# Food Price Inflation Forecasting

## An Auto-Regressive Random Forest Approach

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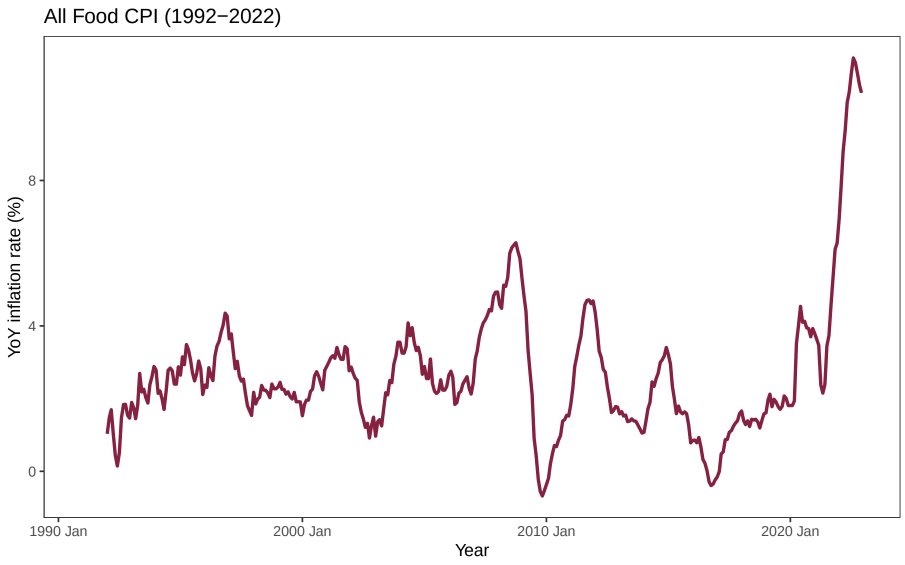


All Food CPI (1992−2022)
YoY inflation rate (%)
8
4
0
1990 Jan
2000 Jan
2010 Jan
2020 Jan
Year

# USDA Forecasts

## Food Price Outlook

- Forecasts US retail food prices since 1961.
- Produced by the United States Department of Agriculture (USDA) Economic Research Services (ERS).
- Used for budgetary planning by government agencies, food industry participants, consumers, and media.
- Since July 2023, a univariate Seasonal Auto-Regressive Integrated Moving Average (SARIMA) is used to forecast food-related.(MacLachlan, Chelius, and Short 2022)

# Issue #1: Exogenous Variables

## Determinants of Inflation

- Agricultural commodity prices (Kuhns et al. 2015)
- Energy Prices (Baek and Koo 2010)
- Core Inflation, Money Supply, Per capita Income, Wages, Transportation, Supply Chain, and Energy Prices(Adjemian et al. 2024)

# Are all the relevant variables included in the model?

- Methods for dealing with high-dimensional data
  - Factor Models (McCracken and Ng 2016)
  - Lasso regression (Hansen and Liao 2019)
  - Ridge regression (Coulombe 2025)
  - Random forest (Goulet Coulombe et al. 2022; Medeiros et al. 2021)
  - Neural networks (Goulet Coulombe et al. 2022; Medeiros et al. 2021)

# Issue #2: Assumes linearity in the parameters

- Structural Changes (Clarida, Gali, and Gertler 2000)
  - smoothe transitions (Teräsvirta 1994)
  - structural breaks (Stock 1994)
- Evolving Parameters (Primiceri 2005)
  - random walk time-varying parameters (Sims 1993)
- Regime Switching (Sims and Zha 2006)
  - threshold/switching regressions (Chen, So, and Liu 2011)
- Random Forest & Neural Networks (Goulet Coulombe et al. 2022; Medeiros et al. 2021)

# Goals and Objectives

## Factor Augmented Auto-Regressive Random Forest (FA-ARRF)

- Derive latent factors from the FRED-MD database following the methods in (McCracken and Ng 2016) & (Goulet Coulombe 2024) and include them in the information set.
- Specify a latent factor informed predictive equation for final predictions
- Perform an out-of-sample forecast targeting avg. YoY inflation for the years 2003-2022

## Evaluation

- Bias
- Accuracy: Root Mean Squared Errors (RMSE), Mariano Diebold (MDM) test,Forecast Encompassing Test

# Data

## All Food CPI series (1991-01-01 to 2023-12-01)

- CPI levels were downloaded directly from the BLS[a]
- Dependent variable ($\pi$): Average 12-month YoY Inflation Rate
- 12 lags of $\pi$

[a] https://www.bls.gov/

## FRED-MD (1991-01-01 to 2023-12-01)

- The FRED-MD database contains 127 monthly time series in 8 categories: Output and Income, Labor Market, Consumption and Orders, Orders and Inventories, Money and Credit, Interest Rates and Exchange Rates, Prices, Stock Market.[a]
- 2 Moving Average Factors for each FRED-MD variable
- 5 Factors derived from FRED-MD(McCracken and Ng 2016)

