AN AUTO-REGRESSIVE INTEGRATED MOVING AVERAGE MODEL OF INFLATION IN MOLDOVA WITH SOME OBSERVATIONS ON THE INFLATION OUTLOOK

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Apostolos PAPAPHILIPPOU,
PhD, Four Assist Development Consulting Limited
https://orcid.org/0000-0002-2193-4035, *e-mail: papaphilippou@4assist.eu*

The author holds a PhD in Economics from the University of Cambridge and is currently the Economic Development Planning Expert of the EU-funded Technical Assistance project "Support the Moldovan Government in identifying and preparing projects linked to the implementation of the Association Agreement". The tables and graphs contained in the paper have been generated using the EViews econometrics programme. The views expressed in the article are personal. The article has benefitted from comments and suggestions by the journal's reviewers.

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ABSTRACT

The paper discusses the properties of Auto-Regressive Integrated Moving Average (ARIMA) models and proceeds to estimate a model for the monthly evolution of the annual inflation rate in Moldova from January 2013 to October 2021. The aim of the paper is to develop a model relying exclusively upon the historical evolution of inflation as an additional instrument for forecasting purposes. The estimated model explains close to 97 % of the monthly variation of the inflation rate over the model's estimation period and is used to generate forecasts of the monthly evolution of the annual inflation rate in short to medium term. The ARIMA-generated forecasts suggest that the acceleration of inflation which characterised the monthly evolution of the annual inflation rate in 2021 up to October 2021 will continue in the next four months, with the inflation rate peaking at 12 % in February 2022 and slowly decelerating from that point onwards towards the 5 % inflation target in the longer term. The paper concludes by suggesting areas for further work and briefly discussing the inflation outlook for the Moldovan economy, considering current international and domestic economic conditions. Natural areas for further work would be to regularly update the econometric estimates and forecasts of the estimated ARIMA model as the economy evolves through time. With regard to the inflation outlook, the analysis contained in the concluding section of the paper suggests that the future evolution of inflation is likely to be more pessimistic than the ARIMA-based generated forecast.

Keywords: *Auto-Regressive Integrated Moving Average models, Inflation, Moldova*

Articolul relevă proprietățile modelelor autoregresive integrate de medie mobilă (ARIMA) și prezintă un model de estimare a evoluției lunare a ratei anuale a inflației în Moldova din ianuarie 2013 până în octombrie 2021. Scopul lucrării îl reprezintă dezvoltarea unui model bazat în exclusivitate pe evoluția istorică a inflației ca instrument suplimentar de prognozare. Modelul estimat explică aproape 97 % din fluctuațiile lunare ale ratei inflației în perioada de estimare a modelului și este utilizat pentru a genera previziuni ale evoluției lunare a ratei anuale a inflației pe termen scurt și mediu. Prognozele generate de ARIMA sugerează că accelerarea inflației. care a caracterizat evoluția lunară a ratei anuale a inflației de la începutul anului 2021 până în octombrie 2021. va continua în următoarele patru luni, astfel, rata inflației atingând un vârf de 12 % în februarie 2022 și înregistrând o scădere lentă din acel moment spre ținta de inflație de 5 % pe termen lung. Articolul se încheie prin sugerarea domeniilor de lucru și discutarea pe scurt a perspectivelor inflaționiste pentru economia Republicii Moldova, ținând cont de condițiile economice internaționale și interne actuale. Activitățile ulterioare ar trebui să se axeze în mod firesc pe actualizarea sistematică a estimărilor și previziunilor econometrice ale modelului estimat ARIMA pe măsură ce economia evoluează în timp. În ceea ce privește perspectiva inflației, analiza cuprinsă în secțiunea finală a lucrării sugerează că evoluția viitoare a inflației ar putea să fie mai pesimistă decât prognoza generată de ARIMA.

Cuvinte cheie: *modele autoregresive integrate de medie mobilă, inflație, Moldova*

