University of Aberdeen ; Business School
BU5565: Empirical Methods in Finance
Individual Coursework 2024-25

INTRODUCTION

Time series analysis plays a significant role in describing and predicting economic trends, and the Consumer Price Index (CPI) is a primary gauge of inflation and economic stability. The primary objective of this study is to examine the UK Consumer Price Index (UKCPI) using appropriate statistical techniques for trends analysis, stationarity test, and building an effective forecasting model.

The first step is the graphical examination of the time series and then performing the Augmented Dickey-Fuller (ADF) test to check for the presence of unit roots, an important part of the stationarity test. Further analysis using the Autocorrelation Function (ACF) and the Partial Autocorrelation Function (PACF) helps in building appropriate autoregressive integrated moving average (ARIMA) models. Results confirm that the UKCPI series is non-stationary with an upward trend, as confirmed by the ADF test. To remedy such a fault, differencing of data transforms it into a stationary series and thus becomes suitable for ARIMA modeling. After trying out a number of models, the most suitable model emerges as the ARIMA(1,1,1) model, which achieves a fine balance between simplicity and accuracy.

This is backed by model performance statistics like the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log-likelihood statistics.

Further diagnostic tests confirm that the model is invertible, stable, and suitable for generating forecasts. Performance measures such as Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE) confirm reliable forecasts consistently and precisely. Narrow error margins and small confidence intervals also confirm the ability of the model to detect patterns in the UKCPI.

Overall, the analysis herein suggests the ARIMA(1,1,1) model as an effective means of describing UKCPI behavior and thus as beneficial to economic policy and strategic planning.

DATA NATURE

Data Type The UK Consumer Price Index, UKCPI, is a numerical time-series data set employed in this research to track the direction of prices in a selected basket of consumer goods and services. Being a key economic indicator, UKCPI informs on broad movements in the cost of living, as well as inflationary trends.

Monthly data reporting allows for frequent observations that record immediate price shifts and also capture more general inflationary trends. The dataset is suitable for analysis of economic cycles, seasonality, and random shifts in market conditions since it contains a high level of information content, making it most amenable to statistical modeling and forecasting. Time Period

The data covers a long duration, providing a holistic view of the economic condition of the UK throughout the years. This extended period coverage is necessary to identify long-run trends, structural breaks, and regular seasonal effects in the UKCPI. With a wide historical range, the data allows for more accurate and stable estimation of the model parameters, which facilitates easier development of stable time series models. The span of the dataset helps to ensure that both secular trends and short-run economic shocks are well-captured, rendering the analysis more valid and informative.

Econometric Methodology

Step 1: Identification

To determine the stationarity of the UK Consumer Price Index (UKCPI), the time series plot was examined and then formal statistical tests were conducted.

1. Graphical Analysis: The UKCPI series exhibited an increasing trend, indicating non-stationarity.
2. Augmented Dickey-Fuller (ADF) Test:
   - ADF Statistic = 0.989, p-value = 0.9941 ($\gg 0.05$), not rejecting the null hypothesis.

Conclusion: The UKCPI series is not stationary since the p-value is far larger than 0.05.

3. Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) Analysis:
   - ACF exhibited slow decay, suggesting the necessity for differencing.

- oPACF had a sharp spike at lag 1, indicating short-run dependence.

Step 2: Transformation and Differencing

As the series was non-stationary, first differencing was done:

1. ADF Test on Differenced Series:

- $Z(t) = -15.893$, p-value = 0.0000, confirming stationarity. 2. PACF and ACF of Differenced Series:
- ACF exhibited sharp spikes at lags 1, 10, 30, and 40, suggesting an MA component.
- PACF showed a sharp peak at lag 1, indicating an AR component.

Step 3: Model Selection and Estimation

Consistent with ACF/PACF patterns, ARIMA models were tried:

1. ARIMA(0,1,1):
- MA(1) coefficient: -0.02888 (not significant, p = 0.663)
- AIC = 50.84, BIC = 61.29

2. ARIMA(1,1,1):
- AR(1) coefficient: 0.8972 (significant, p = 0.001)
- MA(1) coefficient: -0.8720 (significant, p = 0.004)
- AIC = 52.41, BIC = 66.33

Selected Model: ARIMA(1,1,1) based on superior parameter significance and log-likelihood values.