[a] https://www.stlouisfed.org/research/economists/mccracken/fred-databases

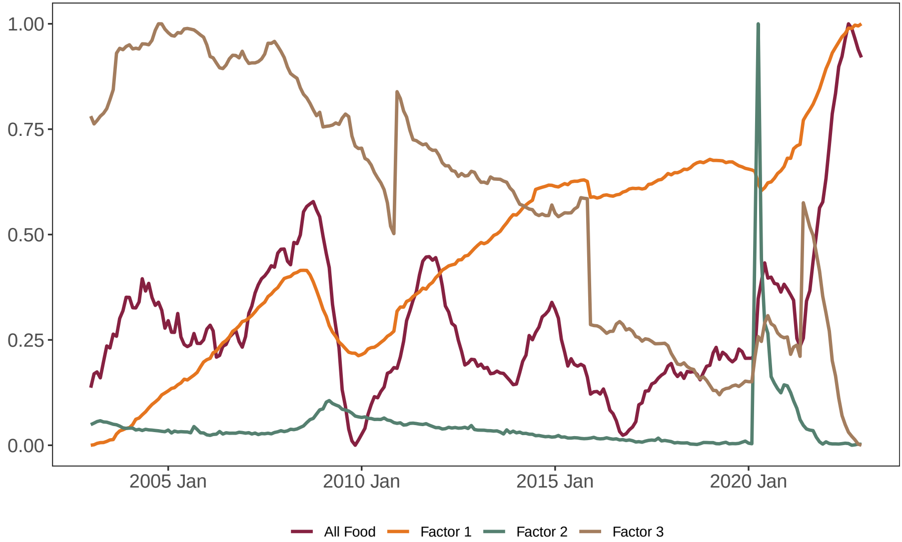
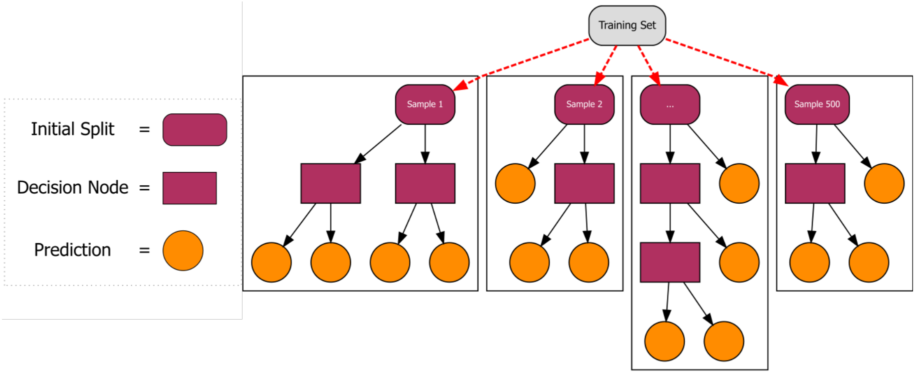
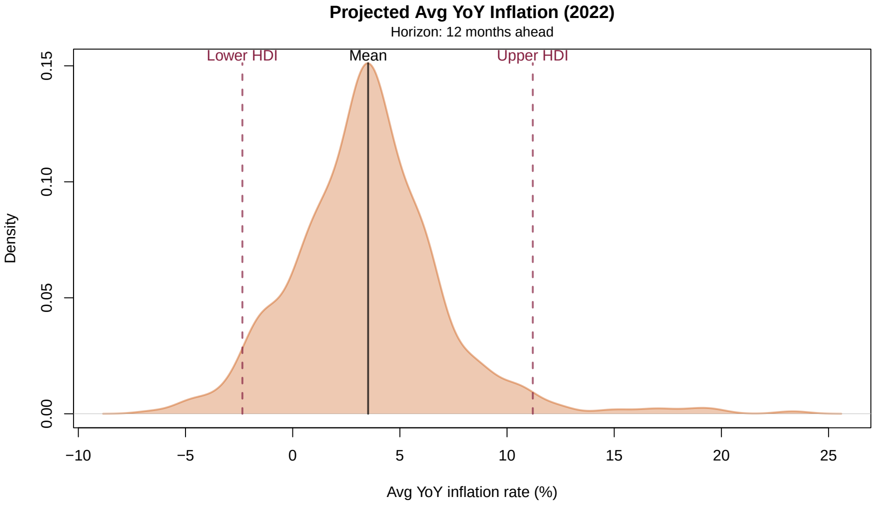
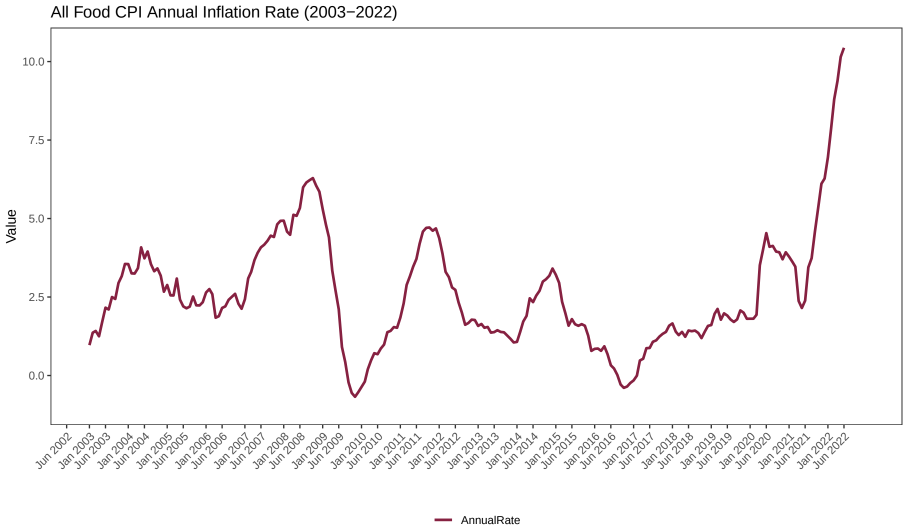



Figure 1: Factor 1: Inflation and Price Dynamics (PCEPI, CPIAUCSL, CPILFESL, etc). Factor 2: Labor Market Conditions (CLAITXSN, UEMPLT5,UNRATE, etc). Factor 3: Industrial Production (IPRODN, IPFBN, AWHMAN, etc.). Factors are subject to changes depending on the window size and location of the information set used to derive them. The December 2023 vintage was used to produce this figure.

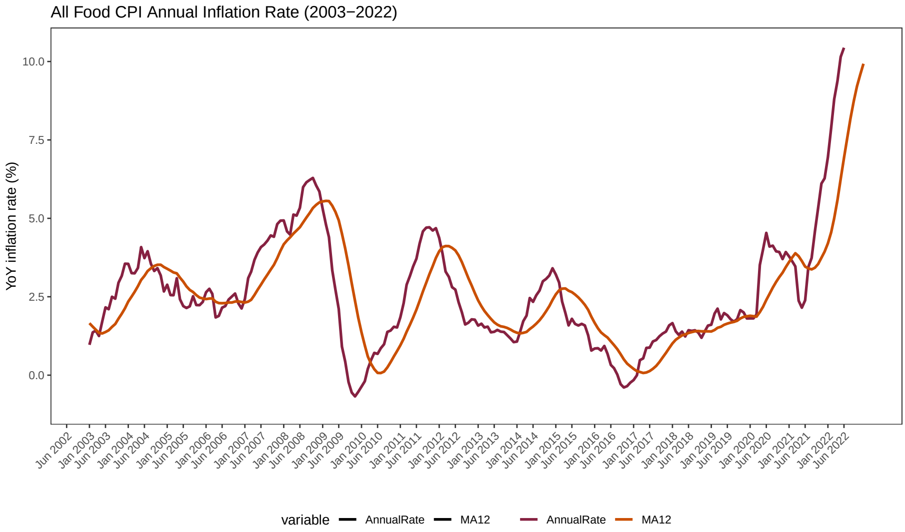

Initial Split =
Decision Node =
Prediction =
Training Set
Sample 1
Sample 2
...
Sample 500

