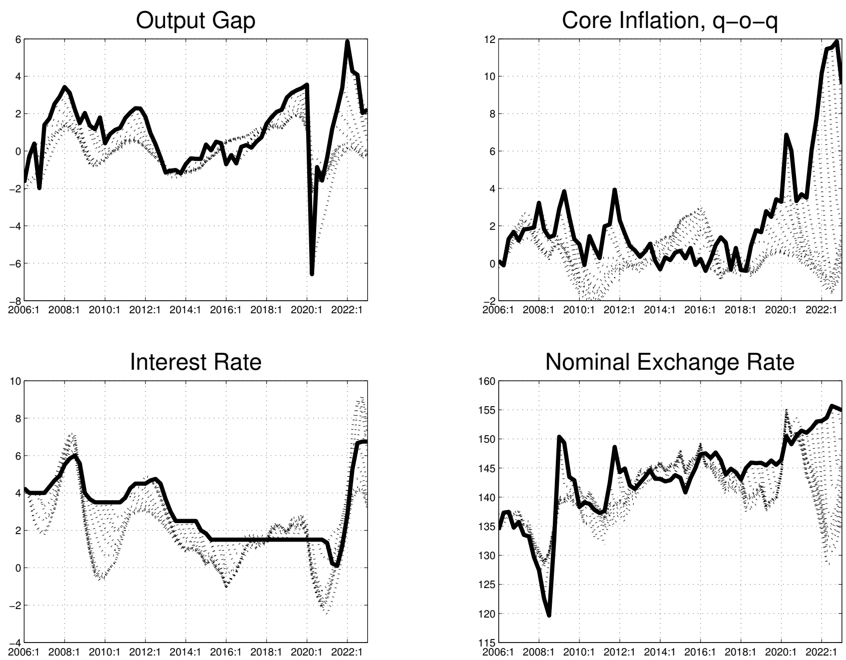


Figure 16: In-sample forecast (Romania)

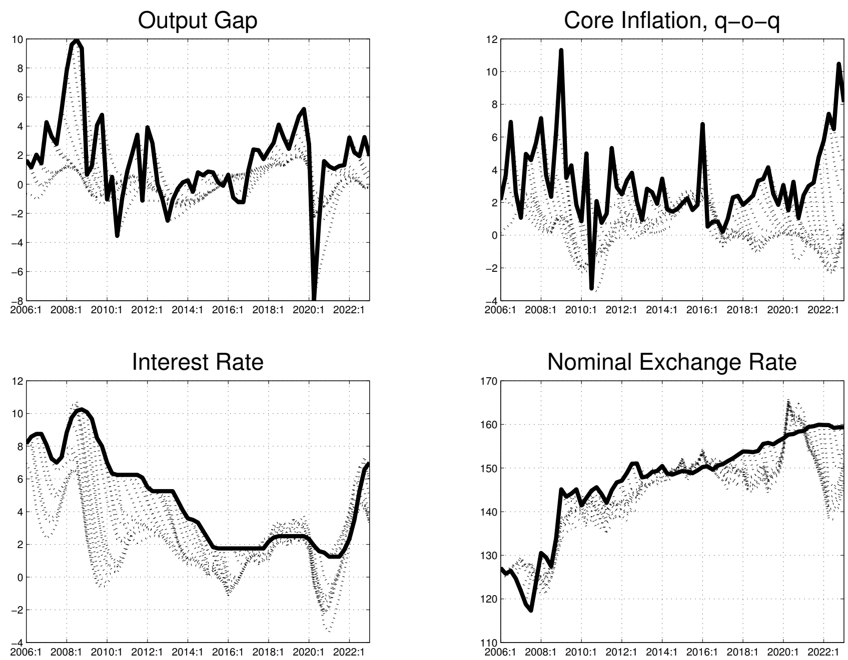


Table 3: Forecasting performance of the in-sample simulations ($t+1$ to $t+6$ forecast)