В статье представлены свойства интегрированной модели авторегрессии-скользящего среднего (ARIMA) и проводится оценка модели ежемесячной эволюции годового уровня инфляции в Молдове с января 2013 г. по октябрь 2021 г. Целью статьи является разработка модели, опирающейся исключительно на историческую эволюцию инфляции как дополнительного инструмента для прогнозирования. Расчетная модель объясняет почти 97 % месячных колебаний уровня инфляции в течение расчетного периода модели и используется для создания прогнозов месячного изменения годового уровня инфляции в краткосрочной и среднесрочной перспективе. Прогнозы составленные ARIMA предполагают, что ускорение инфляции, которое характеризовало ежемесячную динамику годового уровня инфляции с начала 2021 г. по октябрь 2021 г., продолжится в следующие четыре месяца, при этом уровень инфляции достигнет пика на уровне 12 % в феврале 2022 г. и с этого момента зарегистрирует медленный спад до целевого уровня инфляции 5% в долгосрочной перспективе. Статья завершается предложением областей для дальнейшей работы и кратким обсуждением инфляционных перспектив молдавской экономики с учетом текущих международных и внутренних экономических условий. Естественными областями для дальнейшей работы было бы регулярное обновление эконометрических оценок и прогнозов модели ARIMA по мере развития экономики во времени. Что касается перспектив инфляции, анализ, содержащийся в заключительном разделе статьи, предполагает, что будущая эволюция инфляции, вероятно, будет более пессимистичной, чем прогноз, созданный на основе ARIMA.

Ключевые слова: *интегрированная модель авторегрессии-скользящего среднего, инфляция, Молдова.*

JEL Classification: *C22, E31, E37*
UDC: *330.4+336.748.12(478)*

INTRODUCTION

Auto-Regressive Integrated Moving Average (ARIMA) models are widely used in empirical work for analytical and forecasting purposes. The aim of this paper is to estimate an ARIMA model on the monthly evolution of the annual inflation rate in Moldova, use the estimated model to generate short to medium-term monthly forecasts of the annual inflation rate in Moldova and discuss further these forecasts taking into account the current economic conditions and trends, both domestic and international.

This research intends to develop a model of inflation relying exclusively upon the historical evolution of the monthly annual inflation rate as an additional instrument for short to medium term forecasting purposes. An additional empirical model to assist the forecasting of the inflation rate in Moldova will be useful given the importance of inflation forecasting for macroeconomic management in general and the conduct of monetary policy in particular.

The paper is organised as follows: Following a discussion section on the properties and estimation of ARIMA models, the paper presents the data to be used for the estimation. This is followed by a section which includes the econometric estimates of the ARIMA model and its forecasts. The paper concludes by suggesting areas for further work and discussing the inflation outlook for the Moldovan economy briefly.

ON ARIMA MODELS: A BRIEF LITERATURE SURVEY

ARIMA models are widely used for analytical and forecasting purposes. Though frequently a-theoretical ARIMA models have proved to be useful tools in order:

- *To provide insight and analyse the data-generating process of a particular time series; and*
- *To generate forecasts of the time series in question. In particular, the forecasts generated by ARIMA models are frequently used as benchmarks: the generated forecasts are taken into account and are combined with other economic indicators and additional empirical analysis of the structural characteristics of the economy under consideration and its external environment.*

ARIMA models stemmed from the work of Box and Jenkins (1970). They are linear models that incorporate two types of dynamic processes: an autoregressive process and a moving average process.

In more detail, for a time series variable, y_t:

1. An Auto-Regressive (AR) process is one where the current value of y_t is a function of its own past values and an error term, u_t:
$y_t = f(y_{t-1}, y_{t-2}, \ldots) + u_t$
2. A Moving Average (MA) process is one where the contemporaneous value of y_t is a function of past as well as contemporaneous values of the error term, u_t
$y_t = g(u_{t-1}, u_{t-2}, \ldots) + u_t$

The first step in developing an ARIMA model is to ensure that the time series that will be modelled is stationary or, in other words, that the series to be modelled by an ARIMA model does not contain a unit root, as it is well-known that a non-stationary time-series may give rise to spurious regressions. A time-series that follows a stationary process has the property that its mean, variance and autocorrelation structure is finite and constant over time.

Stationarity is tested through statistical tests. If the time series under investigation is not stationary, following the Box and Jenkins methodology, the first difference of the time series is taken, and the resulting time series is subsequently tested for stationarity. The differencing process is repeated until the resulting time series is stationary. The number of times the time series in question has to be differenced in order to arrive at a stationary series determines the order of integration of the ARIMA model.

An ARIMA model could be characterised by a vector of three numbers (p,d,q), where:

- ***p*** *refers to the number of lags in the AR process in the model;*
- ***d*** *refers to the order of integration (i.e. the number of times the time-series needs to be differenced to obtain a stationary series); and*
- ***q*** *is the number of lags in the MA process in the model.*

At the ARIMA model identification stage, the researcher also seeks to analyse briefly the property of the time series under investigation, including determining whether the dependent time series exhibits seasonality and identifying the order for the seasonal autoregressive and/or seasonal moving average terms.