# Predictions



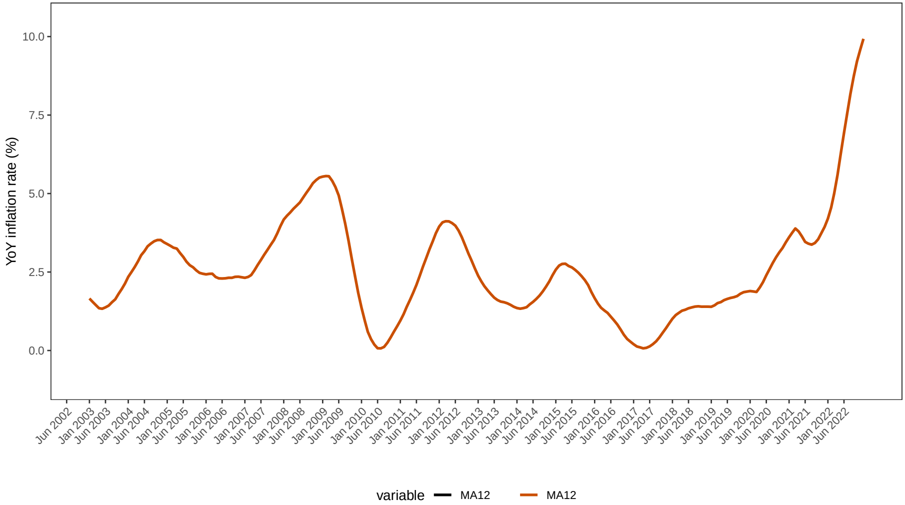


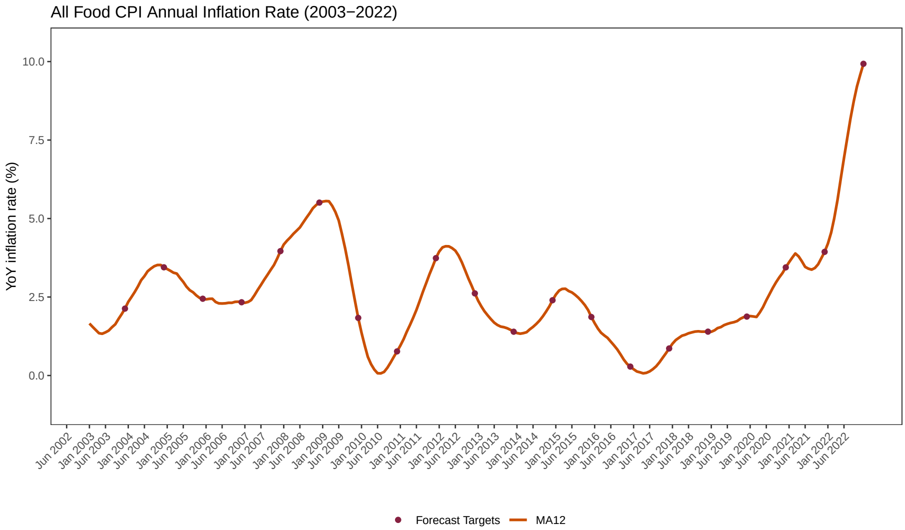
All Food CPI Annual Inflation Rate (2003−2022)
Value
10.0
7.5
5.0
2.5
0.0
Jun 2002
Jan 2003
Jun 2003
Jan 2004
Jun 2004
Jan 2005
Jun 2005
Jan 2006
Jun 2006
Jan 2007
Jun 2007
Jan 2008
Jun 2008
Jan 2009
Jun 2009
Jan 2010
Jun 2010
Jan 2011
Jun 2011
Jan 2012
Jun 2012
Jan 2013
Jun 2013
Jan 2014
Jun 2014
Jan 2015
Jun 2015
Jan 2016
Jun 2016
Jan 2017
Jun 2017
Jan 2018
Jun 2018
Jan 2019
Jun 2019
Jan 2020
Jun 2020
Jan 2021
Jun 2021
Jan 2022
Jun 2022
AnnualRate



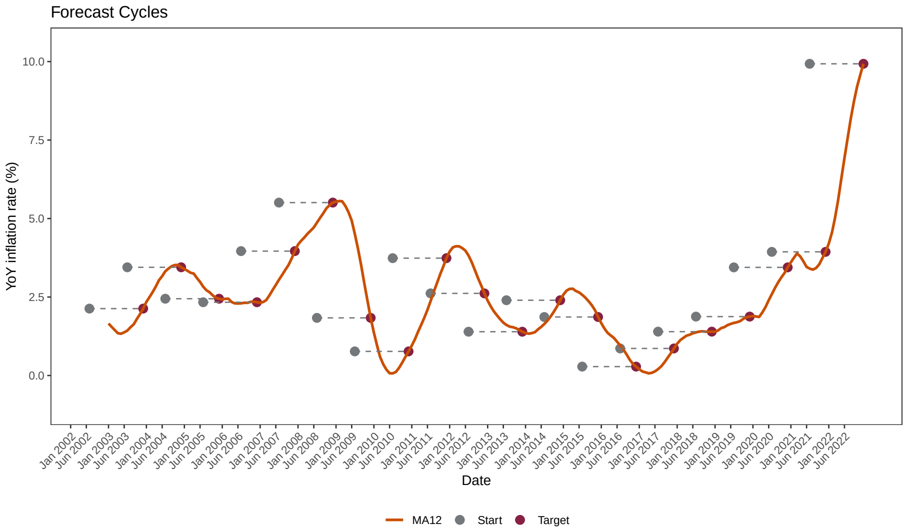
All Food CPI Annual Inflation Rate (2003−2022)
YoY inflation rate (%)
10.0
7.5
5.0
2.5
0.0
Jun 2002
Jan 2003
Jun 2003
Jan 2004
Jun 2004
Jan 2005
Jun 2005
Jan 2006
Jun 2006
Jan 2007
Jun 2007
Jan 2008
Jun 2008
Jan 2009
Jun 2009
Jan 2010
Jun 2010
Jan 2011
Jun 2011
Jan 2012
Jun 2012
Jan 2013
Jun 2013
Jan 2014
Jun 2014
Jan 2015
Jun 2015
Jan 2016
Jun 2016
Jan 2017
Jun 2017
Jan 2018
Jun 2018
Jan 2019
Jun 2019
Jan 2020
Jun 2020
Jan 2021
Jun 2021
Jan 2022
Jun 2022
variable
AnnualRate
MA12
AnnualRate
MA12

All Food CPI Annual Inflation Rate (2003−2022)

