

# Simulation of Impact of Migration Caused by the War in Ukraine on COVID-19 Epidemic Process in Moldova

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## Abstract

The novel coronavirus pandemic has become a global challenge and has shown that health systems worldwide are unprepared for pandemics of this magnitude. The war in Ukraine, escalated by Russia on February 24, 2022, brought deaths and a humanitarian catastrophe and stimulated the spread of COVID-19. Most refugees who evacuated from the war crossed the border with other countries. At the end of July, almost 550 thousand people crossed the border with Moldova. This study is devoted to modeling the impact of migration processes on the dynamics of COVID-19 in Moldova. For this, a machine learning model was built based on the polynomial regression method. The forecast accuracy a month before the escalation of the war was from 98.77% to 96.37% for new cases and from 99.8% to 99.75% for fatal cases. The forecast accuracy for the first month after the escalation of the war was from 99.96% to 99.34% for new cases and from 99.91% to 99.88% for fatal cases. The high accuracy of the model, both before the war and with the start of its escalation, suggests that the migration flows of refugees from Ukraine to Moldova did not affect the dynamics of COVID-19.

## Keywords 1

COVID-19, machine learning, epidemic model, polynomial regression, war

## 1. Introduction

The COVID-19 pandemic began in December 2019 in Wuhan, China. In the first few months, the virus spread throughout the planet. The rapid spread of the new coronavirus has led the World Health Organization to declare a global pandemic of COVID-19. At the end of July 2022, almost 580 million cases were registered worldwide, almost 6.5 million of which died [1].

In Moldova, the first case of COVID-19 was registered on March 7, 2020. The number of infected people overgrew, and on March 17, Parliament declared a state of emergency in the country. On March 18, 2020, the first death was registered. By March 23, the total number of patients with COVID-19 reached 100 cases; by April 7, it exceeded 1000 cases [2]. At the end of July 2022, more than 520 thousand cases were registered in Moldova, more than 11.5 thousand of which ended in death.

Russia's wanton and bloody invasion of Ukraine on February 24, 2022, resulted in numerous casualties and the destruction of entire cities, including public health infrastructure, leading to a humanitarian crisis. The escalation of the war has also affected the spread of COVID-19. According to the International Organization for Migration, the number of internally displaced persons in Ukraine exceeds 6.2 million [3]. According to the United Nations, the number of refugees from Ukraine in the countries of the European Union exceeds 6.1 million people [4]. At the end of July 2022, almost 550

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thousand people crossed the border with Moldova, and more than 85 thousand people received refugee status in Moldova.

In the first weeks of the escalation of the war, there were large concentrations of people at border crossings and in evacuation transport. At the same time, refugees' documents were checked according to a simplified procedure, and medical documents were not controlled. Mass gatherings, a low level of vaccination against COVID-19 in Ukraine, and the lack of control of medical records can lead to outbreaks of infectious diseases in countries hosting refugees.

The COVID-19 pandemic has given impetus to the development of health information tools. Groups of scientists around the world have developed tools for modeling epidemic processes [5], analyzing medical data [6], medical diagnostics [7], assessing social factors [8], decision-making for healthcare organizations [9], and processing medical data [10], etc.

The study aims to build a machine learning model based on the polynomial regression method for assessing the incidence of COVID-19 in Moldova after the escalation of the Russian war in Ukraine.

The relevance of the study is justified by the fact that the escalation of the Russian war in Ukraine affects the dynamics of infectious diseases not only in Ukraine, but also in countries that have received a large number of refugees. Therefore, this study is the first step - testing the hypothesis of the influence of migration flows on the dynamics of the incidence of COVID-19 in Moldova.

Research is part of a complex, intelligent information system for epidemiological diagnostics, the concept of which is discussed in [11].

## 2. Materials and Methods

Regression analysis is a set of methods for studying the influence of one or more independent variables on the dependent one [12]. Regression analysis reflects only the mathematical dependence of variables and not a causal relationship. The main tasks for which regression analysis is used are predicting the value of a dependent variable using independent variables, determining the contribution of individual independent variables to the variation of the dependent variable, and determining the degree of determination of the variation of the dependent variable by independent variables.

Polynomial regression is a machine learning algorithm that trains a linear model on non-linear data [13]. Polynomial regression allows you to use a linear model even if the data is non-linear by adding additional features to the data.