The model's identification requires the exercise of informed judgement supplemented by diagnostic tools and tests. Graphs of the autocorrelation and partial autocorrelation functions are frequently employed to determine the number of lags in modelling the AR and/or the MA process in the specified ARIMA model. The autocorrelation and partial autocorrelation functions are summarised in the correlogram of the time series, which displays the autocorrelation and partial autocorrelation functions up to the specified number of lags. In particular:

- *the autocorrelation function displays the coefficients of correlation between a time series and lags of the same series, while*
- *by partial autocorrelation we refer to the correlation between a variable and a lag of itself that is not explained by the correlations of all lower-order-lags.*

It is well known that:

- *A pure AR process is characterised by a geometrically decaying autocorrelation function, while the partial auto-correlation function drops to zero after a number of lags. The spikes in the partial autocorrelation function are indicative of the AR order to be introduced in the model's specification;*
- *For a pure MA process: the number of spikes in the autocorrelation function is indicative of the MA order to be introduced in the specification. An MA process is characterised by a geometrically decaying partial autocorrelation function and an autocorrelation function that drops to zero after a few lags.*
- *If the correlogram of a time series is characterised by geometrically decaying autocorrelation and partial auto-correlation functions, this is indicative that a mixed AR and MA process may be the appropriate specification.*

Finally, one of the aims of the ARIMA model identification and selection process is to arrive at a model that:

1. *Is parsimonious, or as small as possible; while, at the same time,*
2. *Passes the diagnostic tests.*

A parsimonious ARIMA model is desirable because:

- *Including irrelevant time-lags in the model increases the coefficient standard errors (and therefore reduces their t-statistics).*
- *Models that incorporate large numbers of time-lags tend not to forecast well: these models are more likely to fit data-specific features of the data under estimation (thus explaining much of the random features in the data set rather than providing a better reflection of the underlying data generating process).*

In the estimation and testing steps of the model development, various descriptive statistics and statistical tests are employed to assist the analysis, model selection and validation. These also include information criteria used to compare different alternative specifications and balance the goodness of fit requirement with the need for a parsimonious (i.e. simple) specification.

Variants of ARIMA-type models have been used to analyse empirically certain aspects of the inflationary process in a number of economies and have proven to be useful instruments for analytical and forecasting purposes. The paper by Meyler et al. (1998) used ARIMA models to forecast inflation in Ireland. The article by Kelikume and Salami (2014) developed an ARIMA model and a Vector Auto-Regression model to forecast inflation in Nigeria. The study by Pintilescu et al. (2015) estimated a variant of a seasonal ARIMA model to empirically analyse Romania's inflation rate. The paper by Samrad et al. (2021) developed an ARIMA model to forecast the annual inflation rate in Iran. Within the context of the Moldovan economy, the paper by Mija et al. (2013) developed a Vector Auto-Regression model to evaluate the second round effects on core inflation.

DATA SET

The data set we use in our estimation and forecasting work is the monthly evolution of the annual growth rate of the Consumer Price Index in Moldova over the period from January 2013 to October 2021. The data source is the website of the National Bank of Moldova which reproduces the monthly estimates compiled by the National Bureau of Statistics of Moldova. The data exclude the Transnistrian region and are rounded to the first decimal place.

Table 1 below presents the data set used in our empirical work.