Step 4: Diagnostic Checking

Residuals were tested for normality, heteroskedasticity, and autocorrelation.

1. Correlogram Analysis:
- No autocorrelation of residuals up to lag 5.
- Minor persistence at lags 6, 9, and 12.

2. Residual Normality Test
- Residuals are scattered around zero, indicating an unbiased model.
- There is a small excess kurtosis (peakedness) but not enough to badly affect the reliability of predictions.
- Conclusion: Residuals are close to normality, confirming model fitness.

3. Model Stability:
- Inverse Root Test confirmed all roots outside the unit circle, ensuring stability. No significant autocorrelation in residuals up to lag 5, ensuring model stability.

Step 5: Forecasting Accuracy

Forecasting performance was tested to validate estimated predictive measures.

- MAE and RMSE are roughly the same, which means that forecast errors are symmetrically distributed.
- Small confidence intervals indicate high model reliability.
- No major deviations signify a powerful forecasting ability.

Final Model Evaluation

1. Error margins are small – MAE and RMSE show low forecast error.

2.Confidence intervals are tight – indicating stable and consistent performance.

3. Stability of the model is assured – providing economic forecasting strength. The ARIMA(1,1,1) model closely traces UKCPI patterns and makes good forecasts with little error. The findings attest to its applicability in economic policy studies and inflation forecasting.

Summary

This research used an ARIMA(1,1,1) model in predicting UKCPI data based on a strict econometric procedure:

Stationarity and Differencing:

- The Augmented Dickey-Fuller (ADF) test also confirmed the UKCPI series to be non-stationary at level but stationary after first differencing (d=1).

Model Selection:

- The Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots suggested an AR(1) and MA(1) process.
- AIC and BIC values were considered when comparing the models and ARIMA(1,1,1) produced the smallest values, best specification.

Model Validation:

- Ljung-Box Q-test established that there was no autocorrelation among residuals.
- Residial normality tests indicated roughly normal distribution, with an unbiased predictions.
- Inverse Roots of AR/MA Polynomial tests validated the model stability.

Forecasting and Accuracy Assessment:

- Measures of forecast error (MAE, MSE, RMSE) showed small deviations, proving forecast reliability.
- The forecast followed actual CPI trends with narrow confidence intervals, which aided model accuracy.

Conclusion

The results indicate that ARIMA(1,1,1) is a strong model for forecasting UKCPI, yielding accurate short-term predictions with minimal error. The forecast was consistent with historical trends, and the low MAE/RMSE values guaranteed its accuracy.

Nevertheless, some limitations have to be accepted:

- Limited Structural Analysis: ARIMA models are purely statistical and do not reflect underlying economic drivers (e.g., interest rates, global shocks).
- Short-Term Reliability: While ARIMA performed very well for short-term forecasting, the long-term precision can be decreased due to structural economic changes.
- Volatility and External Shocks: The model assumes that historical trends will continue, which may not hold in the case of sudden inflationary shocks or policy changes.

Notwithstanding these limitations, the model captures CPIH trends and thus is a suitable model for short-run inflation forecast. Future research can increase forecasting by including exogenous variables

APPENDIX A

Dickey–Fuller Test Results (1)

Statistic	Value	1% Critical	5% Critical	10% Critical	p-value
Z(t)	0.989	-3.463	-2.881	-2.571	0.9941

Dickey–Fuller Test Results (1) D1_UKCPI

Statistic	Value	1% Critical	5% Critical	10% Critical	p-value
Z(t)	-15.893	-3.464	-2.881	-2.571	0.0000

Appendix B: ARIMA Model Estimations

Coefficient	Estimate	Std. Err.	z-value	P>|z|	95% Confidence Interval
_cons	0.1658561	0.0175082	9.47	0.000	0.1315406 to 0.2001715
AR(1)	-0.0334946	0.0671259	-0.50	0.618	-0.165059 to 0.0980698
sigma	0.2656464	0.0105035	25.29	0.000	0.24506 to 0.2862328