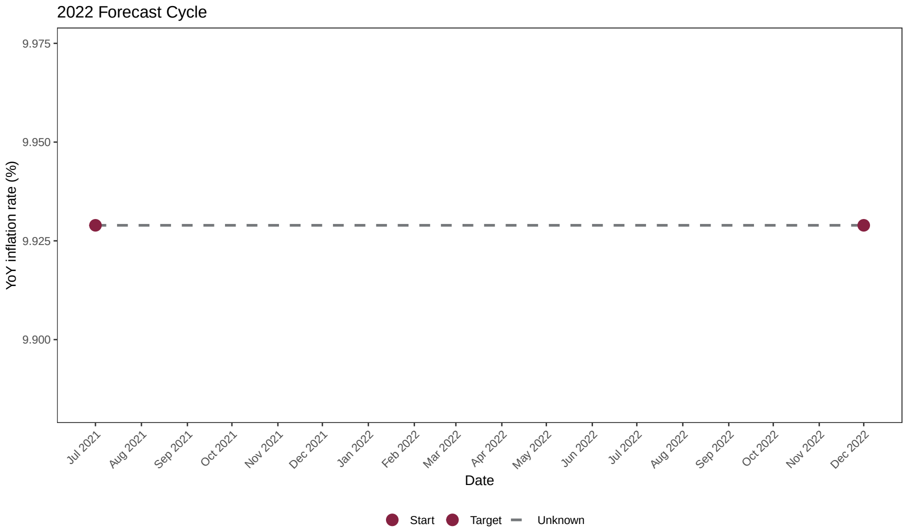


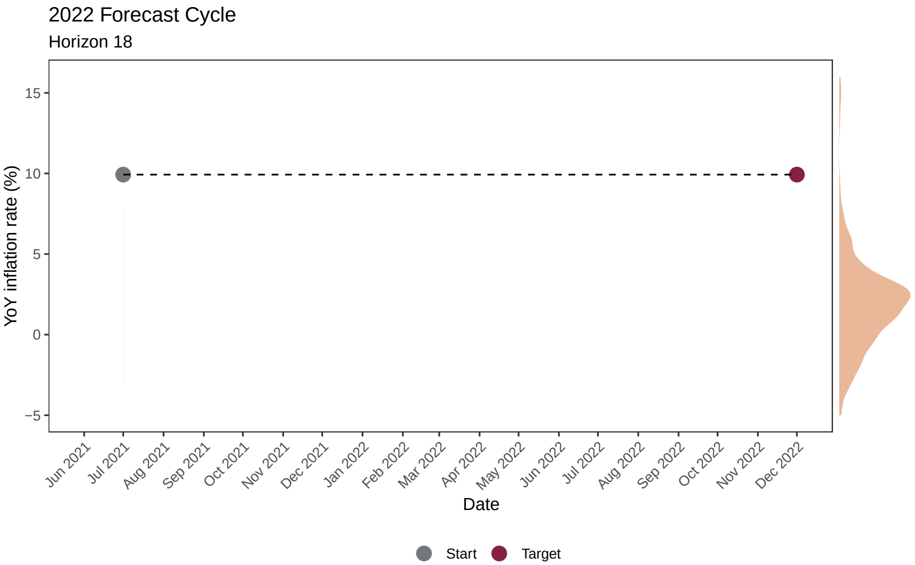


All Food CPI Annual Inflation Rate (2003−2022)
YoY inflation rate (%)
10.0
7.5
5.0
2.5
0.0
Jun 2002
Jan 2003
Jun 2003
Jan 2004
Jun 2004
Jan 2005
Jun 2005
Jan 2006
Jun 2006
Jan 2007
Jun 2007
Jan 2008
Jun 2008
Jan 2009
Jun 2009
Jan 2010
Jun 2010
Jan 2011
Jun 2011
Jan 2012
Jun 2012
Jan 2013
Jun 2013
Jan 2014
Jun 2014
Jan 2015
Jun 2015
Jan 2016
Jun 2016
Jan 2017
Jun 2017
Jan 2018
Jun 2018
Jan 2019
Jun 2019
Jan 2020
Jun 2020
Jan 2021
Jun 2021
Jan 2022
Jun 2022
Forecast Targets
MA12

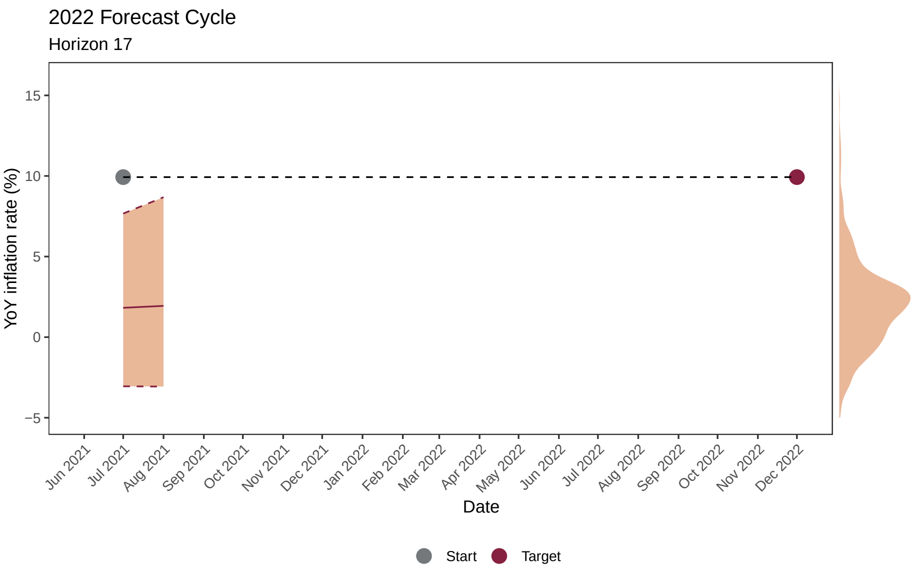


Forecast Cycles
YoY inflation rate (%)
10.0
7.5
5.0
2.5
0.0
Jan 2002
Jun 2002
Jan 2003
Jun 2003
Jan 2004
Jun 2004
Jan 2005
Jun 2005
Jan 2006
Jun 2006
Jan 2007
Jun 2007
Jan 2008
Jun 2008
Jan 2009
Jun 2009
Jan 2010
Jun 2010
Jan 2011
Jun 2011
Jan 2012
Jun 2012
Jan 2013
Jun 2013
Jan 2014
Jun 2014
Jan 2015
Jun 2015
Jan 2016
Jun 2016
Jan 2017
Jun 2017
Jan 2018
Jun 2018
Jan 2019
Jun 2019
Jan 2020
Jun 2020
Jan 2021
Jun 2021
Jan 2022
Jun 2022
Date
MA12
Start
Target