The polynomial regression model has the following form:

$$y_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 + \dots + \beta_m x_i^m + \varepsilon_i. \quad (1)$$

A polynomial regression model can be expressed in matrix form:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & x_1 & x_1^2 & \dots & x_1^m \\ 1 & x_2 & x_2^2 & \dots & x_2^m \\ 1 & x_3 & x_3^2 & \dots & x_3^m \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & x_n & x_n^2 & \dots & x_n^m \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \vdots \\ \varepsilon_n \end{bmatrix}. \quad (2)$$

Although polynomial regression is a particular case of multiple linear regression, interpreting a fitted polynomial regression model requires a slightly different perspective. When fitting polynomial regression, it is often difficult to interpret individual coefficients because the underlying monomials can be highly correlated. Although orthogonal polynomials can reduce the correlation, it is usually more informative to consider the fitted regression function as a whole. The point of simultaneous confidence intervals can then be used to determine the uncertainty of the estimate of the regression function.

Polynomial regression makes it possible to model non-linear shared data. A polynomial regression model is more flexible and can model complex relationships. However, models require careful design, and prior knowledge of the data is required.

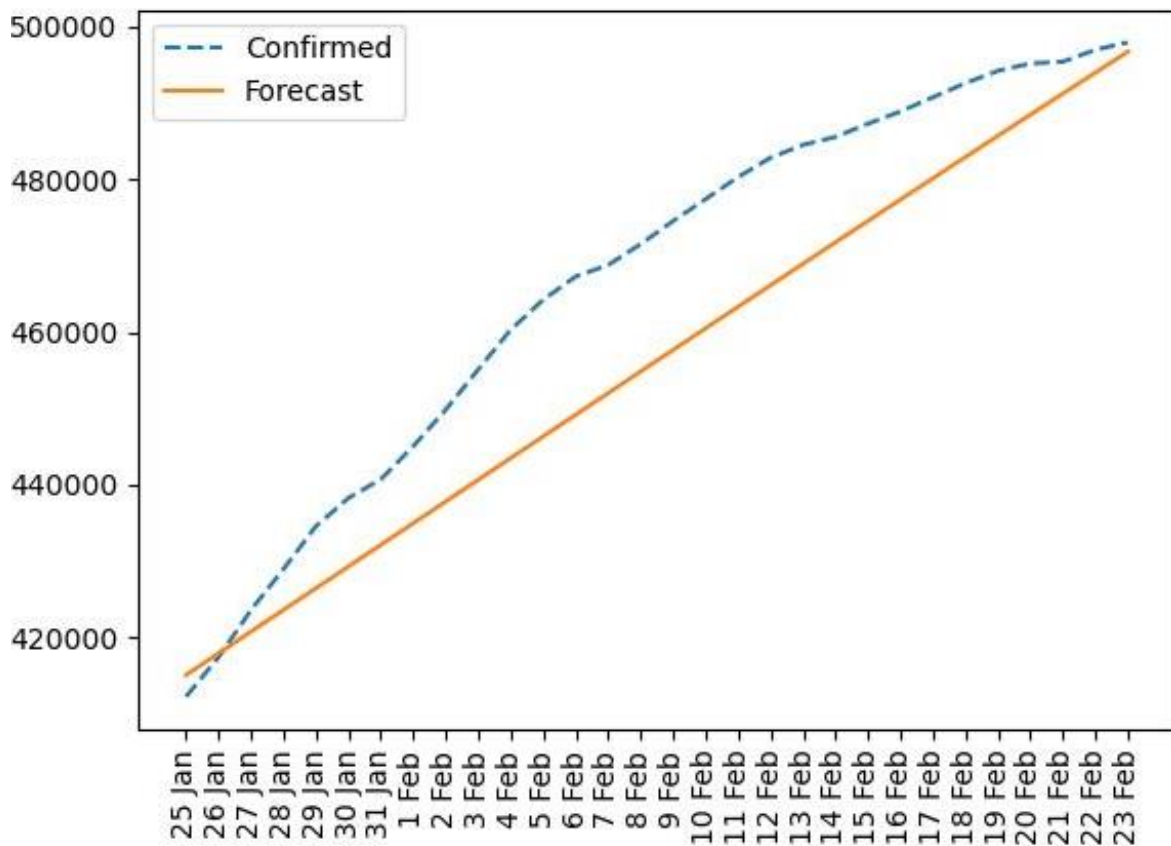
To assess the accuracy of the forecast, the mean absolute error was used:

$$MAPE = \frac{1}{n} \sum_{i=1}^n \frac{|Y_i - \hat{Y}_i|}{Y_i}, \quad (3)$$

where  $Y_i$  is the registered incidence for the analyzed period,  $\hat{Y}_i$  is the predicted incidence for the analyzed period,  $n$  is the number of periods.