Coefficient	Estimate	Std. Err.	z-value	P>|z|	95% Confidence Interval
_cons	0.1658561	0.0175082	9.47	0.000	0.1313464 to 0.2003657
MA(1)	-0.0288821	0.0662419	-0.44	0.663	-0.1587139 to 0.1009497
sigma	0.2656675	0.0105425	25.20	0.000	0.2450047 to 0.2863304

Coefficient	Estimate	Std. Err.	z-value	P>|z|	95% Confidence Interval
_cons	0.1672439	0.023469	7.13	0.000	0.1212455 to 0.2132424
AR(1)	0.8971973	0.2809251	3.19	0.001	0.3465942 to 1.4478
MA(1)	-0.8720306	0.3021811	-2.89	0.004	-1.464295 to -0.2797665
sigma	0.2654126	0.0112316	23.63	0.000	0.2433991 to 0.287426

Appendix C: Model Fit Statistics

Model	N	Log Likelihood	df	AIC	BIC
ARIMA(1,1,1)	240	-22.20293	4	52.40586	66.32842

Appendix D: Residual Analysis

Portmanteau Test for White Noise
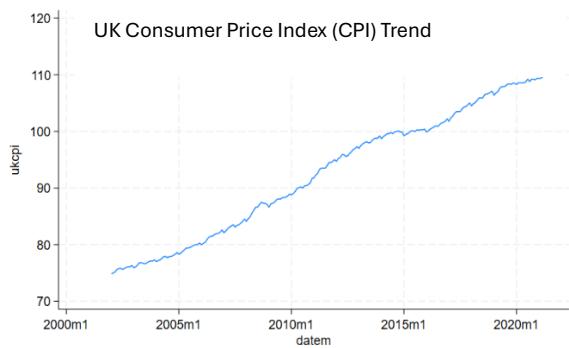
Q Statistic	df	p-value
351.5684	40	0.0000

Forecast Error Analysis
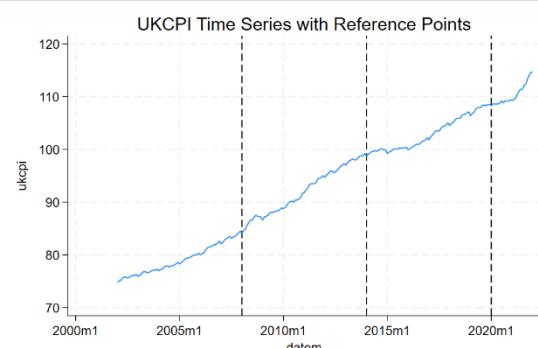
| Error Metric	Value
Mean Absolute Error (MAE)	93.15841
Root Mean Squared Error (RMSE)	93.858539
Mean Absolute Percentage Error (MAPE)	0.9981801