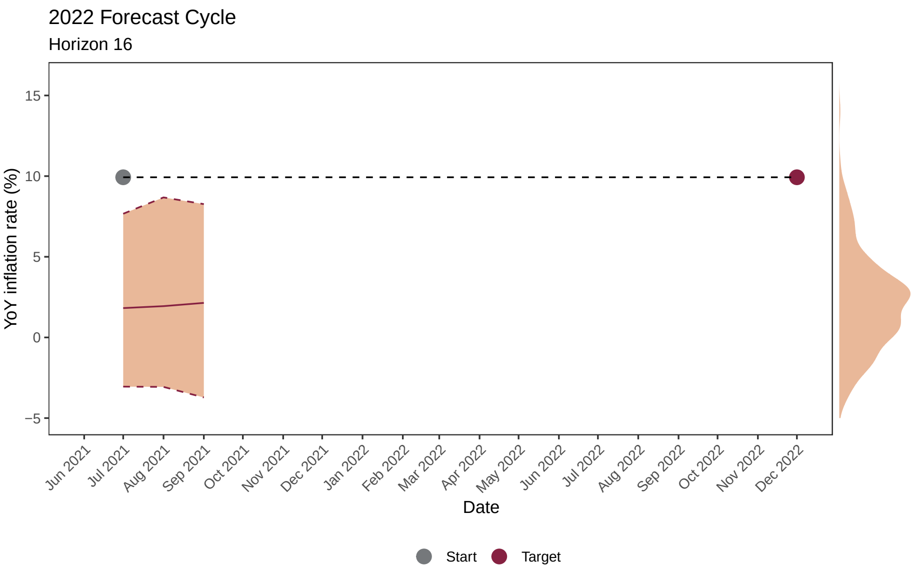

2022 Forecast Cycle
9.975
9.950
9.925
9.900
YoY inflation rate (%)
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target
Unknown



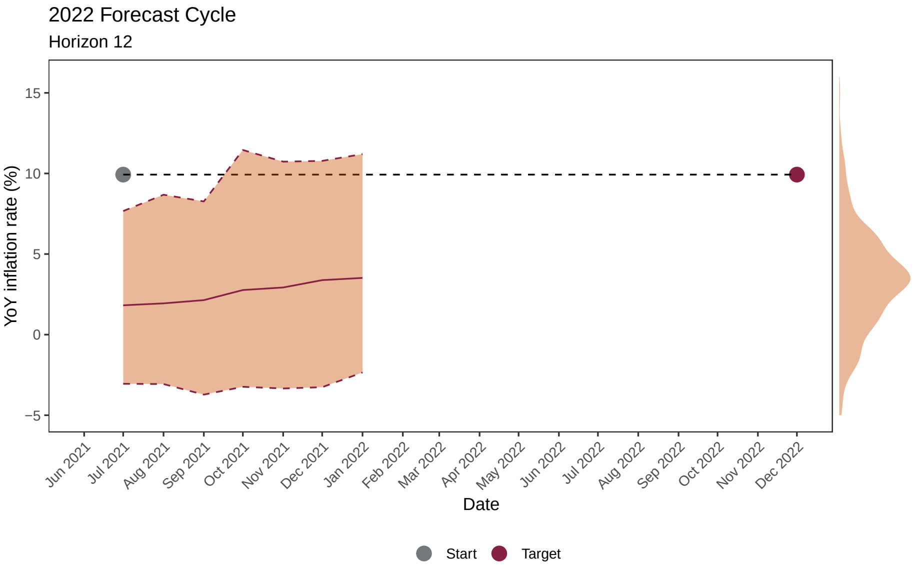
2022 Forecast Cycle
Horizon 18
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target

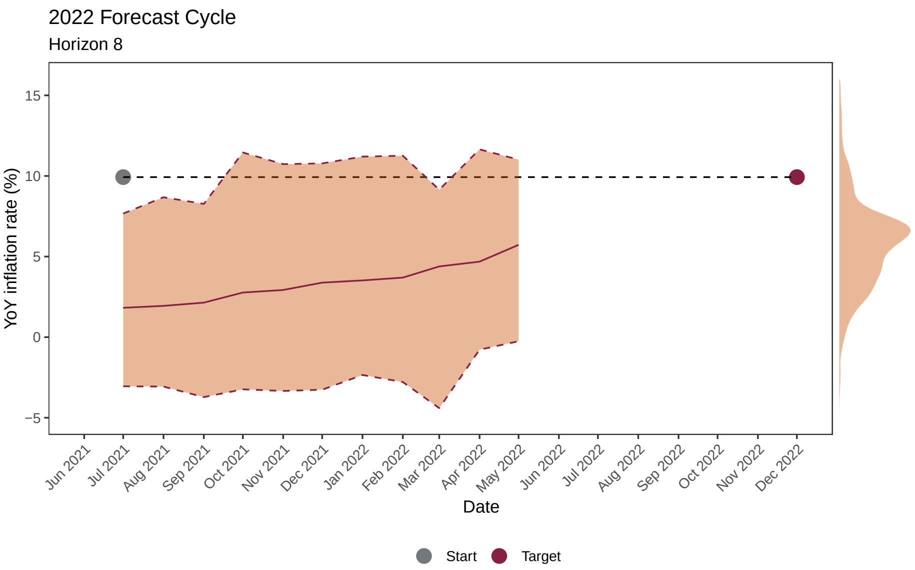


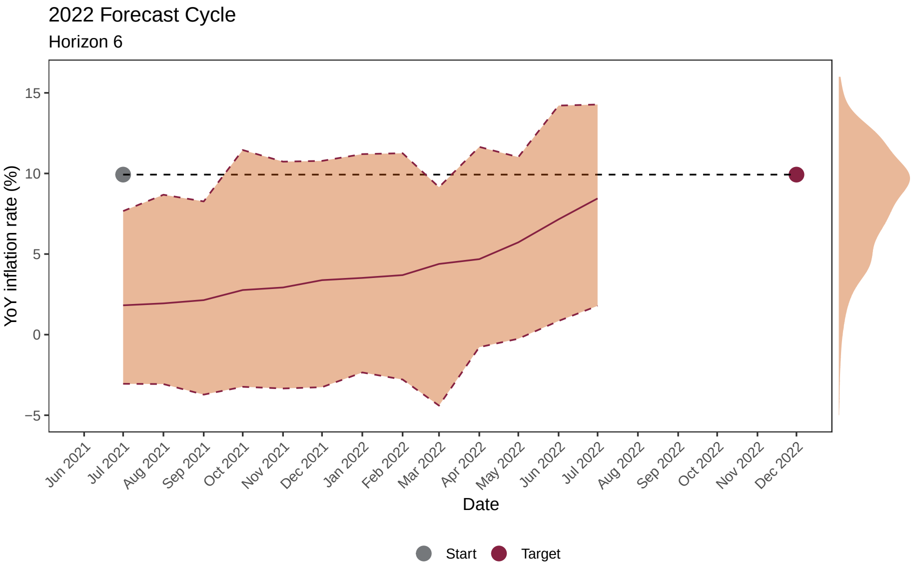
2022 Forecast Cycle
Horizon 17
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target

