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Forecasting Inflation in a Non-Eurozone EU Country: An Econometric Analysis of Poland

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Abstract. Poland, an emerging economy in eastern Europe, became a member of the EU since 2004, however, due to economic and political reasons, the country is not yet in the Eurozone and still maintained its own central bank, independent monetary policies, as well as their local currency Zloty. Historically, the country has experienced high inflation during its systematic economic reformation after the end of its communist era, but it successfully maintained a low inflation rate afterwards until the start of the Ukrainian War in 2022. Through utilizing Python, this research analyzed the effect of both Poland's and Eurozone's monetary policy as well as key economic and geopolitical events on Poland's inflation rate. The research discovered that the only exogeneous factors that influenced Poland's inflation rate is its domestic monetary policy and the Ukrainian War. The research also made a 12-month ahead forecast on Poland's inflation rate and made recommendations to global corporations amid the uncertainties.

Keywords: Macroeconomics; Econometrics; Inflation; Monetary & Fiscal Policy; Eastern Europe.

1. Introduction

The Eurozone is a currency union consisting of 20 membership nations from the EU which adopted the Euro as the primary trading currency for daily usage. However, there exist some EU membership nations such as Poland that continue using their own currencies, the Polish Zloty, and kept its central bank to remain monetary policy independence. Although the European treaties required Poland to adopt the Euro at some point in the future, despite the volatility of the Polish Zloty's exchange rate against the Euro, keeping the Zloty and monetary policy independence remained economically advantageous and politically favorable as Poland's GDP per capita doubled in real terms since 2004 [1]. In addition to the sustainable economic growth the Poland's central bank has fostered through its independent monetary policy, the inflation of the country remained low as well after the initial spikes between 1989 and around 2000, which is the period of Poland's systematic economic reform after the end of the communist era. However, Poland is one of the nations that faced the most severe impact from the Ukrainian War since 2022, as the nation faced refugee waves, potential energy crisis, weakening external demand, etc. which created a high inflationary pressure that forced its central bank to adopt a tightening monetary policy [2]. This paper will analyze the effect of both the domestic and EU's monetary policy on Poland's inflation through an ARMAX model, analyze the effect of key economic and geopolitical events, conduct impulse response on the significant exogeneous factors, and make a time series econometric forecast through using Python.

The existing literatures had carried a series of research regarding both the analysis of Poland's inflation and the prospective forecast. First, Blaszczyk, Kwilinsky, and Pajak had made a survey level comprehensive analysis regarding Poland's inflation, diagnosed the inflation cycle of the country between the systematic economic reform and the start of the Ukrainian War, as well as analyzed the effect of the Ukrainian War on Poland's inflation. The main discovery by the authors is that the Ukrainian War will persistently increase Poland's inflation [3]. The article of Borowski and Jaworski focused on the effect of the Ukraine War on Poland's inflation and its monetary policy along with its policy coordination with the Eurozone. The authors discovered that the Polish Zloty depreciated against the Euro after the start of war which increased headline inflation, and the Polish monetary policy autonomy was constrained due to the increasing geopolitical tension in the region. The authors

suggested that Poland should seek for the Eurozone's membership to contain exchange rate volatility and inflationary pressure in the long run [4]. Lastly, the article of Cepni and Clements focused on the local inflationary factors within the emerging European countries including Poland. The authors' research validated the statement that inflation is a 'global phenomenon', and it is also true for the European emerging markets not just for developed and high-income economies [5].

The previous researchers have well studied the historical and current inflation of Poland as well as the effect of the Ukrainian war on the country's inflation from the theoretical side. However, the previous researchers did not focus on the empirical side regarding the forecast of the Poland's inflation rate in the near future. Thus, this research will conduct a time series analysis and forecast to fill-in the gap of the previous research.

