FORECASTING DEFLATION PROBABILITY IN THE EA:A COMBINATORIC APPROACH

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11th International Research Conference
Central Bank of Sri Lanka – 7 Dec 2018

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Research idea

Central banks complies with a price stability mandate

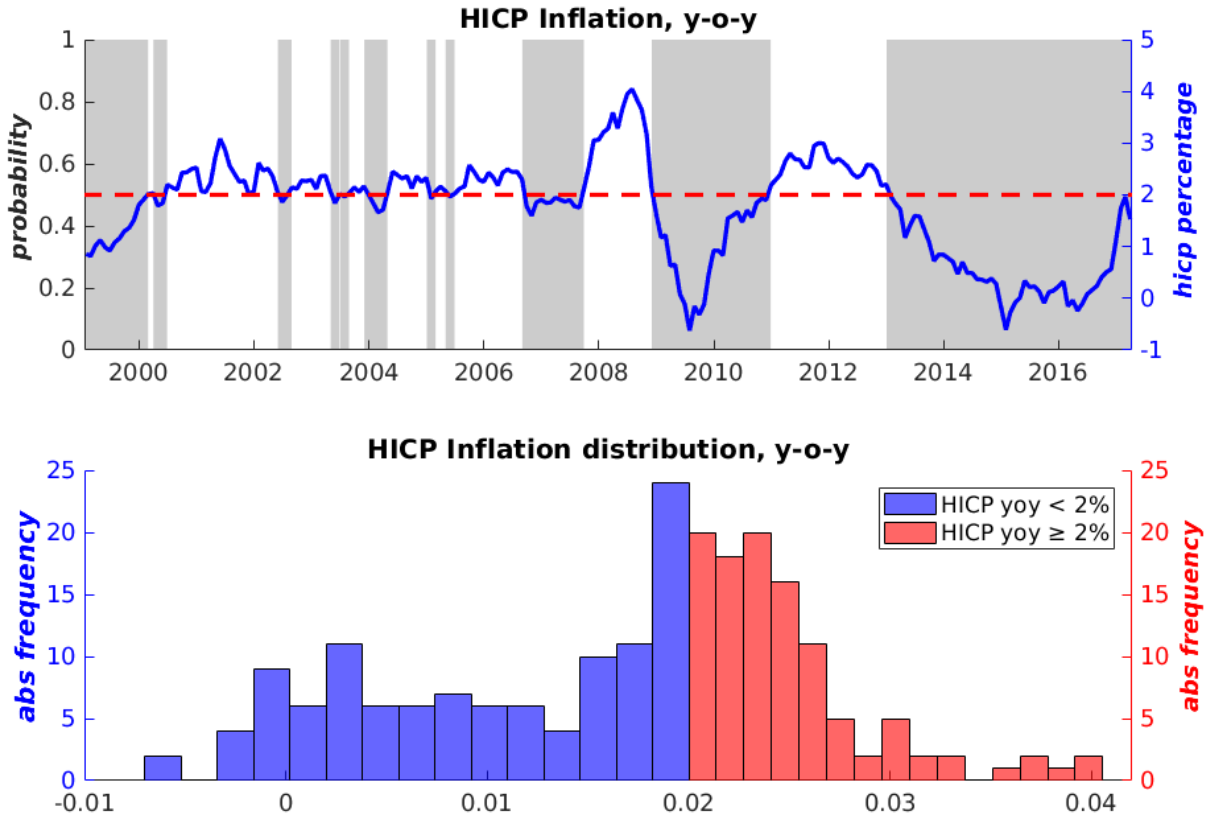
- Arduous task for two reasons:

1. Policy actions based on forecasts
   - Prices are sticky
   - Real variables have lagged reactions

2. General medium-term forecast horizon
   - up to two years

Harmonised Index of Consumer Prices

year on year



- Inflation above the "confidence zone" ($\Pi_t = 0$ *if* $\pi_t \geq 2\%$).
- Inflation below the "confidence zone" ($\Pi_t = 1$ *if* $\pi_t < 2\%$).

Proposal

Deflationary Pressure Index – DPI

Building an index to predict:

1. Probability of having inflation below the 2% level...
2. ...over the next two years

- Increase likelihood of a correct forecast
  - Predicting probability of having a point in a range
- Addressing medium-term orientation
  - Averaging forecast over time

Simple Taylor rule example

Why predicting probabilities?

Probabilities measures the interest rate direction:

$$i_t = \phi_\pi \left(\mathbb{E}_t \pi_{t+h} - \pi^* \right) \tag{1}$$

- $\mathbb{E}_t \pi_{t+h} > \pi^* \Longrightarrow i_t \uparrow$
- $\mathbb{E}_t \pi_{t+h} < \pi^* \Longrightarrow i_t \downarrow$

Notation: i_t: central bank interest rate; π_t: is inflation measure; π^*: central bank inflation target; ϕ_π: reaction coefficient.

How is the DPI built?

Two step procedure

- First step: univariate probit – out-of-sample selection
- Second step: "combinatoric probit" – out-of-sample selection

$$Pr\left(\Pi_{T+h} = 1 \middle| x_t^{(j)}\right) = G\left(x_t^{(j)}; \theta\right) \tag{2}$$

$$h = [1, 3, 6, 9, 12, 15, 18, 24], \quad j = \{i, c\}$$

Notation: i and c are single and combinations of variables. $x_t^{(j)}$ predictors and $G(\cdot)$ a c.d.f. parametrized by θ.

Features:

1. Taylored to predict inflation probabilities of being below 2%
2. Select best models to predict specific horizons

Advantages

Deflationary Pressure Index – DPI

Relative advantages ▸ ECB Models

- With respect to surveys:
  1. Interpretable
  2. Updatable
- With respect to in-house models:
  1. Taylored for forecasting probabilities
  2. Employ metrics build for discrete models: AUROC

Absolute advantages

- Deal with a general horizon
- Interval forecast easier than point forecast

Relative disadvantages

- Combinatoric approach cumbersome $\Rightarrow$ Parallelization

Dataset

- Jannuary 1999 to March 2017 (219 monthly observations)
- Around 100 variables at national and EA level:
  1. Real indicators
  2. Prices
  3. Monetary aggregates
  4. Financial variables
  5. Commodities
  6. Yields
  7. Surveys
- Series transformed to be approximately stationary

Methodology

Roadmap

1. Build a discrete dependent variable for inflation
2. Select best predictors in univariate out-of-sample exercise
   - First step
3. Select best models among all combinations of best predictors
   - Second step
4. Build index averaging the best models along time dimension

First step

Algorithm

1. For each variable i, pre-estimating the model 1999M1-2007M3
2. For each horizon h,estimating out-of-sample 2007M3-2017M3
3. For each pair (i, h), assessing the model: ▸ AUROC rev.
   - *Area Under the Receiver Operating Characteristics* (AUROC)
   - *Mean Absolute Error* (MAE)
   - *Root Mean Squared Error* (RMSE)
4. Selecting the 2 best predictors for each h and criterion (48)
5. Keeping only unique predictors (20)

First step

Selected predictors

Table: Results from the first step, all criteria and horizons.