### 3. Results

The Python programming language was used to implement the study. Data used for modeling included new cases and deaths provided by the World Health Organization Coronavirus (COVID-19) Dashboard [1]. To verify the model, a forecast of new cases and deaths from COVID-19 in Moldova was built for January 25, 2022 - February 23, 2022. Figure 1 shows the forecast for new cases of COVID-19.



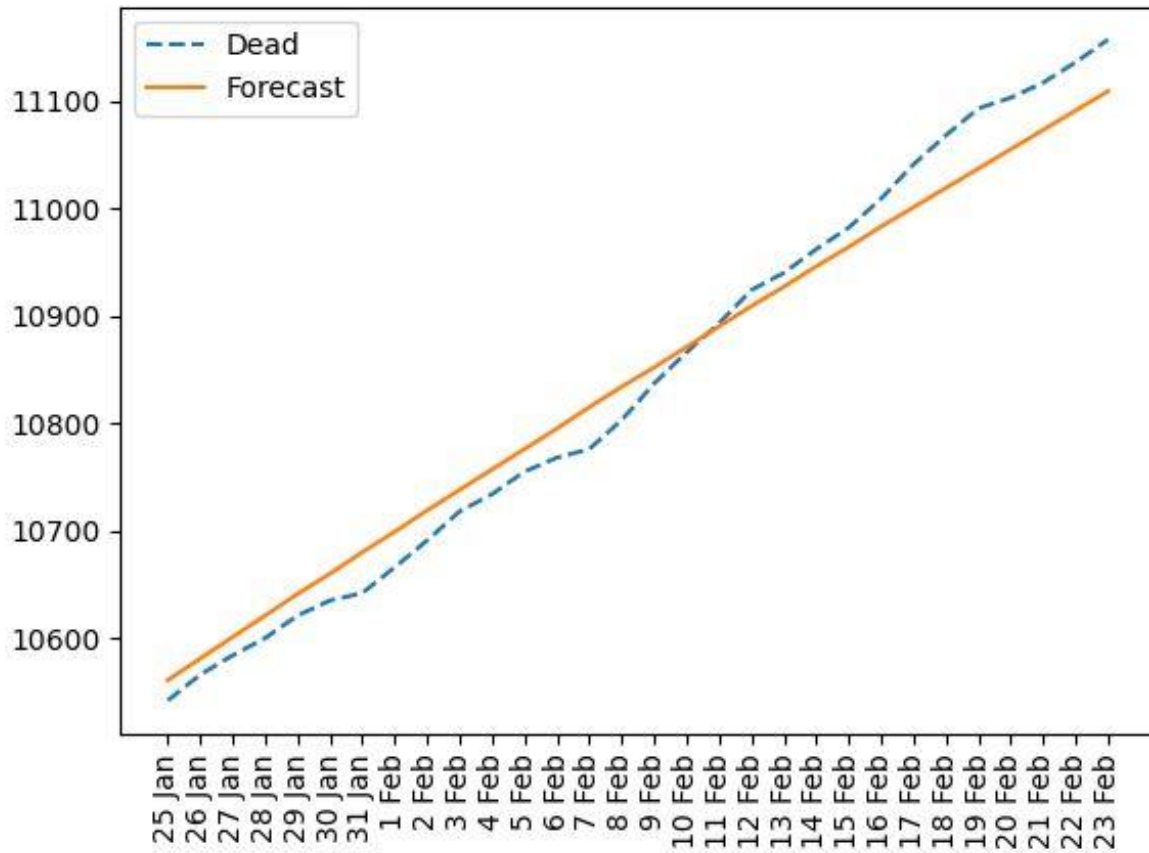
**Figure 1:** Forecasting of COVID-19 cumulative cases (25.01.22 – 23.02.22)

Table 1 shows the forecast accuracy of the constructed model in Moldova for the period from January 25, 2022, to February 23, 2022.