The following parts of this article will be: Section II is the research design which contains the data description, unit root test, Granger causality test, and the ARMAX model specification. Section III is the empirical results and analysis which contains the Akaike Information Criterion (AIC) for p,q,r,s determination, ARMAX model results, impulse response, and a 12-month ahead forecast. Section IV is the discussion which includes the recommendation for global businesses. Lastly, section V is the article's conclusion.

2. Research Design

2.1. Data Construction and Variables

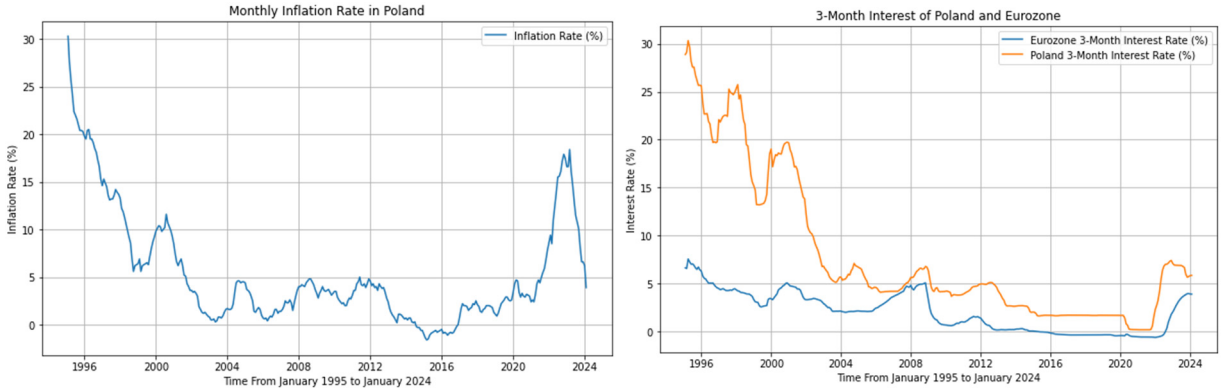

Figure 1. Data Visulization

This research is an economic analysis and time series forecast based on historical data, thus, the dataset should include data between 1989, when Poland's the systematic economic reform started, to the present. However, due to the limitation on data availability, this research will only use the monthly data of Poland's inflation rate issued by the Central Statistical Office of Poland available on the website Trading Economics from January 1995 to January 2024 [7]. Specifically, the inflation rate within the dataset is based on the consumer price index of Poland, which consisted of the following weights: food and non-alcoholic beverages 24%; housing energy/maintenance 21%; transport 9%; recreation and culture 7%. alcohol and tobacco, health, other goods and services, and clothing account for 6% each. Communication, restaurants and hotels, household equipment and education account for the remaining 17% of total weight. The change in CPI or the inflation percentages are measured on a year-over-year basis. Additionally, to enhance the predictive power of the model, the following exogeneous regressors with the same start and end date will be added into the dataset: the three-month interest rate of Poland issued by the Polish central bank available on the website Y-Charts, and the three-month interest rate of the Eurozone issued by the European Central Bank available on the website Y-Charts [7][8]. The data visualization for Poland's inflation rate and the exogeneous variables are:

The figure of the monthly inflation rate of Poland suggested that the country experienced high inflation after the end of the communist era until around 2000, which captures the stage of the

systematic economic transition. The data showed mean persistency after 2000 with some seasonality and no cyclical pattern until the start of Ukrainian War in 2022. The data for the three-month interest rate of Poland and that of the Eurozone showed high correlation as policy makers continuously cutting interest rates and maintained a low interest rate in both regions until the start of Ukrainian War in 2022.

In addition to the exogeneous variables, the research will also analyze the effect of key geopolitical and economic events on Poland's inflation within the time duration through adopting dummy variables. The first event that will be considered is Poland's inflation targeting since 1998, a monetary policy framework that is commonly adopted by transitioning economies [9]. The second event that will be considered is Poland's accession of the EU membership in 2004, which fundamentally impacted the economic development of the country [10]. The third event that will be considered is the EU Fiscal Compact of 2012, which potentially stifled the economic growth of its membership nations [11]. The last event that will be considered is the Ukrainian War from 2022 which changed the fundamentals of the macroeconomic outlook of Poland and the geopolitical atmosphere in the region [12].