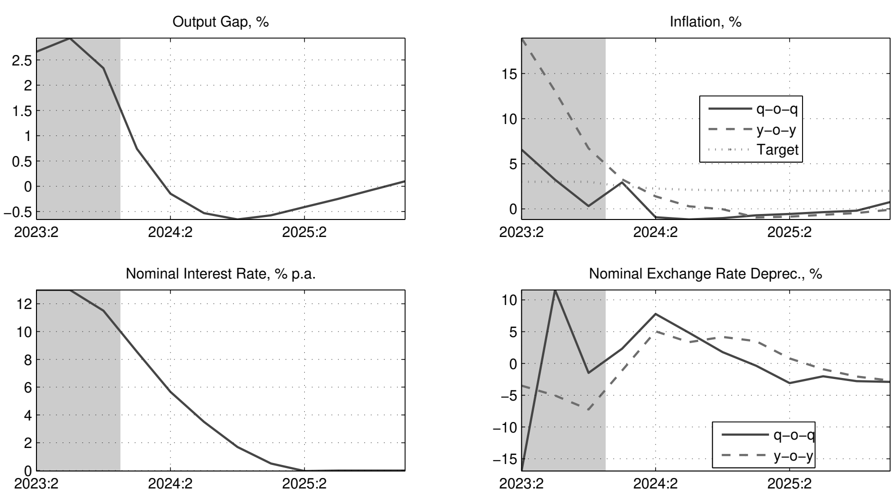
Hungary												
	Output gap							Core inflation, q-o-q				
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-1.04	-1.29	-1.40	-1.40	-1.37	-1.32	Mean	-2.16	-2.67	-2.86	-2.87	-2.80	-2.74
Median	-0.94	-1.18	-0.99	-1.06	-1.23	-1.15	Median	-1.43	-2.16	-2.42	-2.39	-2.40	-2.32
Std. dev.	2.11	2.20	2.26	2.26	2.25	2.24	Std. dev.	3.19	3.74	3.99	4.03	4.00	3.98
	Interest rate							Nominal exchange rate, $100 * \log$					
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-0.88	-1.46	-1.87	-2.11	-2.22	-2.26	Mean	-2.44	-2.55	-2.72	-3.12	-3.70	-4.36
Median	-0.86	-1.16	-1.46	-1.64	-1.76	-1.80	Median	-0.81	-0.68	-0.92	-1.08	-1.62	-2.40
Std. dev.	1.72	2.07	2.31	2.48	2.61	2.60	Std. dev.	1.72	2.07	2.31	2.48	2.61	2.69
Poland												
	Output gap							Core inflation, q-o-q					
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-0.65	-0.82	-0.90	-0.97	-0.96	-0.93	Mean	-1.45	-1.80	-1.95	-1.98	-1.98	-1.98
Median	-0.65	-0.76	-0.86	-0.96	-0.92	-0.93	Median	-0.69	-1.18	-1.45	-1.49	-1.51	-1.52
Std. dev.	1.19	1.32	1.40	1.41	1.41	1.41	Std. dev.	2.62	3.20	3.44	3.46	3.39	3.33
	Interest rate							Nominal exchange rate, $100 * \log$					
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-0.34	-0.68	-0.94	-1.10	-1.18	-1.21	Mean	-1.79	-1.93	-2.15	-2.49	-2.88	-3.30
Median	-0.57	-0.75	-0.96	-1.18	-1.31	-1.36	Median	-0.44	-0.04	-0.50	-1.14	-1.79	-2.00
Std. dev.	1.20	1.22	1.17	1.21	1.27	1.31	Std. dev.	5.49	5.81	6.00	6.19	6.42	6.67

Table 3: Forecasting performance of the in-sample simulations ($t+1$ to $t+6$ forecast), cont.

Romania													
	Output gap							Core inflation, q-o-q					
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-1.11	-1.39	-1.50	-1.56	-1.51	-1.46	Mean	-2.12	-2.59	-2.73	-2.76	-2.74	-2.65
Median	-1.19	-1.38	-1.57	-1.49	-1.45	-1.26	Median	-1.81	-2.17	-2.28	-2.39	-2.41	-2.21
Std. dev.	2.45	2.49	2.45	2.47	2.49	2.51	Std. dev.	2.27	2.65	2.82	2.82	2.73	2.69
	Interest rate							Nominal exchange rate, $100 * \log$					
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$		$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$
Mean	-0.95	-1.55	-2	-2.27	-2.4	-2.46	Mean	-2.06	-2.15	-2.4	-2.83	-3.45	-4.17
Median	-0.91	-1.43	-1.85	-2.21	-2.41	-2.36	Median	-0.91	-1.43	-1.85	-2.21	-2.41	-2.36
Std. dev.	1.54	1.75	1.85	1.96	2.08	2.18	Std. dev.	4.81	5.11	5.24	5.29	5.31	5.36

We present in Table 3 some statistics related to the real-time simulations of six period-ahead forecasts, i.e. mean, median and standard deviation. Recall that this is a log linearization of the model around the steady state, or the long run equilibrium level. However, we can see that the standard deviations increase over the forecasting horizon, which is consistent with the economic theory that the further you go with the projection horizon, the uncertainty of the estimation is higher. The indicators that have the lowest degree of uncertainty associated with the estimates are the output gap and the interest rate, which means that the model performs better in these cases. In practice, QPM is widely used for as a medium-term modelling and forecasting tool in the monetary policy framework. Thus, in Figure 17 to Figure 19 we illustrate an out-of-sample exercise to forecast output gap, inflation, interest rate and nominal exchange rate depreciation. According to the model, under normal conditions when there are no other exogenous shocks that affect the economies, the trajectories of the indicators could converge to the equilibrium after about two or four quarters, except for the nominal exchange rate depreciation, where the convergence is after eight quarters.