Price	**Interest rate**	**Real**	**Monetary**	**Survey**
HICP DE	EA3Y	Inter. goods	M1	Ind. conf
HICP FR	EA5Y	Capital	M3	Price 12M
HICP IT	EA7Y	IP FR		
DE CPI SA	EA10Y	IP DE		
FR CPI SA	DE10Y			
IT CPI SA	US10Y			

▸ New Keynesian interpretation

Second step

Algorithm

1. For each combination c, pre-estimating the model 1999M1-2007M3
2. For each horizon h,estimating out-of-sample 2007M3-2017M3
3. For each pair (c, h), assessing the model: ▸ AUROC Rev
   - *AUROC*, *MAE*, *RMSE*
4. Repeating 1–3 augmenting models with a factor extracted from the full dataset
5. Selecting the best combination for each h and criterion (24) ▸ Computation time

$$C = \sum_{k=1}^{10} \binom{20}{k} \approx 616,665 \times H \times T^{out} \times 2 \Rightarrow 1.2bn \quad (3)$$

Second step

AUROC: selected models

Results from the second step of the variable selection procedure: ▸ MAE ▸ RMSE ▸ Naive comparison

	$h = 1$	$h = 3$	$h = 6$	$h = 9$	$h = 12$	$h = 15$	$h = 18$	$h = 24$
AUROC	1.02	1.05	1.19	1.63	1.64	1.81	1.54	1.51
Factor	0	1	1	1	1	0	1	0
#Var	5	9	8	10	8	7	8	8
	Capital	M1	Capital	Inter.	Inter.	Ind.Conf.	Capital	M3
	Ind.Conf.	M3	M3	Capital	Capital	M1	M1	HICP DE
	IP FR	IP DE	IP DE	Ind.Conf.	Ind.Conf.	M3	M3	HICP FR
	IT CPI SA	IP FR	IP FR	M3	M3	EA10Y	IP DE	HICP IT
	FR CPI SA	US10Y	HICP IT	HICP DE	IP FR	IT CPI SA	IP FR	DE10YT
		DE10YT	EA7Y	US10Y	US10Y	FR CPI SA	US10Y	EA3Y
		EA3Y	DE CPI SA	DE10YT	DE10Y	PRICE 12M	EA10Y	EA5Y
		EA7Y	PRICE 12M	EA10Y	EA10Y		FR CPI SA	FR CPI SA
		EA10Y		DE CPI SA				
				PRICE 12M				

Deflationary Pressure Index

Horizontal average

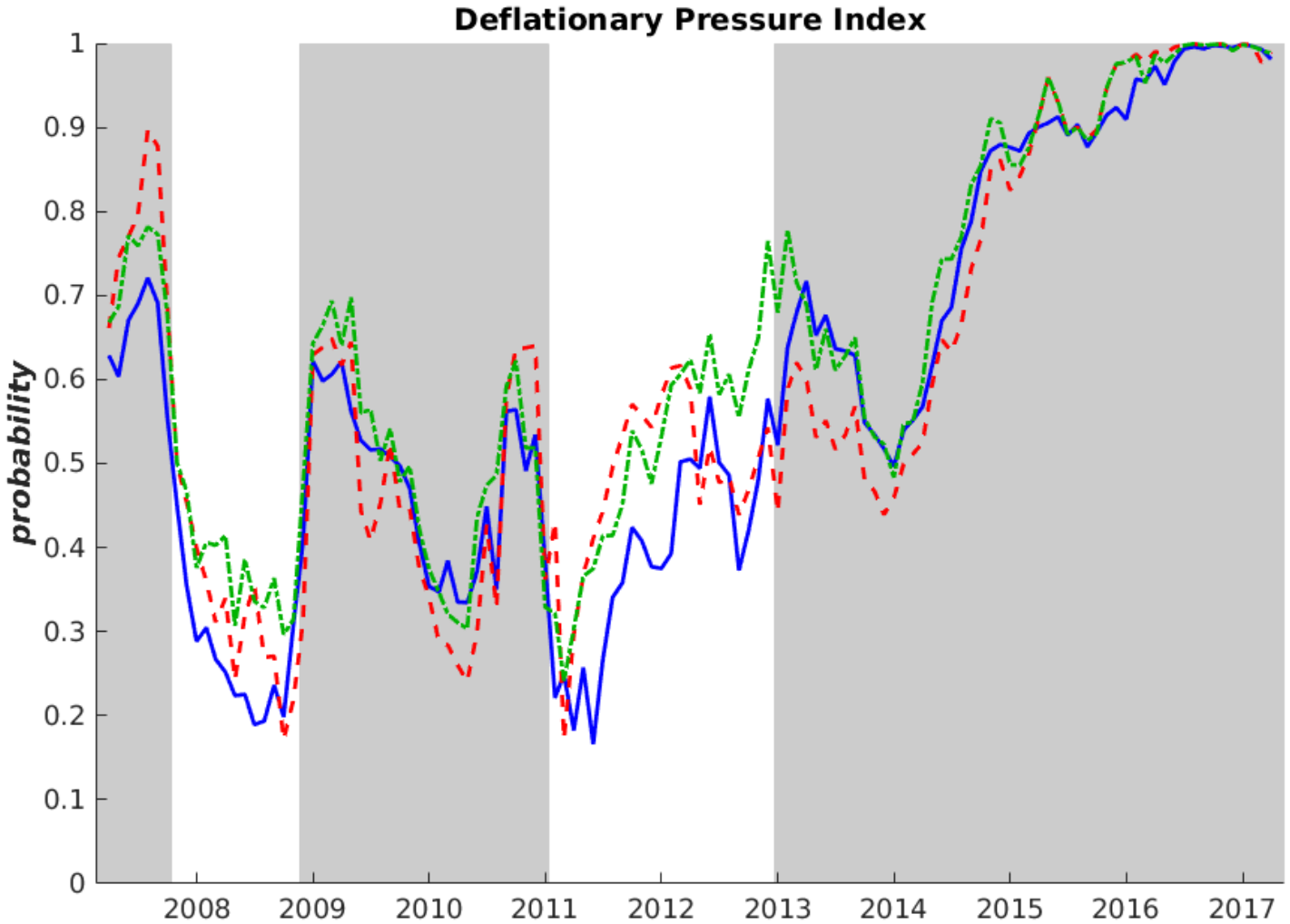
Averaging best models:

- Along time dimension
- For each criteria $\Rightarrow$ allowing for comparison

$$DPI_t^{(C)} = \frac{1}{H} \sum_h \hat{\Pi}_{T+h|T}^{*(C)} \tag{4}$$

$$C = \{AUROC, MAE, RMSE\}, \quad h = [1, 3, 6, 9, 12, 15, 18, 24]$$

Deflationary Pressure Index



Legend: AUROC, MAE, RMSE ▸ In-sample ▸ Out-of-sample ▸ Predictions

Survey of Professional Forcasters – SPF

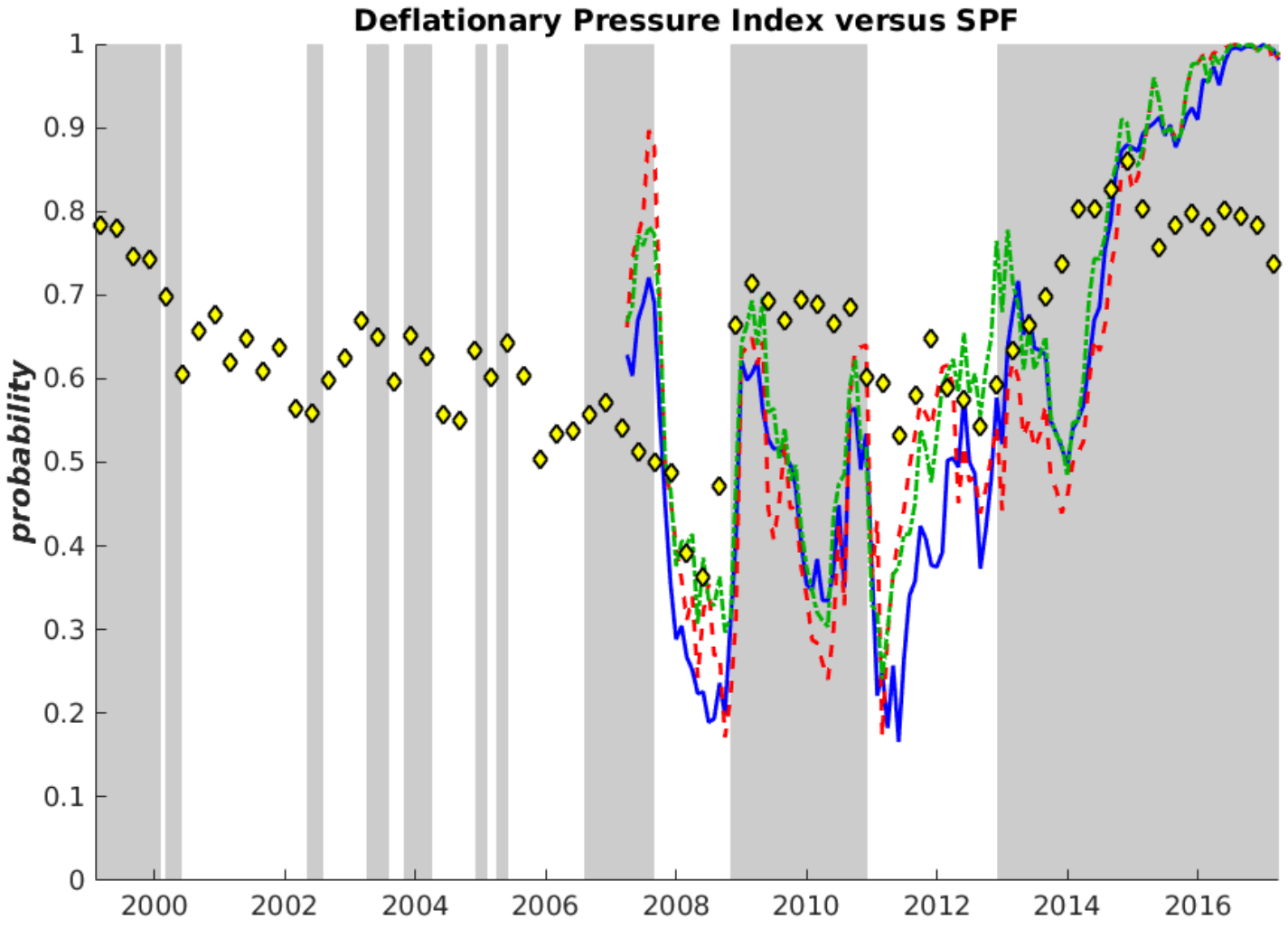
Survey of Professional Forcasters

- Starting in January 1999
- Quarterly collected by the ECB
- Interviewing more than 80 professional forecasters
- Expressing point forecast and probabilities
- HICP y-o-y below, in between or above certain thresholds
- Thresholds range -1% to 4% stepping by 0.4% (12 bins)
- Probabilities sum to one, and refers to 24 months horizon

Different from DPI but...

Alternative bins can be constructed by cumulating probabilities!

Deflationary Pressure Index vs SPF



Conclusion

- Central banks rely on forecasts...
- ... since monetary policy affects output and prices with a lag
- Also, they have a general medium-term orientation.
- I propose an index built at “micro-level” to predict a general horizon inflation direction
- The index build on a two-step methodology, based on a combinatoric approach
- Exploit parallel computation in Julia (NFP.jl on Github)
- Inflation in the medium-term unlikely above 2% before 2019

THANKS FOR LISTENING!

References

Christoffel, K. P., Coenen, G., and Warne, A. (2008). The new area-wide model of the euro area: a micro-founded open-economy model for forecasting and policy analysis. *ECB Working Paper, 944*.

Dieppe, A., Pandiella, A. G., Hall, S. G., and Willman, A. (2011). The ECB's New Multi-Country Model for the euro area: NMCM-with boundedly rational learning expectations. *ECB Working Paper Series, 1316*.

Dieppe, A., Pandiella, A. G., and Willman, A. (2012). The ECBs New Multi-Country Model for the euro area: NMCM Simulated with rational expectations. *Economic Modelling*, 29(6):2597–2614.