2.2. Unit Root Test

Before starting the regression analysis and forecasting, this research performed an Augmented Dickey-Fuller (ADF) test to check for the stationarity of both the Poland's inflation rate series and the series for the two exogeneous regressors as a requirement of time series analysis. The following hypothesis tests is then performed:

Ho: The following series contains unit root and is non-stationary

Ha: The following series does not contain unit root and is stationary

Table 1. ADF Test for all Series

Variables	ADF Statistics	p-value
Poland's Inflation Rate	-4.051	0.001
Eurozone three-month interest rate	-2.557	0.102
Poland three-month interest rate	-2.813	0.056

The p-value for Poland's inflation rate series is smaller than 0.05, suggesting that it is a stationary process. However, the p-value for both the Eurozone's and Poland's three-month interest rate series is larger than 0.05, suggesting that they contain unit roots and are non-stationary. Thus, the differencing technique will be adopted for the two non-stationary series, and the Augmented Dickey-Fuller test will be performed again for both after they are differenced.

Ho: The following series contains unit root and is non-stationary

Ha: The following series does not contain unit root and is stationary

Table 2. ADF Test for the Differenced Series

Variables	ADF Statistics	p-value
Eurozone three-month interest rate	-5.859	0.000
Poland three-month interest rate	-6.374	0.000

2.3. Granger Causality Test

To determine the significance of the exogeneous regressors and the dummy variables, the Granger causality test will be performed. The number of lags included in the Granger causality test is arbitrarily set to 10. The test is being performed as the following:

Ho: The variables do not Granger-cause changes in Poland's inflation rate

Ha: The variables do Granger-cause changes in Poland's inflation rate

Table 3. Granger Causality P-Value of SSR Based X^2 Test

Lags	Eurozone Three-Month Interest Rate	Poland Three-Month Interest Rate	Poland Inflation Targeting of 1998	Poland's Accession of EU Membership in 2004	EU Fiscal Compact of 2012	Ukrainian War 2022
1	0.2416	0.0001	0.5980	0.1516	0.5471	0.6885
2	0.6289	0.0217	0.7354	0.9043	0.7198	0.0935
3	0.4440	0.0312	0.7921	0.9937	0.7429	0.0000
4	0.6911	0.0755	0.7568	0.9342	0.8456	0.0000
5	0.2711	0.2638	0.7682	0.4035	0.8239	0.0000
6	0.1360	0.0833	0.7156	0.3151	0.4172	0.0000
7	0.1672	0.0193	0.7719	0.3993	0.4156	0.0000
8	0.0741	0.0080	0.2959	0.4765	0.5232	0.0000
9	0.1405	0.0214	0.3026	0.4677	0.5952	0.0000
10	0.1541	0.0198	0.0551	0.5749	0.6111	0.0000

The result of the Granger causality test above suggested that only the fluctuation of Poland's three-month interest rate and the effect of the Ukrainian War in 2022 will Granger-cause the fluctuation in Poland's inflation rate as they are the only variables that contained p-values smaller than 0.05 within the first 10 lags. As a result, all the other variables will be dropped at this point due to their statistical insignificance as revealed from the Granger causality test.

2.4. ARMAX Model Specification

To make the forecast on Poland's inflation, the ARMAX model will be adopted. The equation for the ARMAX(p,q,r,s) model is displayed below:

$$Y_t = \alpha + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \epsilon_{t-j} + \sum_{k=1}^{r} \beta_k X_{t-k} + \sum_{l=1}^{s} \gamma_l W_{t-l} + \epsilon_t$$

The model is consisted of three parts: the autoregressive (AR) which captures the influence of past data on current values, the moving average (MA) which captures the effect of shocks from previous periods on the current value, and the exogeneous input (X), which in this case is the Poland's three-month interest rate series and the dummy variable representing the Ukrainian War.