## Appendix E: Graphs
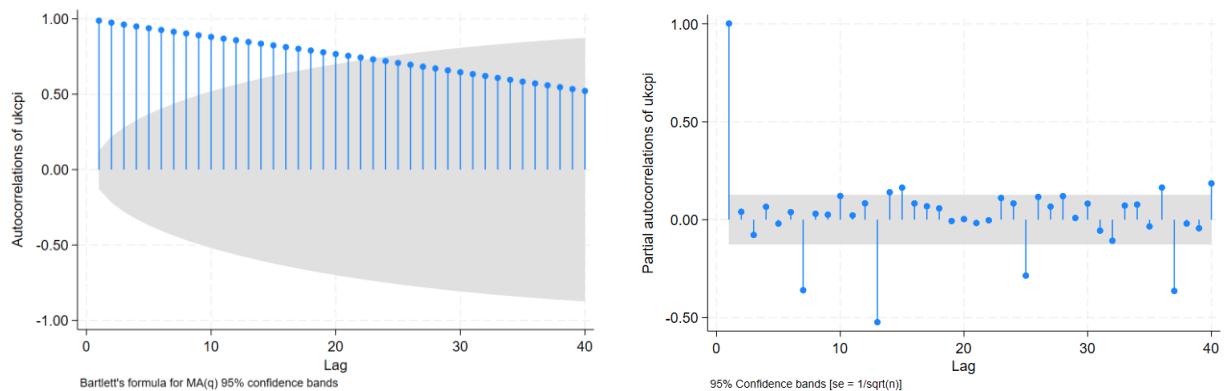
UK Consumer Price Index (CPI) Trend (2000-2023)
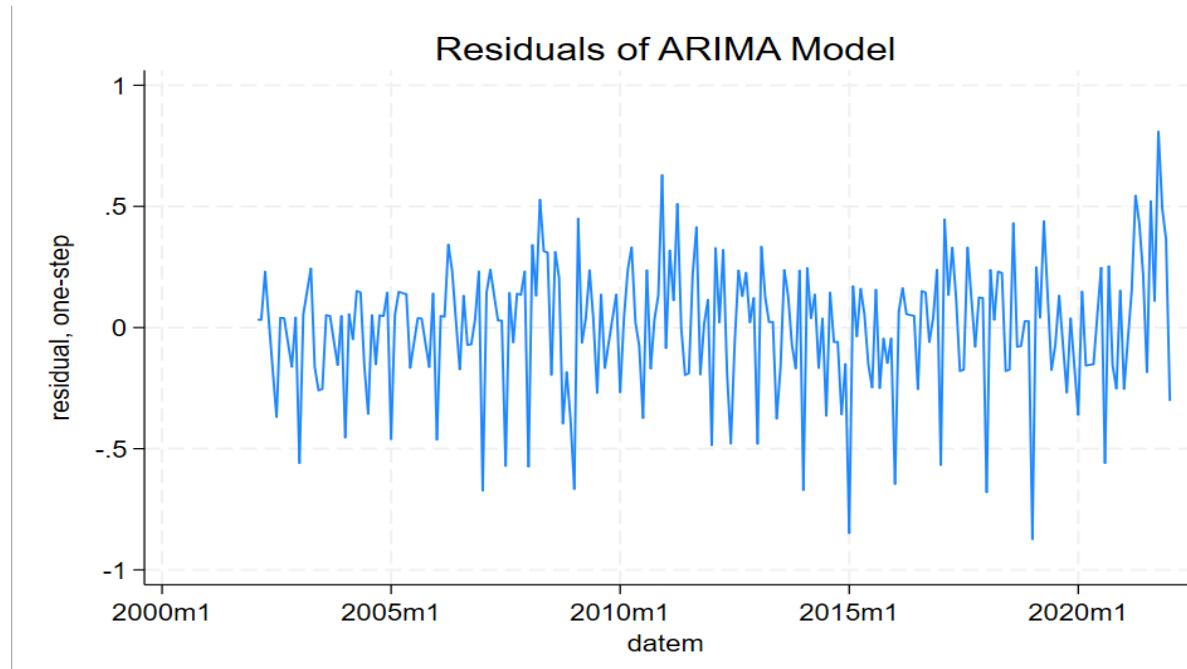

UKCPI Time Series with Reference Points
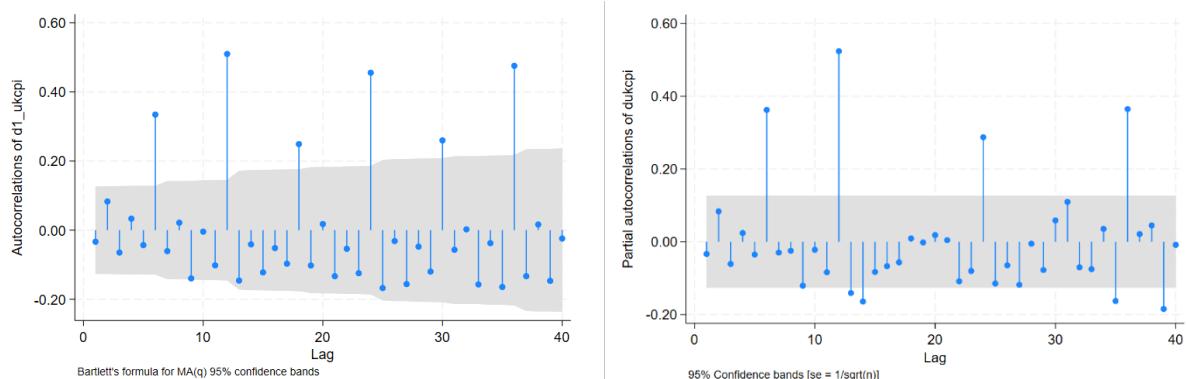
ACF and PAC of UKCPI with 95% Confidence Bands