**Table 1**  
MAPE (25.01.2022 – 23.02.2022)

Duration of forecast	New cases	Death cases
7 days	1,22769 %	0,20877 %
10 days	1,67109 %	0,22193 %
20 days	2,62635 %	0,19983 %
30 days	2,30780 %	0,25049 %

Figure 2 shows the forecast of fatal cases of COVID-19 in Moldova from January 25, 2022, to February 23, 2022.



**Figure 2:** Forecasting of COVID-19 cumulative death cases (25.01.22 – 23.02.22)

The results of COVID-19 simulations in Moldova a month before the Russian war in Ukraine showed high accuracy for both short-term and long-term forecasts for 30 days.

To assess the impact of migration processes, a forecast was made of the dynamics of the COVID-19 epidemic process in Moldova for the first month after the escalation of the Russian war in Ukraine. Figure 3 shows the forecast of cumulative new cases of COVID-19 in Moldova from February 24, 2022, to March 25, 2022.

Figure 4 shows the forecast of cumulative fatal cases of COVID-19 in Moldova from February 24, 2022, to March 25, 2022.

Table 2 shows the forecast accuracy of the constructed model in Moldova for the period from February 24, 2022, to March 25, 2022.

**Table 2**

MAPE (24.02.2022 – 25.02.2022)

Duration of forecast	New cases	Death cases
7 days	0,04258 %	0,12488 %
10 days	0,03682 %	0,11316 %
20 days	0,13747 %	0,11180 %
30 days	0,65784 %	0,08799 %

Figure 5 shows the forecast of daily new cases of COVID-19 in Moldova from February 24, 2022, to March 25, 2022.

Figure 6 shows the forecast of daily COVID-19 deaths in Moldova from February 24, 2022, to March 25, 2022.

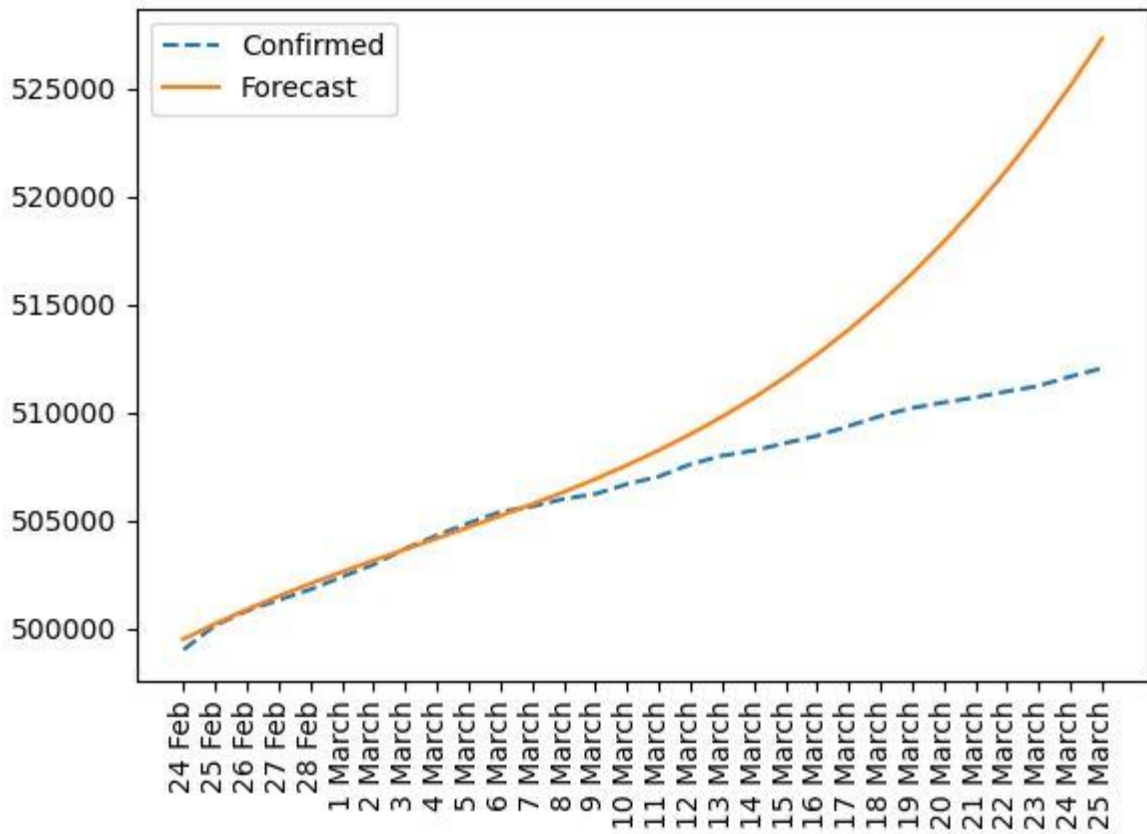


Figure 3: Forecasting of COVID-19 cumulative cases (24.02.22 – 25.03.22)