3. Empirical Result Analysis

3.1. Akike Information Criterion for p,q,r,s Determination

The Akaike Information Criterion (AIC) is designed to find models with the lowest forecast risk, through selecting the model with the lowest AIC value. The basic formula Python used for AIC value calculation of ARMA and ARMAX model is displayed below:

$$AIC = 2k + nln(\frac{RSS}{N})$$

The research will first determine the p and q value for the ARMA part based on the Akaike Information Criterion. The maximum lags are arbitrarily set to six for both p and q, and later for r and s, since half a year is enough time for a lagging response to appear while keeping the overall model simple to avoid the overfitting problem.

Table 4. AIC Values for Different p,q Values in the ARMA Part

	AR0	AR1	AR2	AR3	AR4	AR5	AR6
MA0	2211.16	640.72	569.99	566.96	560.44	558.71	554.29
MA1	1758.47	587.34	555.91	567.46	561.85	558.03	544.12
MA2	1418.04	580.26	1103.43	555.05	560.25	561.03	550.50
MA3	1168.21	574.74	555.40	543.67	550.14	536.79	548.28
MA4	1056.25	573.90	555.26	543.84	541.44	544.32	565.48
MA5	908.28	567.65	550.69	566.54	541.24	560.84	559.18
MA6	866.03	568.28	703.85	560.26	543.41	543.70	544.63

The AIC value when p equals five and q equals three is the smallest, thus, ARMA (5,3) should then be adopted for the ARMA part. The research will proceed and determine the value for r and s based on ARMA (5,3).

Table 5. AIC Values for Different Lags for Poland Interest Rate in ARMAX

Lags	0	1	2	3	4	5	6
AIC	538.76	532.64	530.71	523.73	524.15	541.45	539.89

The AIC value when including three lags for Poland's three-month interest rate will generate the smallest AIC value. However, the proceeding regression showed that when including three lags for Poland's three-month interest rate as exogeneous variable, the regression result suggests that multiple key variables became statistically insignificant. Thus, the research will slightly deviate from the AIC value criterion here and choose to include five lags which would produce a regression result that made the most regressors statistically significant. The research will proceed and determine the number of lags for the Ukrainian War dummy variable when p equals 5, q equals 3, and r equals 5.

Table 6. AIC Values for Different Lags for Ukrainian War in ARMAX

Lags	0	1	2	3	4	5	6
AIC	539.83	523.27	522.13	518.56	515.16	507.78	511.44

The AIC value when including five lags for the Ukrainian War dummy variable will generate the smallest AIC value. However, the proceeding regression showed that when including five lags for Ukrainian War dummy variable, the regression results suggested that multiple key variables became statistically insignificant. Thus, the research will slightly deviate here again and choose to include four lags which would produce a regression result that have most regressors statistically significant. Thus, the final model the research will use is the ARMAX (5,3,5,4) model.

3.2. ARMA Model Result

3.3. Impulse Response

To analyze the effect of the Ukrainian War on Poland's inflation, the impulse response will then be performed.

The impulse response that is visually displayed above suggested that the Ukrainian War will have a persistent effect on Poland's inflation rate which validated the finding of Blaszczyk, Kwilinsky, and Pajak. Specifically, the impulse response suggested that the war had caused an initial spike in Poland's inflation rate followed by a persistent high inflation rate with a slightly decreasing trend in the long run.