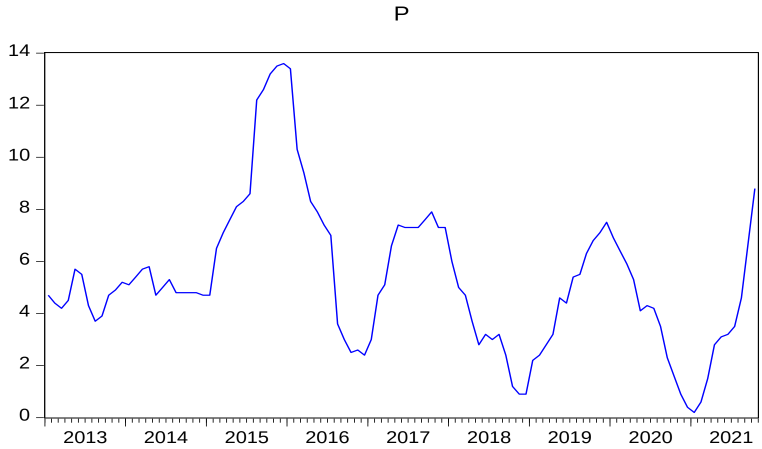
Table 1: Data set

2013M01	4.7	2015M01	4.7	2017M01	3.0	2019M01	2.2	2021M01	0.2
2013M02	4.4	2015M02	6.5	2017M02	4.7	2019M02	2.4	2021M02	0.6
2013M03	4.2	2015M03	7.1	2017M03	5.1	2019M03	2.8	2021M03	1.5
2013M04	4.5	2015M04	7.6	2017M04	6.6	2019M04	3.2	2021M04	2.8
2013M05	5.7	2015M05	8.1	2017M05	7.4	2019M05	4.6	2021M05	3.1
2013M06	5.5	2015M06	8.3	2017M06	7.3	2019M06	4.4	2021M06	3.2
2013M07	4.3	2015M07	8.6	2017M07	7.3	2019M07	5.4	2021M07	3.5
2013M08	3.7	2015M08	12.2	2017M08	7.3	2019M08	5.5	2021M08	4.6
2013M09	3.9	2015M09	12.6	2017M09	7.6	2019M09	6.3	2021M09	6.7
2013M10	4.7	2015M10	13.2	2017M10	7.9	2019M10	6.8	2021M10	8.8
2013M11	4.9	2015M11	13.5	2017M11	7.3	2019M11	7.1		
2013M12	5.2	2015M12	13.6	2017M12	7.3	2019M12	7.5		
2014M01	5.1	2016M01	13.4	2018M01	6.0	2020M01	6.9		
2014M02	5.4	2016M02	10.3	2018M02	5.0	2020M02	6.4		
2014M03	5.7	2016M03	9.4	2018M03	4.7	2020M03	5.9		
2014M04	5.8	2016M04	8.3	2018M04	3.7	2020M04	5.3		
2014M05	4.7	2016M05	7.9	2018M05	2.8	2020M05	4.1		
2014M06	5.0	2016M06	7.4	2018M06	3.2	2020M06	4.3		
2014M07	5.3	2016M07	7.0	2018M07	3.0	2020M07	4.2		
2014M08	4.8	2016M08	3.6	2018M08	3.2	2020M08	3.5		
2014M09	4.8	2016M09	3.0	2018M09	2.4	2020M09	2.3		
2014M10	4.8	2016M10	2.5	2018M10	1.2	2020M10	1.6		
2014M11	4.8	2016M11	2.6	2018M11	0.9	2020M11	0.9		
2014M12	4.7	2016M12	2.4	2018M12	0.9	2020M12	0.4		

Source: *National Bank of Moldova reproducing data compiled by the National Bureau of Statistics of Moldova*

Figure 1 portrays the evolution of the above data set graphically. It is notable that from January 2021 onwards the inflation rate has accelerated throughout the period up to and including October 2021.

Figure 1:
Graph of the monthly evolution of the annual inflation rate in Moldova



Source: *National Bank of Moldova reproducing data compiled by the National Bureau of Statistics of Moldova*

Monetary policy in Moldova aims at retaining the inflation rate in the economy within a corridor of plus/minus 1.5 % around the 5 % inflation target.

MAIN RESULTS: ECONOMETRIC ESTIMATES AND FORECASTS

We first establish that the time series we will be using in our estimation and forecasting work is stationary. The stationarity test reported in table 2 below indicates that the probability that the time series under investigation has unit root is only around 5 %.

Table 2: Stationarity test

Null Hypothesis: P has a unit rootv
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.878840	0.0513
Test critical values:	1% level	-3.495021	
	5% level	-2.889753	
	10% level	-2.581890	

**MacKinnon (1996) one-sided p-values.*
Source: *EViews-generated estimates on the data set*

The absence of a unit root implies that we may fit an ARIMA model to the actual data set with no need to difference the time series under consideration prior to the estimation. It is well-known that the monthly evolution of inflation in Moldova is likely to exhibit significant seasonality due to a large extent to the behaviour of the food component of the index which varies in line with the supply conditions over the year.

Our econometric work suggests that a simple (2,0,1) ARIMA model augmented with SAR(12) and SMA(12) terms to capture the inherent seasonality of the time series under consideration provides a very good fit over the data set.

Table 3 below provides the least squares estimates of our preferred ARIMA model.