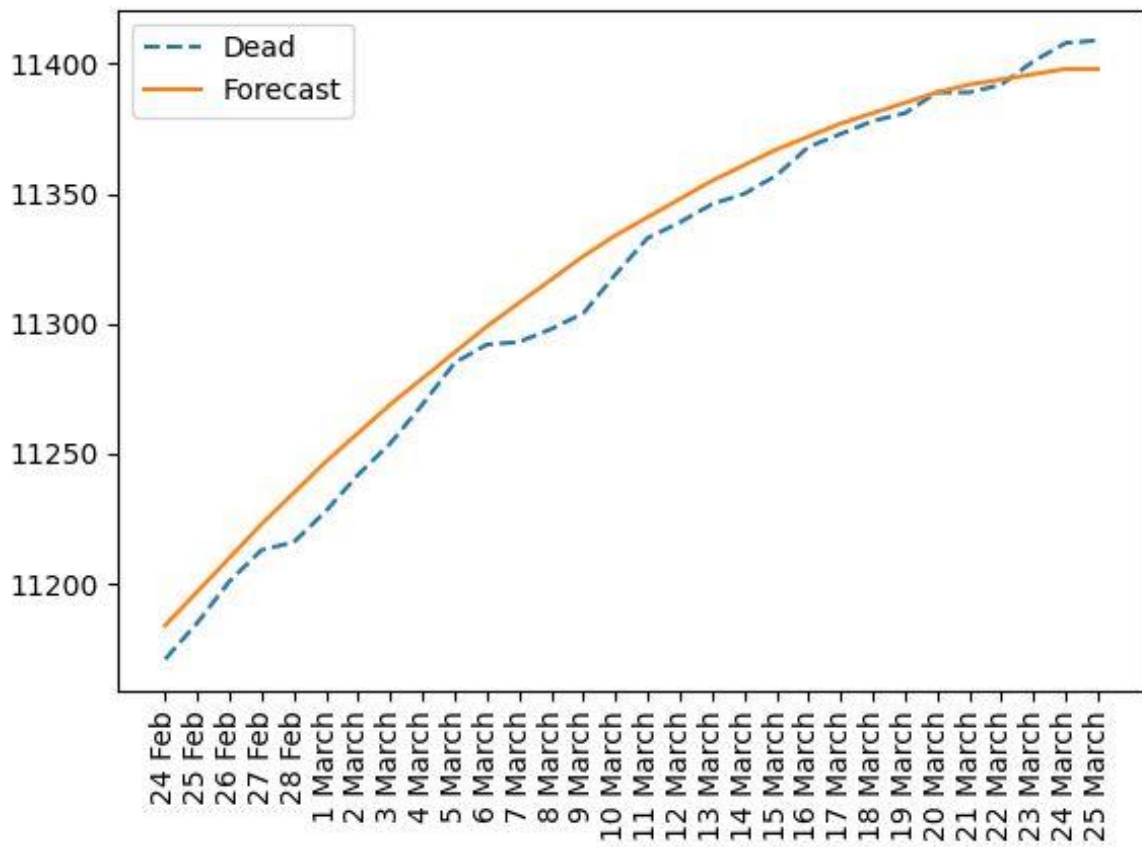


Figure 4: Forecasting of COVID-19 cumulative death cases (24.02.22 – 25.03.22)