Table 7. ARMAX (5,3,5,4) Model Regression Result

Dependent Variable: Poland's Inflation				Number of Observation:	343	
Model:	ARIMA			Log Likelihood:	-236.582	
Sample:	343			AIC:	515.164	
Covariance Type:	opg			BIC:	595.757	
				HQIC:	547.267	
	coefficient	standard error	z	p-value	Pr: 0.025	Pr: 0.975
Constant	4.4551	34.554	0.129	0.897	-63.629	72.179
PL IR	0.0066	0.064	0.103	0.918	-0.119	0.132
PL IR L1	0.0421	0.094	0.447	0.655	-0.143	0.227
PL IR L2	0.1374	0.107	1.280	0.201	-0.073	0.348
PL IR L3	0.2335	0.102	2.279	0.023	0.033	0.434
PL IR L4	0.2628	0.094	2.801	0.005	0.079	0.447
PL IR L5	0.2142	0.055	3.861	0.000	0.105	0.323
War	0.6054	0.930	0.651	0.515	-1.216	2.427
War L1	-1.1172	1.149	-0.972	0.331	-3.369	1.135
War L2	2.1765	1.043	2.087	0.037	0.133	4.220
War L3	1.4675	1.311	1.120	0.263	-1.102	4.037
War L4	1.0576	0.515	2.053	0.040	0.048	2.067
AR L1	0.0642	0.089	0.723	0.470	-0.110	0.239
AR L2	0.1976	0.092	2.139	0.032	0.017	0.379
AR L3	0.4729	0.068	6.911	0.000	0.339	0.607
AR L4	0.7076	0.091	7.760	0.000	0.529	0.886
AR L5	-0.4445	0.060	-7.367	0.000	-0.563	-0.326
MA L1	1.3804	0.082	16.740	0.000	1.219	1.542
MA L2	1.3184	0.082	16.160	0.000	1.159	1.478
MA L3	0.9114	0.068	13.502	0.000	0.779	1.044
MA L4	0.2263	0.014	15.665	0.000	0.198	0.255
Ljung-Box (L1)(Q):	0.71			Jarque-Bera (JB):	444.80	
Prob (Q):	0.40			Prob (JB):	0.00	
Heteroskedasticity:	1.42			Skew:	-0.69	
Prob (H) (two-sided):	0.06			Kurtosis:	8.40	