ECB forecasting toolbox

1. Structural models:
   - *New Area-Wide Model* (Christoffel et al., 2008)
   - *New Multi-Country Model* (Dieppe et al., 2011, 2012).
2. Time–series models:
   - *Vector Autoregressive model* (VAR)
   - Bayesian VAR model
   - *Dynamic Factor Models* (DFM)
3. Surveys
   - *Survey of Professional Forecasters* (SPF)
     - Point forecast
     - Probability forecast

Back to advantages

Loss functions

ROC review

- Assesing model ability: assigning obs. to the correct class

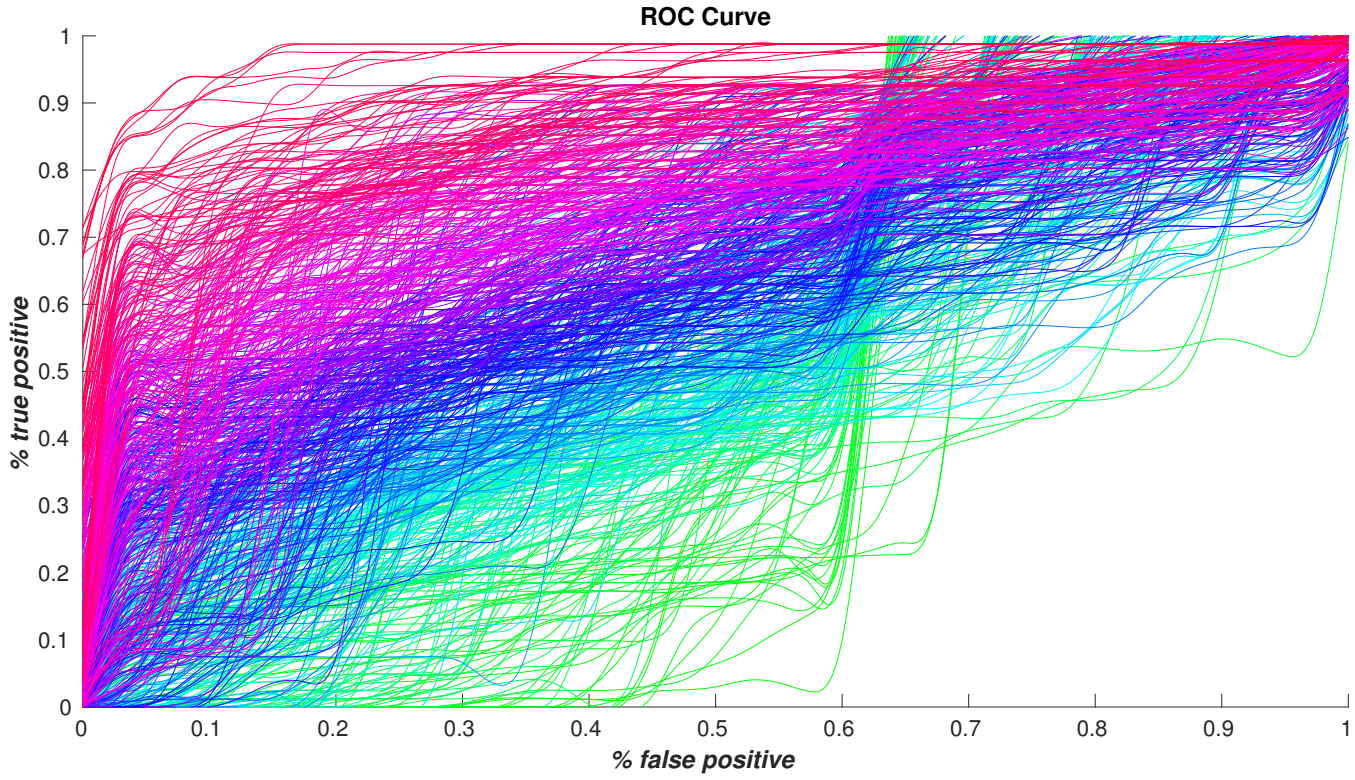
$$\begin{cases} \Pi_t = 0 & \textit{if} \quad \pi_t \geq 2\% \\ \Pi_t = 1 & \textit{if} \quad \pi_t < 2\% \end{cases} \tag{5}$$

- Comparing predicted probability $\hat{\Pi}_t$ against threshold C_i

$$\begin{cases} \hat{\Pi}_t = 0 & \textit{if} \quad \hat{\Pi}_t < C_i \\ \hat{\Pi}_t = 1 & \textit{if} \quad \hat{\Pi}_t \geq C_i \end{cases} \tag{6}$$

- Discretize model outcome

ROC Curve



1. x-axis “True Positive” (TP), y-axis “False Positive” (FP)
2. Left-to-right returns trade-off FP-TP
3. 45° lines is the “random guess” equivalent
4. Best model attains upper-left corner $(0, 1)$
5. Area Under the ROC curve (AUROC)

AUROC

- Scalar measure of the goodness of fit of the model
- Larger area implies a better model

$$\hat{AUROC} = \frac{1}{n_0 n_1} \sum_{i=1}^{n_0} \sum_{j=1}^{n_1} \left(X_i > Z_j + \frac{1}{2} (X_i = Z_j) \right) \tag{7}$$

- n_0 and n_1 are zeros and ones according to the correct classification
- X_i is the estimated probability corresponding to the correct ones
- Z_j corresponding to the correct zeros.
- $\hat{AUROC}$ ranges from 0.5 to 1.

▸ Back to first step ▸ Back to second step

A New-Keynesian interpretation

$$\hat{y}_t = \mathbb{E}_t\left[\hat{y}_{t+1}\right] + \frac{1}{\sigma}\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right]\right) \tag{8}$$

$$\pi_t = \beta\mathbb{E}_t\left[\pi_{t+1}\right] + \kappa\hat{y}_t \tag{9}$$

$$i_t = \phi_\pi(\mathbb{E}_t\pi_{t+1} - \pi_t^*) \tag{10}$$

Notation: $\hat{y}_t$: output gap; π_t is a measure of inflation; i_t: central bank interest rate; π^*: central bank inflation target; σ: relative risk aversion; β: discount factor; κ: Phillips curve sloope; ϕ_π: reaction coefficient.

Back to first step

Computation time

Table: Number of variables, combinations and computational time.