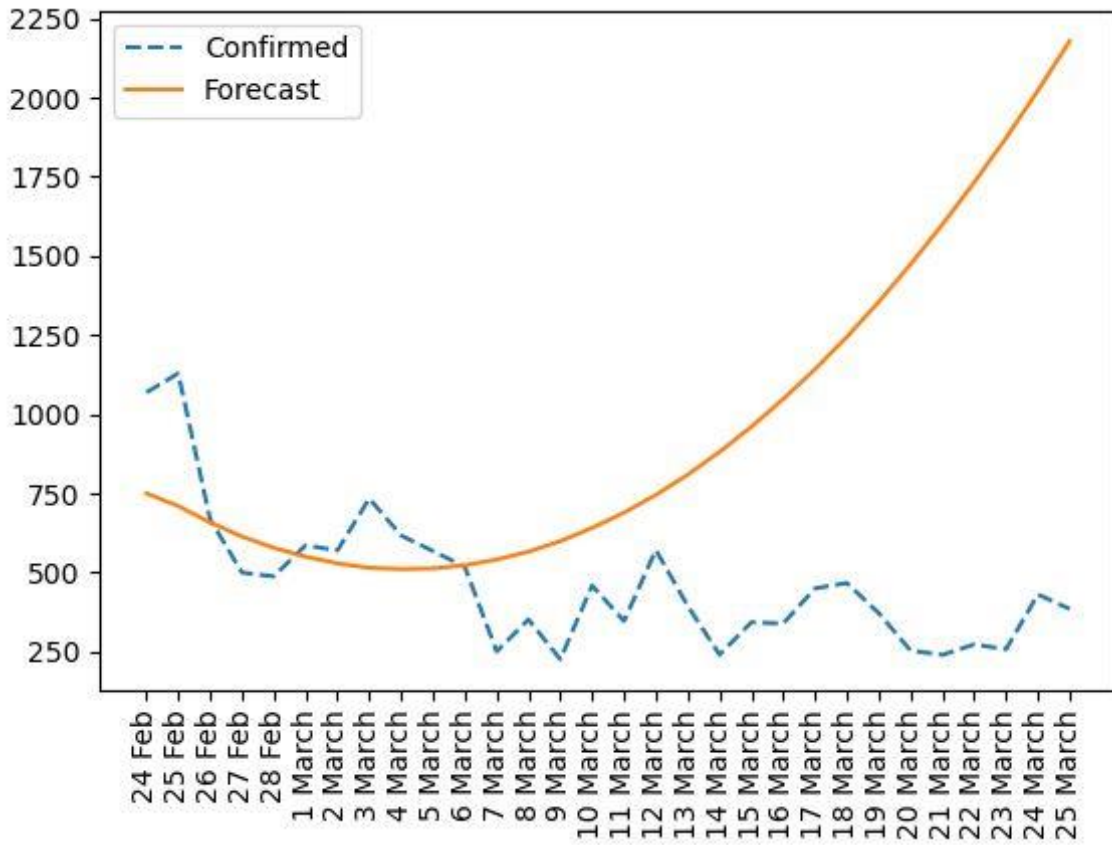


Figure 5: Forecasting of COVID-19 daily new cases (24.02.22 – 25.03.22)