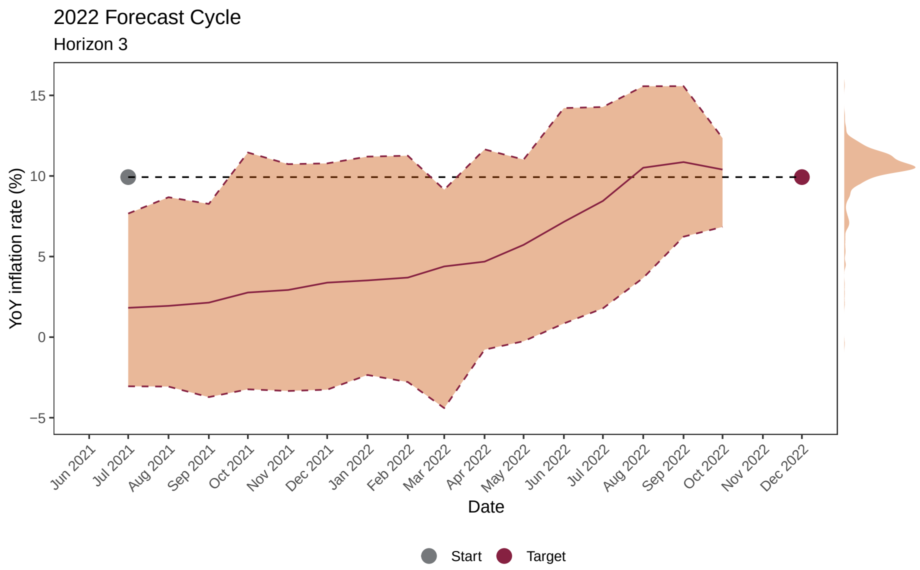


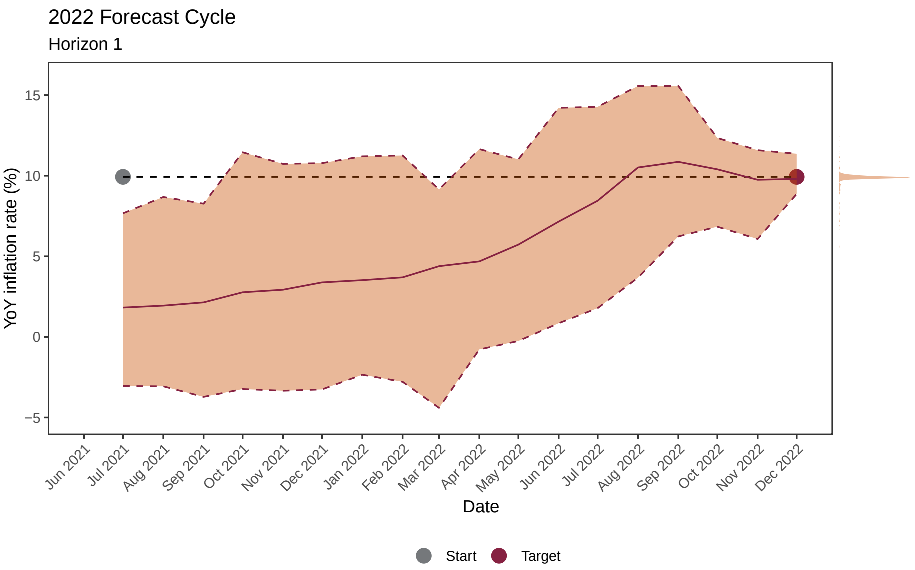
2022 Forecast Cycle
Horizon 16
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target


2022 Forecast Cycle
Horizon 12
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target

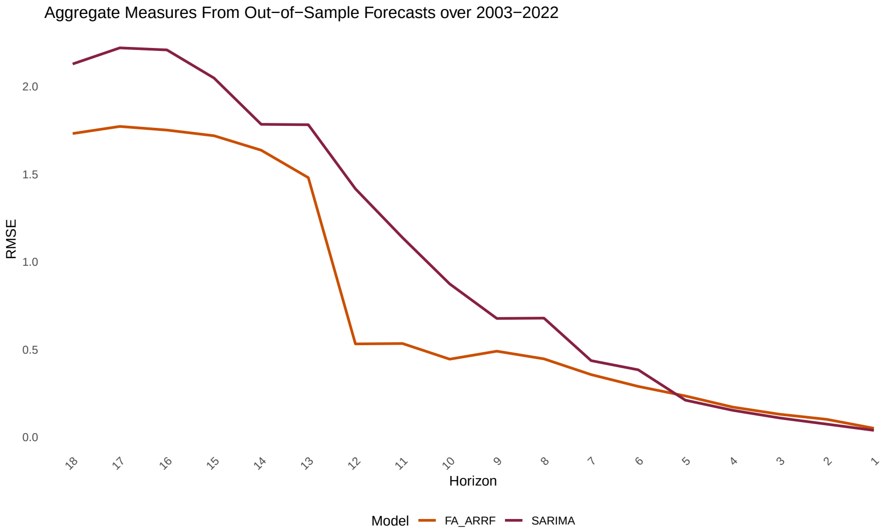

2022 Forecast Cycle
Horizon 8
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target


2022 Forecast Cycle
Horizon 6
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target


2022 Forecast Cycle
Horizon 3
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target

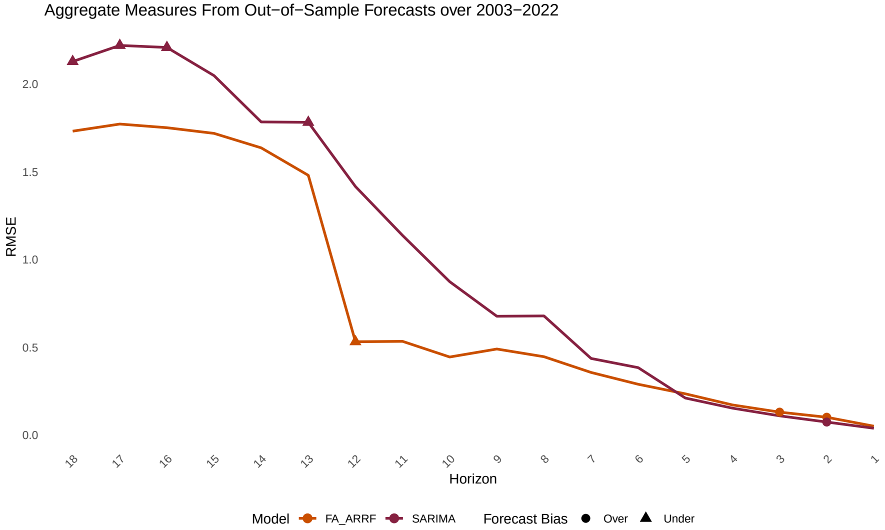

2022 Forecast Cycle
Horizon 1
YoY inflation rate (%)
15
10
5
0
−5
Jun 2021
Jul 2021
Aug 2021
Sep 2021
Oct 2021
Nov 2021
Dec 2021
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Date
Start
Target