#Variables	#Combinations	Time
1	$20 \times H \times T^{out} \times 2$	13s
2	$190 \times H \times T^{out} \times 2$	117s
3	$1,140 \times H \times T^{out} \times 2$	12m
4	$4,845 \times H \times T^{out} \times 2$	48m
5	$15,504 \times H \times T^{out} \times 2$	2h34m
6	$38,760 \times H \times T^{out} \times 2$	6h28m
7	$77,520 \times H \times T^{out} \times 2$	13h02m
8	$125,970 \times H \times T^{out} \times 2$	19h20m
9	$167,960 \times H \times T^{out} \times 2$	28h30m
10	$184,756 \times H \times T^{out} \times 2$	31h20m
Total	616,665	$\approx$ 100h

Back to second step

MAE: selected models

Results from the second step of the variable selection procedure:

	$h = 1$	$h = 3$	$h = 6$	$h = 9$	$h = 12$	$h = 15$	$h = 18$	$h = 24$
MAE	0.25	0.39	0.17	0.11	0.09	0.15	0.12	0.02
Factor	1	1	1	1	1	1	1	1
#Var	10	10	8	10	10	10	8	10
	Inter.	Inter.	Capital	Inter.	Inter.	Inter.	Capital	Capital
	Capital	Capital	M3	M1	Ind.Conf.	Ind.Conf.	M1	M1
	M3	Ind.Conf.	IP DE	M3	M3	M1	M3	M3
	HICP DE	M3	IP FR	IP FR	IP DE	M3	IP DE	IP DE
	DE10YT	HICP FR	HICP IT	HICP DE	IP FR	HICP DE	IP FR	IP FR
	EA3Y	HICP IT	EA7Y	HICP FR	HICP DE	HICP FR	US10Y	EA5Y
	EA5Y	EA3Y	DE CPI SA	HICP IT	DE10YT	US10Y	EA10Y	EA7Y
	EA7Y	EA5Y	PRICE 12M	EA3Y	IT CPI SA	EA7Y	FR CPI SA	EA10Y
	IT CPI SA	EA7Y		EA7Y	DE CPI SA	EA10Y		DE CPI SA
	DE CPI SA	DE CPI SA		PRICE 12M	FR CPI SA	FR CPI SA		FR CPI SA

▸ Back to second step

RMSE: selected models

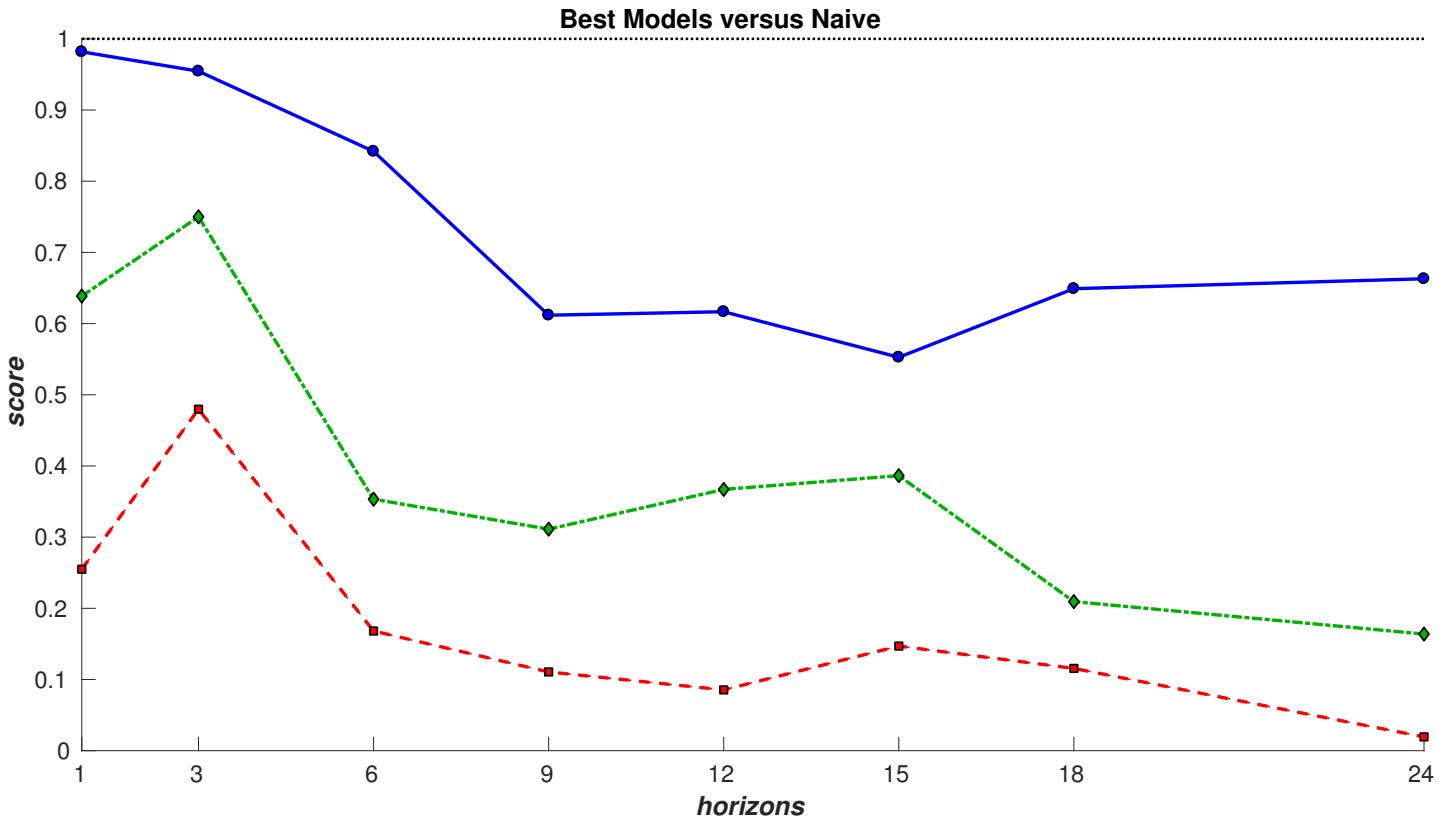
Results from the second step of the variable selection procedure:

	$h = 1$	$h = 3$	$h = 6$	$h = 9$	$h = 12$	$h = 15$	$h = 18$	$h = 24$
RMSE	0.64	0.75	0.35	0.31	0.37	0.39	0.21	0.16
Factor	0	0	1	1	1	0	1	1
#Var	8	4	8	8	10	6	8	10
	Ind.Conf.	Capital	Capital	Inter.	Inter.	Capital	Capital	Capital
	M1	Ind.Conf.	M3	M1	Ind.Conf.	IP DE	M1	M1
	M3	EA7Y	IP DE	M3	M3	IP FR	M3	M3
	IP FR	FR CPI SA	IP FR	HICP IT	IP DE	HICP DE	IP DE	IP DE
	US10Y		HICP IT	DE10YT	IP FR	EA10Y	IP FR	IP FR
	EA5Y		EA7Y	EA10Y	HICP DE	PRICE 12M	US10Y	EA5Y
	EA10Y		DE CPI SA	FR CPI SA	DE10YT		EA10Y	EA7Y
	FR CPI SA		PRICE 12M	PRICE 12M	IT CPI SA		FR CPI SA	EA10Y
					DE CPI SA			DE CPI SA
					FR CPI SA			FR CPI SA