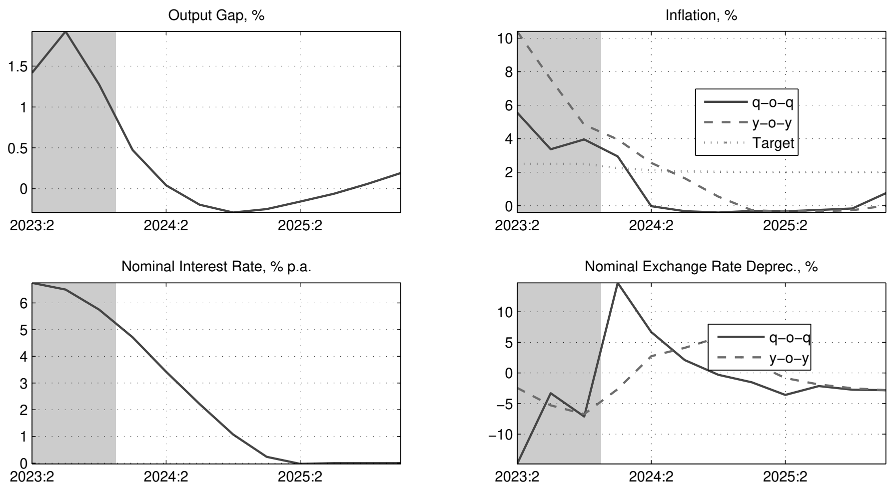
Figure 17: Forecast for the main indicators (Hungary)



8 Conclusions

In this paper, we developed a small quarterly projection model for a group of selected CEE countries: Hungary, Poland, and Romania. These economies have very similar characteristics; therefore, we proposed a comparative analysis of the results. The

Figure 18: Forecast for the main indicators (Poland)



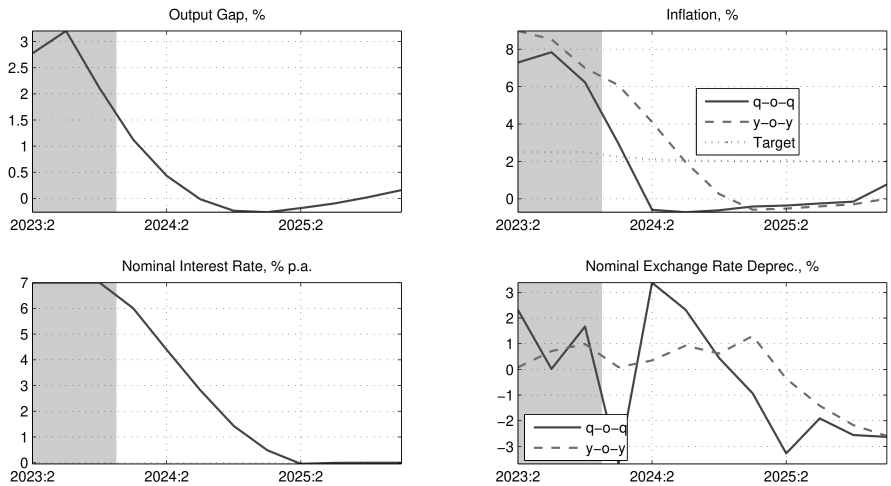
model provides good performance given that the predicted values were very close to the magnitude of the economic downturn from the outbreak of the COVID-19 pandemic in these countries. The recovery from the pandemic shock follows a very similar pattern in Hungary and Poland. In Romania's case, the recovery was only partial and volatile.

The real marginal costs indicator is the most important driver of inflation in the Phillips curve, whose contribution is mostly driven by the output gap and the real exchange gap having a restrictive impact over the last quarters amid imported prices (more pronounced in Poland compared with Hungary and Romania). The evolution of interest rates displays a high degree of inertia (that plays the most significant role in case of Hungary, in recent periods), and after the pandemic, the positive contribution of inflation expectations acted to tighten the monetary policy.

We performed simulation of a real-time in-sample forecasting exercise to provide the accuracy of the model forecasts of the main relevant indicators: output gap, core inflation, nominal interest rate and nominal exchange rate. The assessment of the future trajectory for these indicators is quite close to the actual evolution in normal times. However, in times marked by uncertainty, such as the financial international crisis and pandemic crisis, the results forecasted underestimate the true data, highlighting the inherent challenges in forecasting during such periods. During the COVID-19 pandemic, the model predicts the economic downturn and the subsequent recovery at lower magnitudes than what economies have experienced. Simultaneously, the model signals a more aggressive tightening of monetary policy for Hungary and Poland.

An out of sample forecasting exercise for the period 2024Q1-2026Q1 revealed that,

Figure 19: Forecast for the main indicators (Romania)



under normal conditions when there are no other exogenous shocks that affect the economies, the trajectories of the indicators could converge to the equilibrium after about two or four quarters, except for the nominal exchange rate depreciation, where the convergence is assessed after eight quarters. However, all the global economies need more accuracy in predicting the magnitude of this unprecedented shock and its effects on the economy.

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