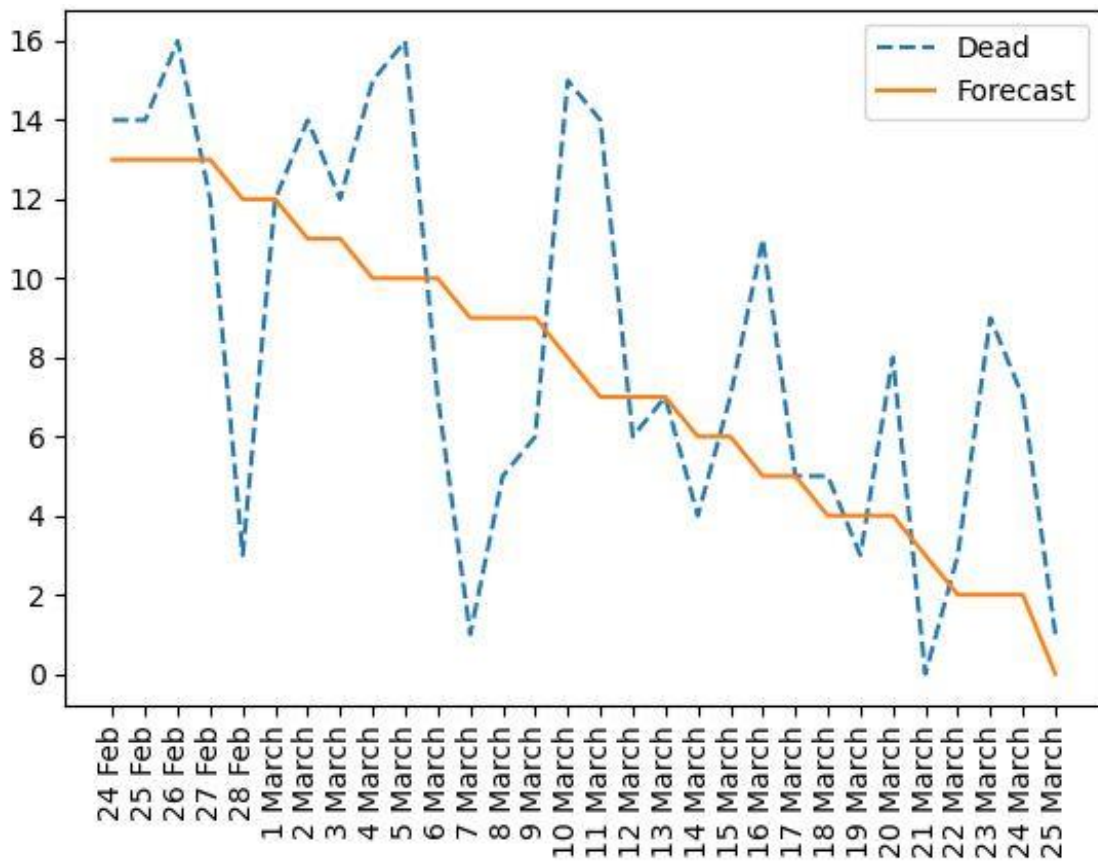
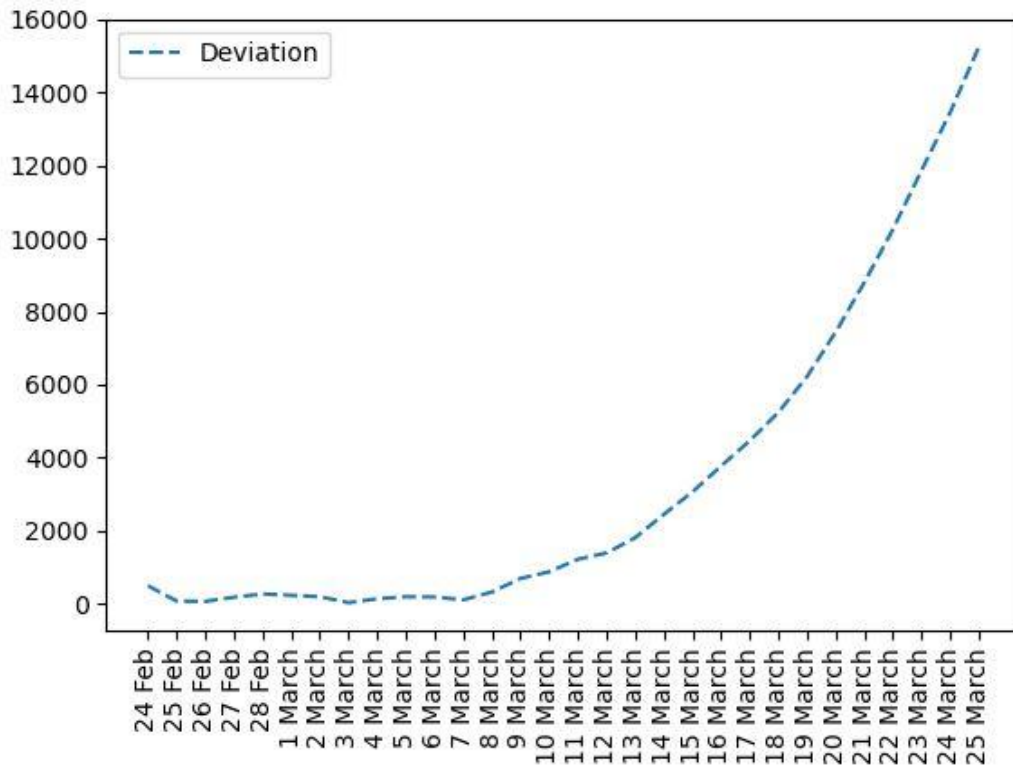
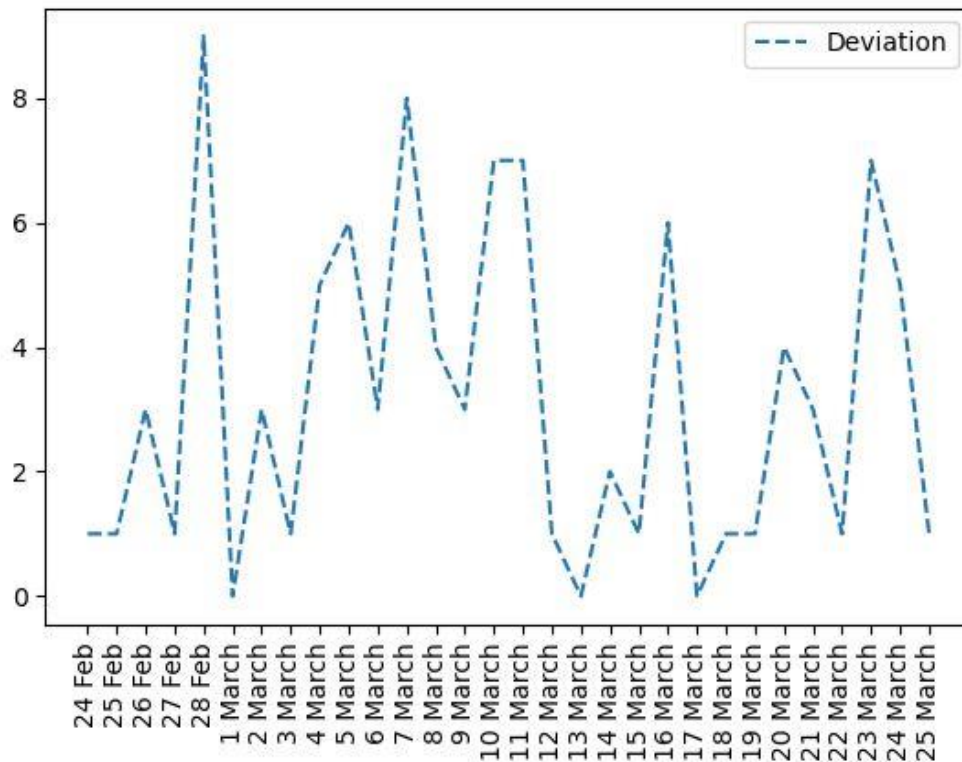