▸ Back to second step

Comparison against naive

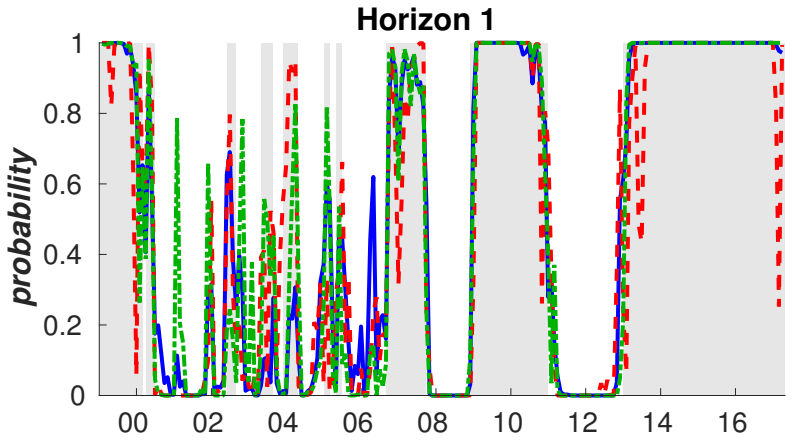
Best models from second step

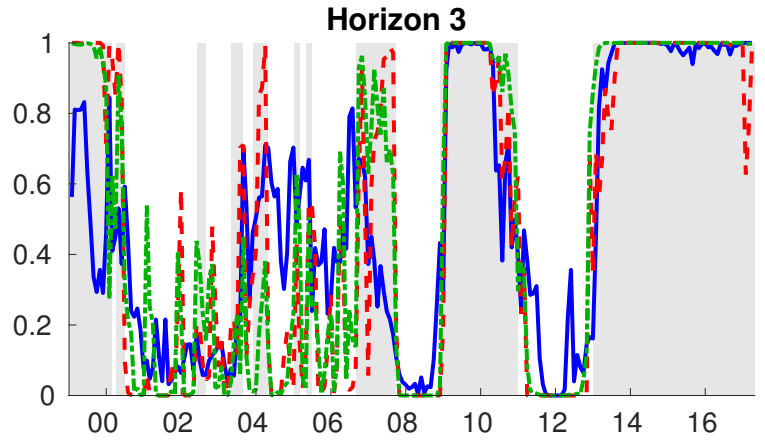


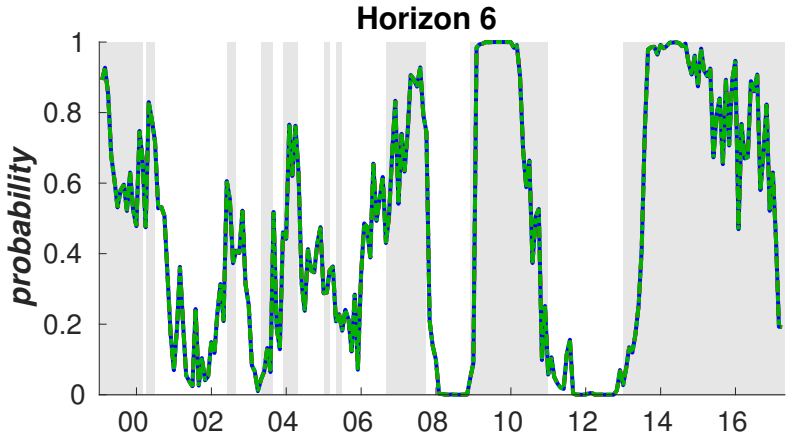
Legend: AUROC, MAE, RMSE Back to second step