# Results



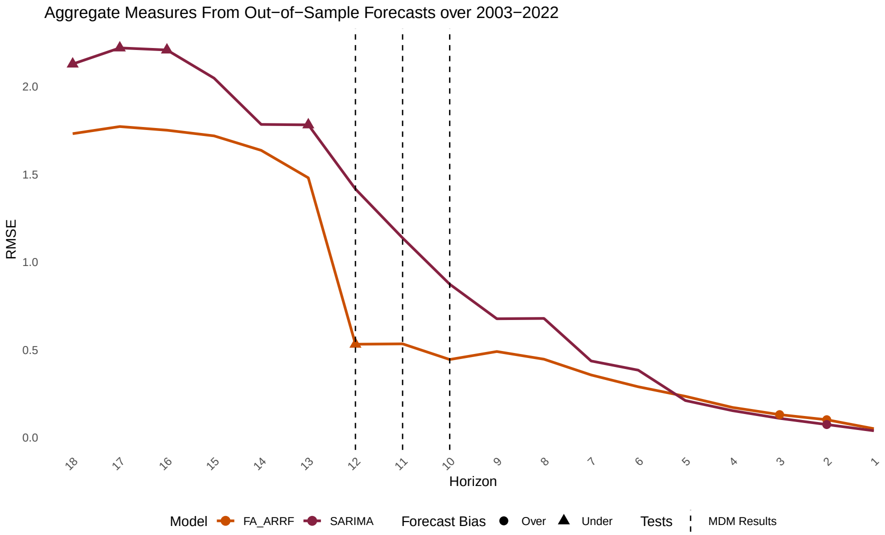
Aggregate Measures From Out−of−Sample Forecasts over 2003−2022
RMSE
2.0
1.5
1.0
0.5
0.0
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Horizon
Model
FA_ARRF
SARIMA

# Results



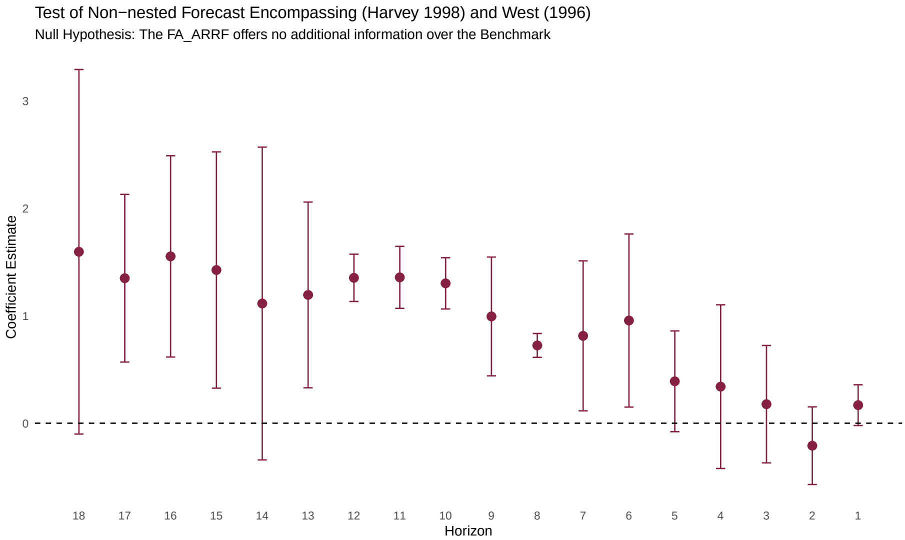
Aggregate Measures From Out−of−Sample Forecasts over 2003−2022
RMSE
2.0
1.5
1.0
0.5
0.0
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Horizon
Model
FA_ARRF
SARIMA
Forecast Bias
Over
Under

# Results



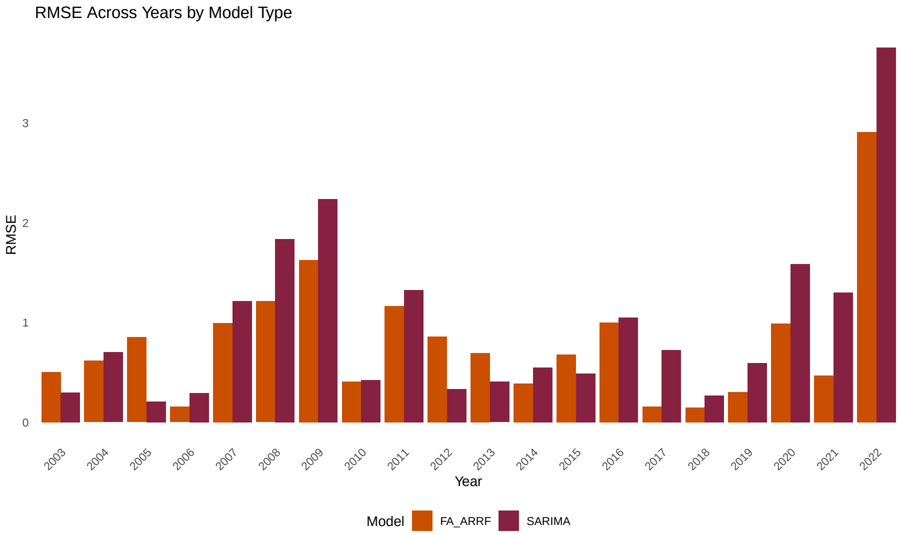
Aggregate Measures From Out−of−Sample Forecasts over 2003−2022
RMSE
2.0
1.5
1.0
0.5
0.0
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Horizon
Model
FA_ARRF
SARIMA
Forecast Bias
Over
Under
Tests
MDM Results

# Results



Test of Non−nested Forecast Encompassing (Harvey 1998) and West (1996)
Null Hypothesis: The FA_ARRF offers no additional information over the Benchmark
Coefficient Estimate
3
2
1
0
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Horizon

# Results by Year



# Conclusion

## Results

- The FA-ARRF offers lower accuracy measures at longer Horizons
- FA-ARRF is found to be bias at fewer horizons
- There is evidence to suggest a horizon specific averaged forecast

## Next Steps: What is the model telling us is driving the Avg Annual YoY inflation rate?

- Interpret the variable Importance Measures across specific years and horizons for any patterns
- Review the time varying parameters to see how the relationship between the Fred Factors and Inflation have changed over the forecast period

*Thank you!*

Presenter: William McWilliams

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# References


Adjemian, Michael K, Shawn Arita, Seth Meyer, and Delmy Salin. 2024. "Factors Affecting Recent Food Price Inflation in the United States." *Applied Economic Perspectives and Policy* 46 (2): 648–76.

Baek, Jungho, and Won W Koo. 2010. "Analyzing Factors Affecting US Food Price Inflation." *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie* 58 (3): 303–20.