Table 3: Regression results

Dependent Variable: P
Method: Least Squares
Sample (adjusted): 2014M03 2021M10
Included observations: 92 after adjustments
Convergence achieved after 11 iterations
MA Backcast: 2013M02 2014M02

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.258628	0.502349	10.46807	0.0000
AR(1)	1.726945	0.146173	11.81436	0.0000
AR(2)	-0.749913	0.143360	-5.230959	0.0000
SAR(12)	-0.292854	0.110904	-2.640600	0.0098
MA(1)	-0.467144	0.187500	-2.491437	0.0146
SMA(12)	-0.888992	0.030036	-29.59724	0.0000
R-squared	0.969843	Mean dependent var		5.423913
Adjusted R-squared	0.968090	S.D. dependent var		3.050072
S.E. of regression	0.544848	Akaike info criterion		1.686375
Sum squared resid	25.52992	Schwarz criterion		1.850839
Log likelihood	-71.57323	Hannan-Quinn criter.		1.752754
F-statistic	553.1487	Durbin-Watson stat		2.001435
Prob(F-statistic)	0.000000			

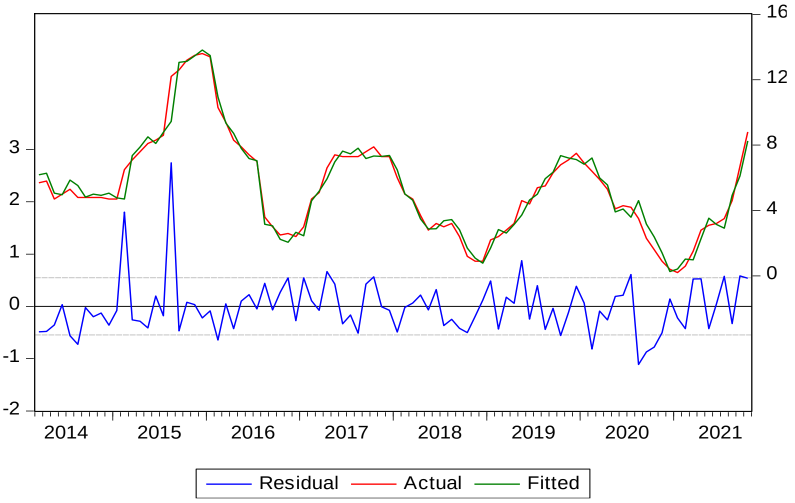
Source: *EViews-generated estimates*

The data sample used for the estimation reported in table 3 covers the period from March 2014 to October 2021 as it must take into account the lagged structure of our preferred ARIMA model. It is notable that all the individual terms of the regression equation reported in table 3 are statistically significant, while the R-squared statistic suggests that the regression explains close to 97 % of the monthly variation of the annual inflation rate over the period of the estimation.

Figure 2: Provides the actual, fitted and residual estimates of the above regression

Figure 2:

Actual, fitted and residuals graph of the regression reported in Table 3

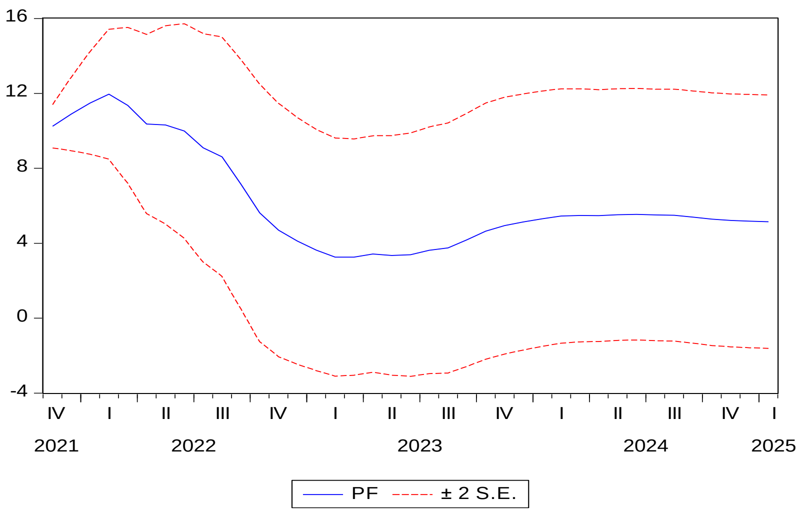


Source: *EViews-generated estimates*

We use our ARIMA model to generate forecasts of the monthly evolution of the annual inflation rate from November 2021 to January 2025. Figure 3 provides the evolution of the ARIMA-generated forecast over the above period, while table 4 presents the results rounded to the first decimal point for the next 12 months. We emphasise the short-term forecasts as it is well-known that ARIMA models are more efficient for short to medium-term forecasting.