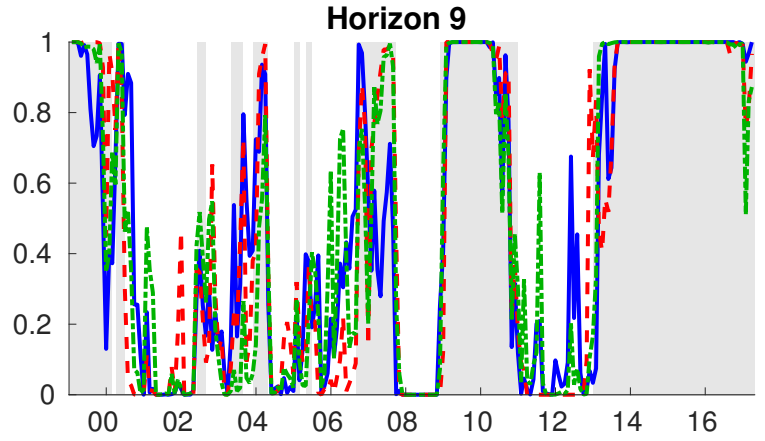
Results

In-sample









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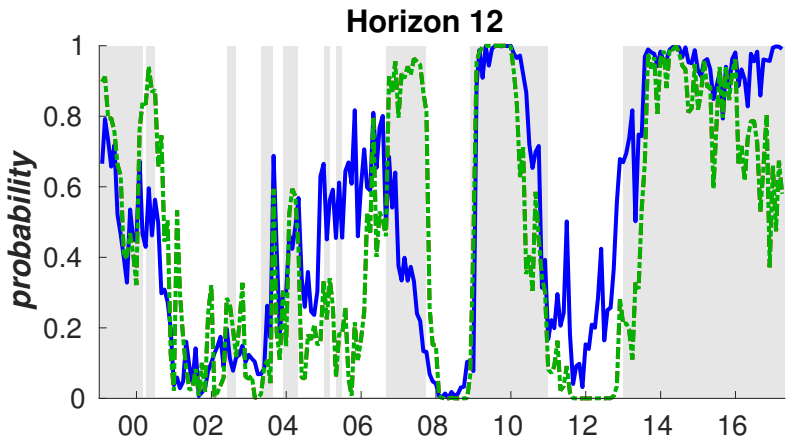
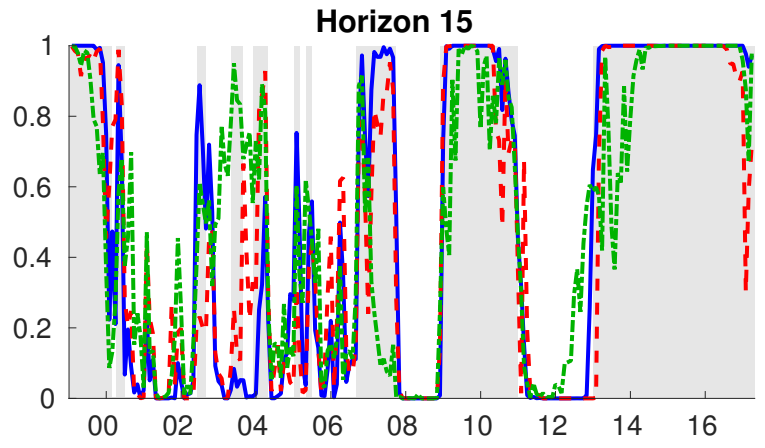
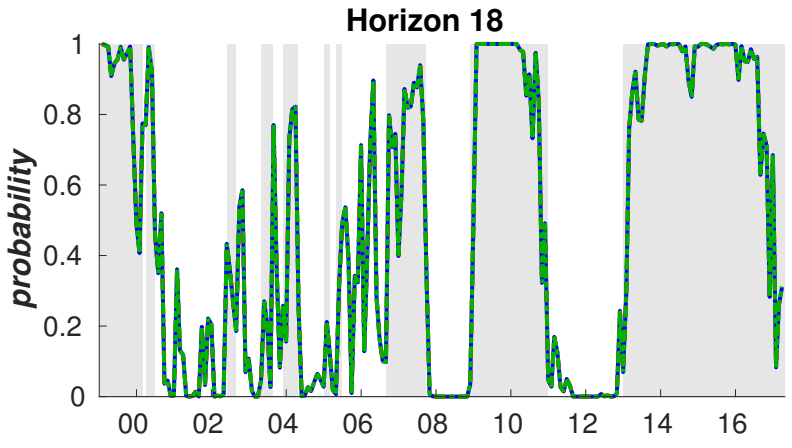
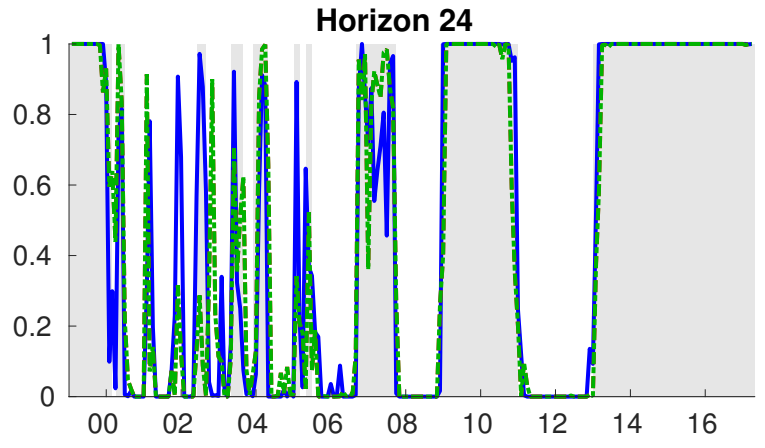
In-sample