Figure 6: Forecasting of COVID-19 daily death cases (24.02.22 – 25.03.22)

Figure 7 shows the forecast deviation of daily new cases of COVID-19 in Moldova from February 24, 2022, to March 25, 2022, from reported cases. Figure 8 shows the deviation of the forecast of daily fatal cases of COVID-19 in Moldova from February 24, 2022, to March 25, 2022, from registered cases.



**Figure 7:** Deviation of COVID-19 daily new cases (24.02.22 – 25.03.22)



**Figure 8:** Deviation of COVID-19 daily death cases (24.02.22 – 25.03.22)

## 4. Conclusions

The escalation of the Russian war in Ukraine has stimulated the spread of COVID-19. Identifying new cases in areas with a destroyed public health infrastructure is challenging. Diagnostics in the temporarily occupied territories are complex due to the impossibility of conducting laboratory tests. Treatment is complicated due to the redistribution of medical capacities to help the armed forces and the affected civilian population. The accumulation of people in bomb shelters and during evacuations stimulates the spread of the virus. Mentally, people feel the danger of war, not infection with COVID-19, so anti-epidemic measures are not observed.

Almost 550,000 refugees from Ukraine crossed the border with Moldova. Social distance, mask regime, and other control measures were not observed during the evacuation. Refugees have not been tested for COVID-19 vaccination status.

However, the high accuracy of the model built as part of this study shows that the migration flows of refugees from Ukraine have not been the critical factor of changing in the dynamics of the spread of COVID-19 in Moldova. It can be concluded that the increase in the incidence associated with the migration of the population was offset by the natural decrease in the incidence of COVID-19 in Moldova, which was observed from late February 2022 – early March 2022.

However, to avoid new outbreaks, it is necessary to analyze the medical data of refugees arriving in third countries. Also, a necessary tool is the prioritization of vaccination against COVID-19 for refugees who have not completed the entire course of vaccination.

This study is only the first step in the study of the impact of the escalation of the Russian war in Ukraine on the public health system and, in particular, on changes in the patterns of behavior of the epidemic process of infectious disease. Therefore, to test the hypothesis about the impact of migration flows on the dynamics of the COVID-19 epidemic process in Moldova, the simplest statistical machine learning method, polynomial regression, was chosen.

Future research directions are developing more complex models and methods that will account for the stochastic nature of the spread of infectious diseases and the heterogeneity of the population. Such models will make it possible to identify specific factors influencing the epidemic process and evaluate their information content.

## 5. Acknowledgements

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