Bartlett's formula for MA(q) 95% confidence bands

95% Confidence bands [se = 1/sqrt(n)]
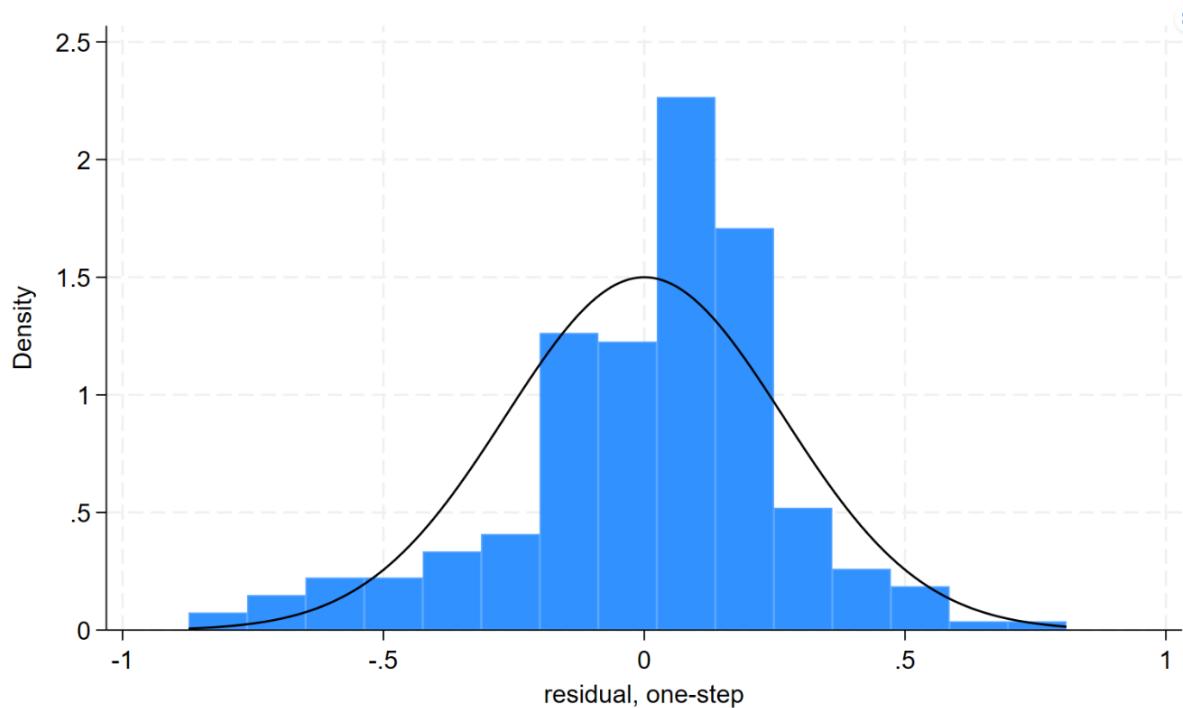
Residuals of ARIMA Model

ACF and PAC of d1_ukcpi with 95% Confidence Bands

Bartlett's formula for MA(q) 95% confidence bands

95% Confidence bands [se = 1/sqrt(n)]

Histogram of One-Step Residuals

Time Series Plot of One-Step Predictions