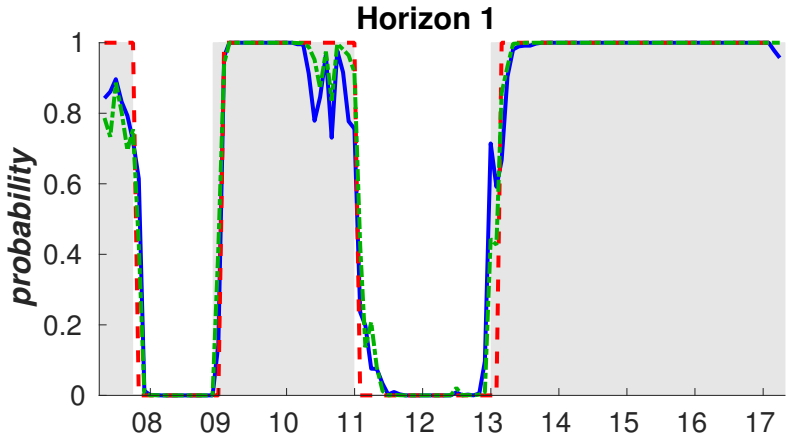


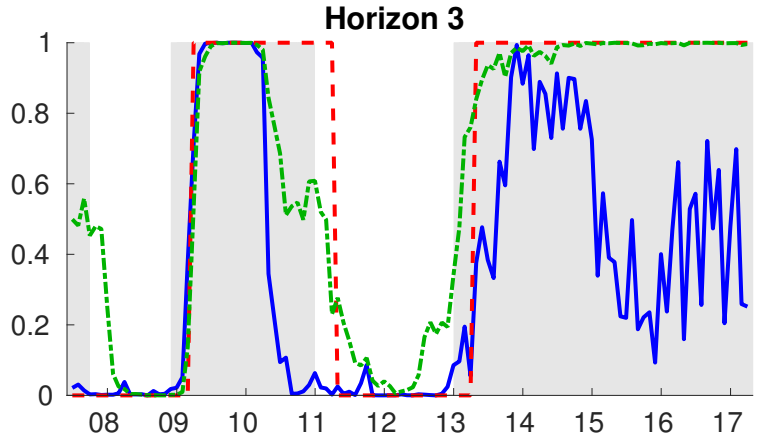


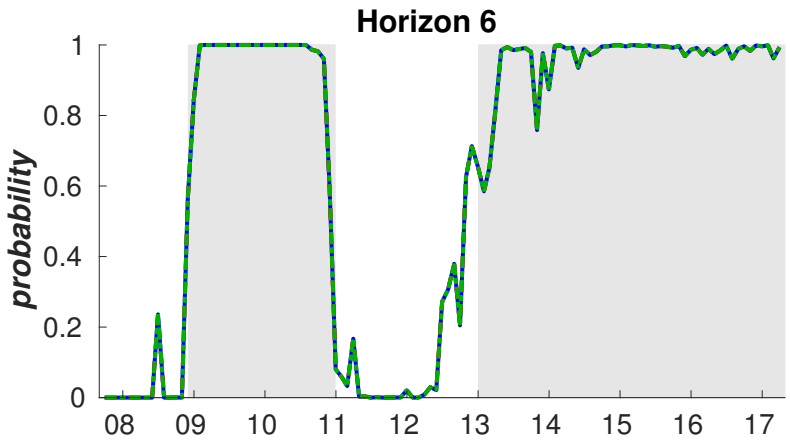
Legend: AUROC, MAE, RMSE

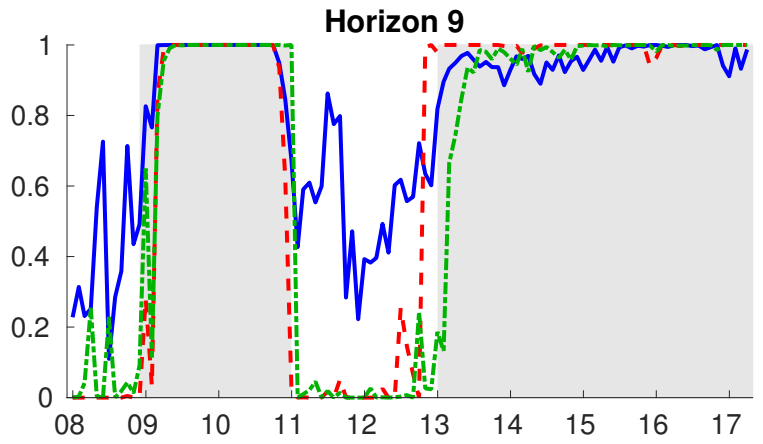
Results

Out-of-sample









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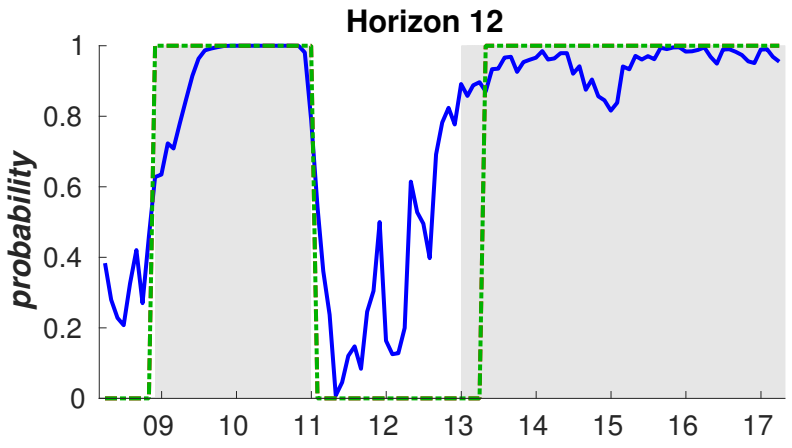
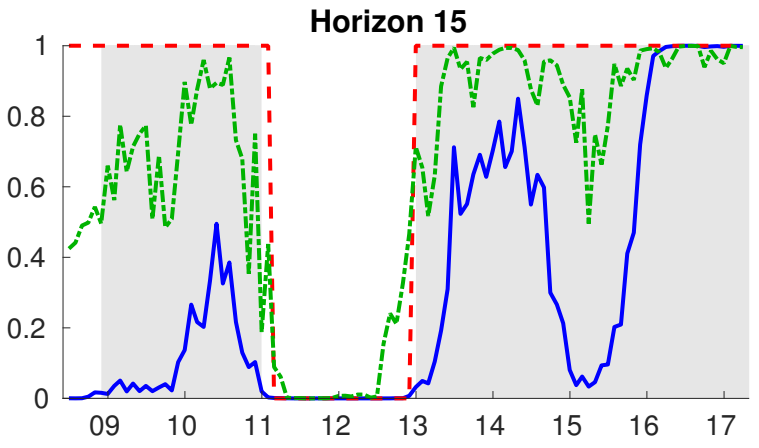
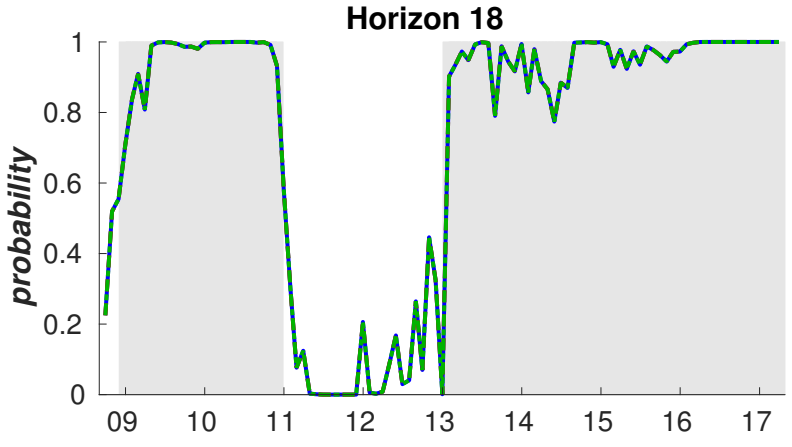
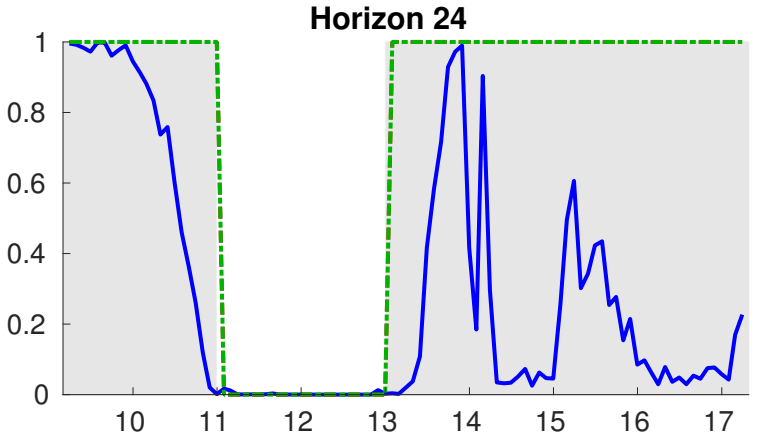
Results

Out-of-sample









Legend: AUROC, MAE, RMSE

Best models – predictions

Table: Best model predictions at different horizons.

Date	AUROC	MAE	RMSE
Apr 2017	0.87	0.99	0.99
Jun 2017	0.99	0.95	0.95
Sep 2017	0.98	0.98	0.98
Dec 2017	0.99	0.98	0.97
Mar 2018	0.99	0.99	0.99
Jun 2018	0.99	0.99	0.99
Sep 2018	0.99	0.99	0.99
Mar 2019	0.99	0.99	0.99