Figure 3:

Figure of the forecasted evolution of the inflation rate



Source: *EViews-generated estimates*

The generated forecasts suggest that the acceleration of inflation which characterised the evolution of inflation in the first ten months of 2021 will continue for the next four months.

Table 4:
Forecasts of the monthly evolution of the annual inflation rate over the period November 2021 to October 2021

2021M11	10.2	2022M05	10.3
2021M12	10.9	2022M06	10.0
2022M01	11.5	2022M07	9.1
2022M02	12.0	2022M08	8.6
2022M03	11.4	2022M09	7.2
2022M04	10.4	2022M10	5.6

Source: *EViews-generated estimates*

The ARIMA forecasts reported in Graph 3 and Table 4 above suggest that the annual inflation rate in Moldova will peak at 12 % in February 2022 and slowly decelerate from that point onwards towards the 5 % inflation target in the longer term. We will discuss further the inflation outlook for the Moldovan economy in the next and final section of the paper.

CONCLUSION:

Areas for further work and discussion on the inflation outlook in Moldova

A natural area for further work would be to update the ARIMA econometric estimates reported in this paper and the model's forecasts as the economy evolves through time in the future and use the results for monitoring and analytical purposes.

As discussed in our literature review section above, the forecasts generated by ARIMA models should be taken as benchmarks that need to be adjusted taking into account other relevant economic indicators to arrive at a forecast reflecting professional judgement.

It is notable that under current conditions, inflation is likely to accelerate in the months to come in Moldova. The inflation outlook internationally has deteriorated recently, though most analysts expect that the acceleration of inflation will be only temporary. Recent economic developments are also likely to contribute to this acceleration in inflation. These include the recent increase in the international and domestic price of food (whose share is very significant in the Consumer Price Index basket in Moldova) the international and domestic price of energy (a key input into the production process - and thus a cost-push factor in the short term), as well as the increases in salaries and pensions in Moldova, with the latter likely to increase domestic demand in the economy. The inflation expectations will also influence the future evolution of inflation in the Moldovan economy and the monetary policy and fiscal policy stance. With regard to expectations, while there are no widely available surveys of inflation expectations in the Moldovan economy, the risk here is that, with the ongoing acceleration of inflation experienced recently, expectations of a more inflationary environment may become entrenched and contribute to future inflation.

A very important variable that influences the evolution of prices is the conduct of monetary policy. It is notable that the last monetary policy decision of October 29 has retained the monetary policy instruments unchanged. Thus, the current level of the base interest rate is 5.5 %, while interest rates on overnight loans and overnight deposits are at the level of 7.5 % and 3.5 %, respectively. However, over the three previous monetary policy decisions, interest rates have been tightened in all three policy decisions to stem the inflationary process underway. According to the latest monthly annual inflation rate of October 2021, the annual inflation rate amounts to 8.81%, which renders the current level of the policy interest rates mentioned above negative in real terms. The next monetary policy decision is due to take place on 3 December 2021. In addition to the impact of the current and future monetary policy decisions, the level of inflation in the future will be partly determined by the fiscal stance and the impact of the budget on aggregate demand in the economy. At the time of writing this article, the annual budget for 2022 was not yet finalised.

To conclude, the ARIMA estimates reported in the previous section suggest that inflation may accelerate in the short term and gradually decelerate from a point onwards make sense. It should be emphasised that the ARIMA-based estimates provide a benchmark evolution of inflation solely based on existing trends and the historical evolution of the inflation rate. The actual evolution of inflation in the future will reflect the joint impact of the evolution of a number of variables over the forecasting period. It is notable that the general economic environment, both domestic and international, may exacerbate the inflationary process underway and/or possibly its duration. It comes as no real surprise that the latest inflation forecast by the National Bank of Moldova is more pessimistic than our ARIMA estimated forecasts. In particular, the National Bank of Moldova foresees the inflation rate to accelerate in the months to come and peak at close to 15 % in the third quarter of 2022 before decelerating back towards the 5 % inflation target by the third quarter of 2023 (National Bank of Moldova, 2021). Compared to the National Bank of Moldova's forecast, our ARIMA-based forecast suggests that inflation in Moldova will peak earlier and at a slightly lower rate, while the longer term evolution of inflation is broadly similar in both forecasts. Given the importance of inflation for economic welfare, the maintenance of macroeconomic stability and the setting of economic policy, it is worth keeping the evolution of the inflation rate and relevant economic variables under review.

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