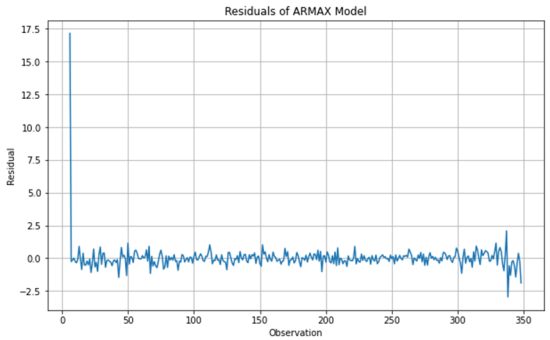

Figure 2. ARMAX Model Residuals

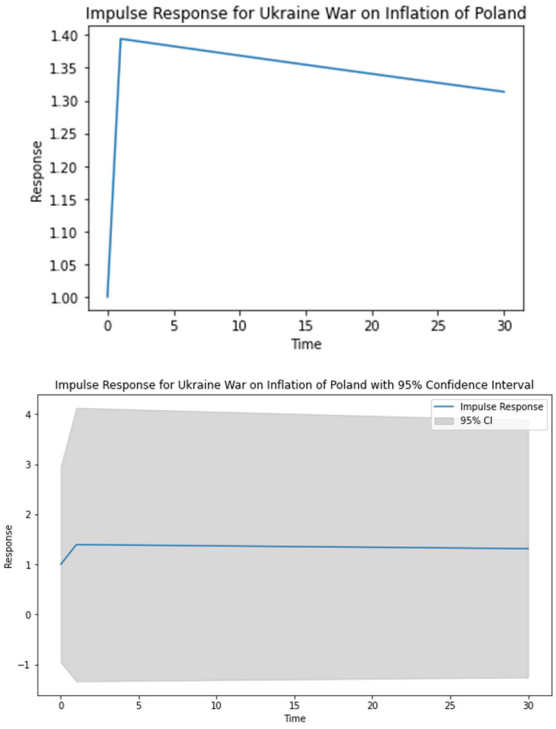

Figure 3. Impulse Response

3.4. 12-Month Ahead Forecast

Table 8. 12 Month Ahead Forecast for Poland's Inflation

Time	Point Forecast	90% CI Forecast Lower Bound	90% CI Forecast Upper Bound
Feb 2024	3.299	2.516	4.081
Mar 2024	3.190	1.185	4.565
Apr 2024	2.577	0.713	4.441
May 2024	2.330	0.006	4.654
Jun 2024	2.639	-0.088	5.365
July 2024	2.767	-0.304	5.838
Aug 2024	2.338	-1.045	5.720
Sep 2024	2.501	-1.186	6.188
Oct 2024	2.701	-1.255	6.658
Nov 2024	2.420	-1.782	6.623
Dec 2024	2.101	-2.342	6.545
Jan 2025	2.467	-2.210	7.145

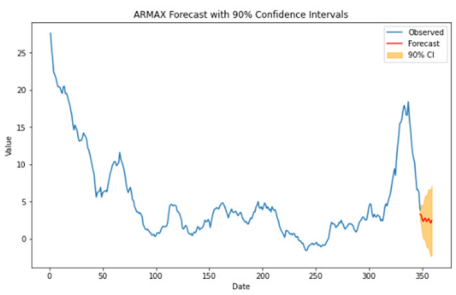

Figure 4. 12 Month Ahead Forecast for Poland's Inflation Graph

4. Discuession

The main finding of this research is that Poland, as a non-Eurozone EU membership nation has relatively stable inflation rate after the fading of the initial spikes during the systematic economic reformation era between 1989 and around 2000. The country's monetary authority had coordinated moves with the European Central Bank making the country's inflation dependent only on the domestic interest rate and independent from the interest rate of the Eurozone. The research also discovered that the key economic and geopolitical events such as Poland's inflation targeting of 1998, EU membership accession of 2004, and the initiation of EU Fiscal Compact of 2012 does not Granger-cause the fluctuation in Poland's inflation rate whereas the Ukrainian War persistently increased Poland's inflation which validated the findings in the previous research by Blaszczyk, Kwilinsky, and Pajak.

The research has important implication for global corporations. As the world businesses actively reinventing the global supply chain in recent years by moving factories away from China to new locations such as the eastern European nations including Poland, understanding Poland's inflation would be crucial for global businesses [13]. According to the forecast of this research, the effective moves of the Polish central bank and the expected mild inflation in the middle and the long run would make Poland a desired destination of building factories. However, the global corporations should also be mindful of the potential risks of the Ukrainian War as the research validated the previous findings that the Ukrainian War would persistently push up Poland's inflation.

5. Conclusion

In conclusion, the main discovery of this research is that only Poland's three-month interest rate and the Ukrainian War have caused the fluctuation and the rise of Poland's inflation rate whereas the Eurozone's three-month interest rate and other key economic and geopolitical events have no effect on the Poland's inflation.

Besides, the 12-month ahead forecasting result of this research suggested that Poland's inflation will be mild due to its effective monetary policy to contain inflation. As a result of the mild inflation, Poland would still be considered a desired destination for global business's outsourcing of manufacturing and production despite the persistent hazardous effect on inflation rate due to the Ukrainian War. Additionally, the research also suggested that the global central bankers should prepare for black swan events in its own region and around the globe, such as the Ukrainian War, which would change the macroeconomic fundamentals of a country and cause problems such as a persistent high inflation rate.

The conclusion of this research is made without incorporating the data between 1989 and 1995, which is a key period for Poland's systematic economic transition after the end of its communist era, due to the lack of data, which may cause potential misunderstanding of Poland's historical inflation.

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