Chen, Cathy WS, Mike KP So, and Feng-Chi Liu. 2011. "A Review of Threshold Time Series Models in Finance." *Statistics and Its Interface* 4 (2): 167–81.

Clarida, Richard, Jordi Gali, and Mark Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *The Quarterly Journal of Economics* 115 (1): 147–80.

Coulombe, Philippe Goulet. 2025. "Time-Varying Parameters as Ridge Regressions." *International Journal of Forecasting*.

Goulet Coulombe, Philippe. 2024. "The Macroeconomy as a Random Forest." *Journal of Applied Econometrics* 39 (3): 401–21.

Goulet Coulombe, Philippe, Maxime Leroux, Dalibor Stevanovic, and Stéphane Surprenant. 2022. "How Is Machine Learning Useful for Macroeconomic Forecasting?" *Journal of Applied Econometrics* 37 (5): 920–64.

Hansen, Christian, and Yuan Liao. 2019. "The Factor-Lasso and k-Step Bootstrap Approach for Inference in High-Dimensional Economic Applications." *Econometric Theory* 35 (3): 465–509.

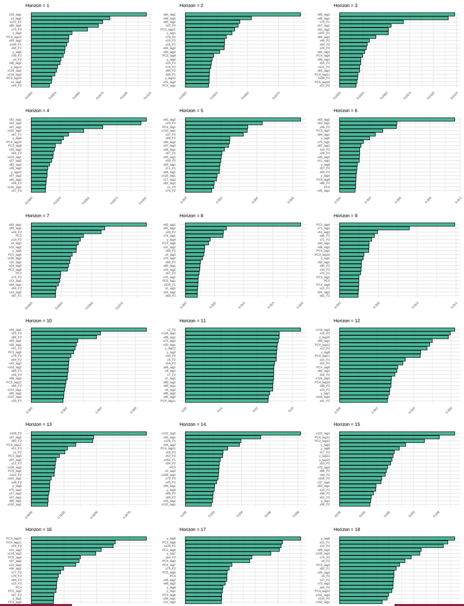
Kuhns, Annemarie, Ephraim Leibtag, Richard Volpe, and Ed Roeger. 2015. "How USDA Forecasts Retail Food Price Inflation."

MacLachlan, Matthew, Carolyn Chelius, and Gianna Short. 2022. "Time-Series Methods for Forecasting and Modeling Uncertainty in the Food Price Outlook."

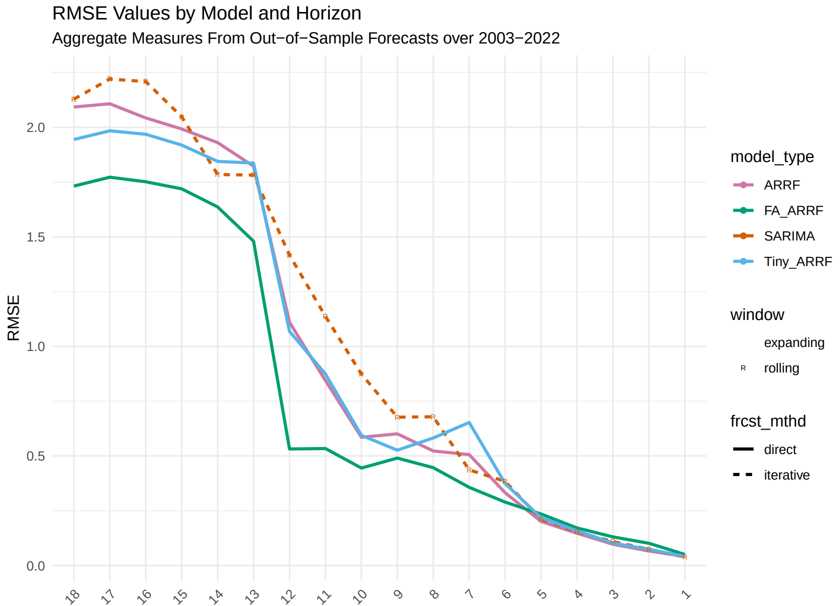
McCracken, Michael W, and Serena Ng. 2016. "FRED-MD: A Monthly Database for Macroeconomic Research." *Journal of Business & Economic Statistics* 34 (4): 574–89.

# Appendix: Variable Importance Measures by Year

# Appendix: Variable Importance Measures by Horizon



# Appendix: Testing Various Model Specifications



# Appendix

Table 1: The Diebold and Mariano (1995) and West (1996) statistic is used to test the null hypothesis that the benchmark forecast MSE is less than or equal to the competing forecast MSE against the (one-sided, upper-tail) alternative hypothesis that the benchmark forecast MSE is greater than the competing forecast MSE .The test of non-nested forecast encompassing(Harvey 1998) and West (1996) statistic is used to test the null hypothesis that the benchmark forecast encompasses the competing forecast against the (two-sided) alternative hypothesis that the benchmark forecast does not encompass the competing forecast.

| | **Modified Diebold Mariano** | | **Forecast Encompassing** | |
|---|---|---|---|---|
| **Horizon** | **Statistic** | **p-value** | **Statistic** | **p-value** |
| 18 | 0.19544 | 0.84712 | 1.84329 | **0.08094** |
| 17 | 0.26845 | 0.79125 | 3.39026 | **0.00307** |
| 16 | 0.32112 | 0.75163 | 3.24901 | **0.00422** |
| 15 | 0.47063 | 0.64326 | 2.54146 | **0.01992** |
| 14 | 0.70829 | 0.48736 | 1.50017 | 0.15001 |
| 13 | 0.64296 | 0.52794 | 2.70790 | **0.01395** |
| 12 | 2.50783 | **0.02138** | 12.05508 | **0** |
| 11 | 1.90165 | **0.07249** | 9.22059 | **0** |
| 10 | 1.90404 | **0.07216** | 10.69097 | **0** |
| 9 | 1.01165 | 0.32442 | 3.52407 | **0.00227** |
| 8 | 0.82958 | 0.41708 | 12.79648 | **0** |
| 7 | 0.58191 | 0.56747 | 2.28304 | **0.03412** |
| 6 | 0.68266 | 0.50306 | 2.32545 | **0.03127** |
| 5 | -0.38148 | 0.70708 | 1.63047 | 0.11947 |
| 4 | -0.44910 | 0.65844 | 0.87569 | 0.39213 |

# Appendix

% latex table generated in R 4.4.1 by xtable 1.8-4 package % Sun Apr 13 20:22:39 2025

| | All Food | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|---|
| All Food | 1.00 | 0.32 | 0.03 | -0.06 |
| Factor 1 | 0.32 | 1.00 | -0.05 | -0.85 |
| Factor 2 | 0.03 | -0.05 | 1.00 | -0.02 |
| Factor 3 | -0.06 | -0.85 | -0.02 | 1.00 |