# Probability forecasts of deflation for the Euro area and Japan: an evaluation using scoring rules for binary outcomes

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## Motivation

### Why do we care about deflation?

- In light of the debate on deflation risks after the Great Recession in the Euro area, there is a renewed interest in deflation phenomenon
- Academic literature is relatively silent on this matter

### How can we measure deflation?

- Definition by Cogley and Sargent (2015) identifies a deflationary period, if the cumulative rate of price changes over the forecast horizon is negative, i.e. $\pi^h_{T+h} = ln(HICP_{T+h}/HICP_T) = \sum_{i=1}^h \pi_{T+i} < 0$

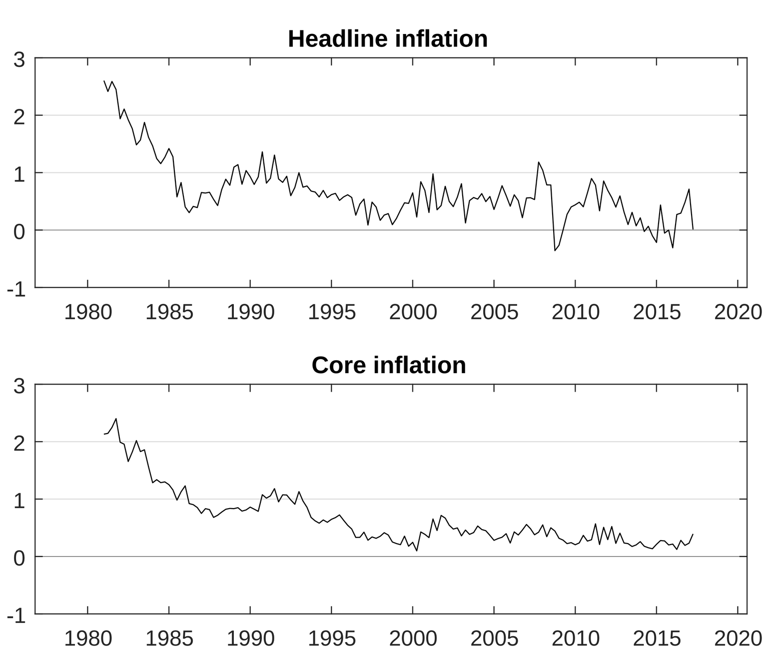
### Our contribution

- We forecast HICP changes and core inflation in the Euro area and Japan using inflation forecast models from the recent literature
- We provide estimated probabilities of future deflation based on individual and pooled density forecasts
- We use scoring rules for binary outcomes to evaluate the probability forecasts

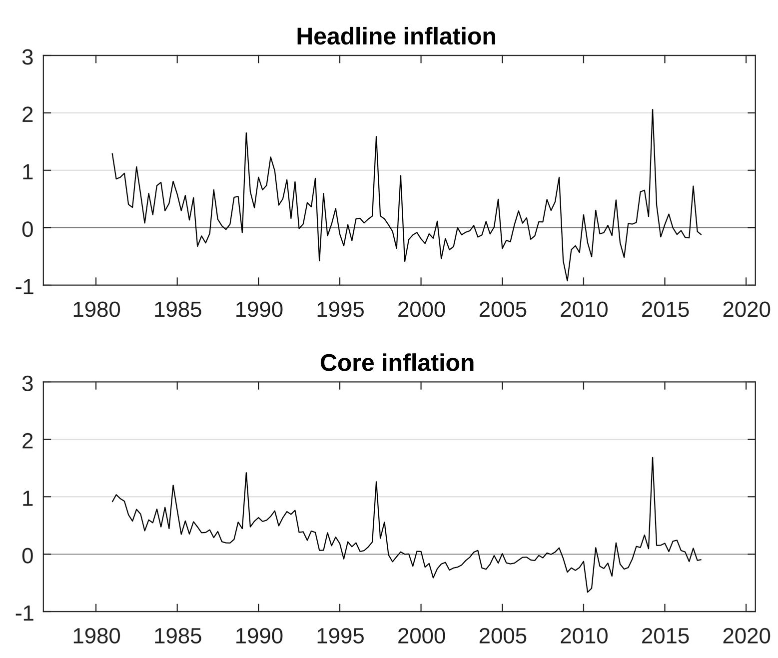
## Data

- We use quarterly data for HICP rates of change, core inflation and real GDP for the Euro area and Japan from 1980Q1 until 2017Q2
- In the Euro area, there are very few short-lived deflation observations for HICP rates of change and no deflation observations at all for core inflation
- In Japan, several deflationary periods are visible in both measures
- Time series properties of headline and core inflation are quite different in the Euro area and in Japan

Euro area




Japan




## Computation of deflation probabilities

- For "deflation" event $\mathcal{D}$, define binary variable $y_{\mathcal{D}} = 1$ if $\mathcal{D}$ occurs and $y_{\mathcal{D}} = 0$ if $\mathcal{D}$ does not occur
- In period $T$, we make prediction $P(\mathcal{D})$, i.e. we forecast the probability that $\mathcal{D}$ occurs between period $T+1$ and $T+h$ given observations $Y^o_{1:T}$: $P(\mathcal{D}) = P(\pi^h_{T+h} < 0 | Y^o_{1:T})$
- We can use the sample-based estimator $P(\pi^h_{T+h} < 0 | Y^o_{1:T}) = \frac{1}{R}\sum_R^{r=1} \mathcal{I}\left(\pi^{h(r)}_{T+h} < 0 | Y^o_{1:T}\right)$ given samples from the predictive density $\pi^{h(r)}_{T+h} \sim p(\pi^h_{T+h})$
- After period $T+h$, we have an observed value $y^o_{\mathcal{D}}$ that can be used to evaluate $P(\mathcal{D})$

## Evaluation using scoring rules for binary outcomes

- Evaluation period starts in 2000Q1 and ends in 2017Q2
- To evaluate $P(\mathcal{D})$, we employ the logarithmic score (*LogS*), the Brier score (*BrS*) and an asymmetric score (*As*) from Elliott, Ghanem and Krüger (2016):

$$LogS = y^o_{\mathcal{D}} logP(\mathcal{D}) + (1 - y^o_{\mathcal{D}}) log(1 - P(\mathcal{D}))$$

$$BrS = y^o_{\mathcal{D}}[-(1 - P(\mathcal{D}))^2] + (1 - y^o_{\mathcal{D}})[-P(\mathcal{D})^2] = -(y^o_{\mathcal{D}} - P(\mathcal{D}))^2$$

$$As = y^o_{\mathcal{D}}[logP(\mathcal{D}) - P(\mathcal{D}) + 1] + (1 - y^o_{\mathcal{D}})[-P(\mathcal{D})]$$

- While *BrS* and *LogS* are indifferent between false negatives and false positives, *As* implies stronger losses for deflation events that were not predicted

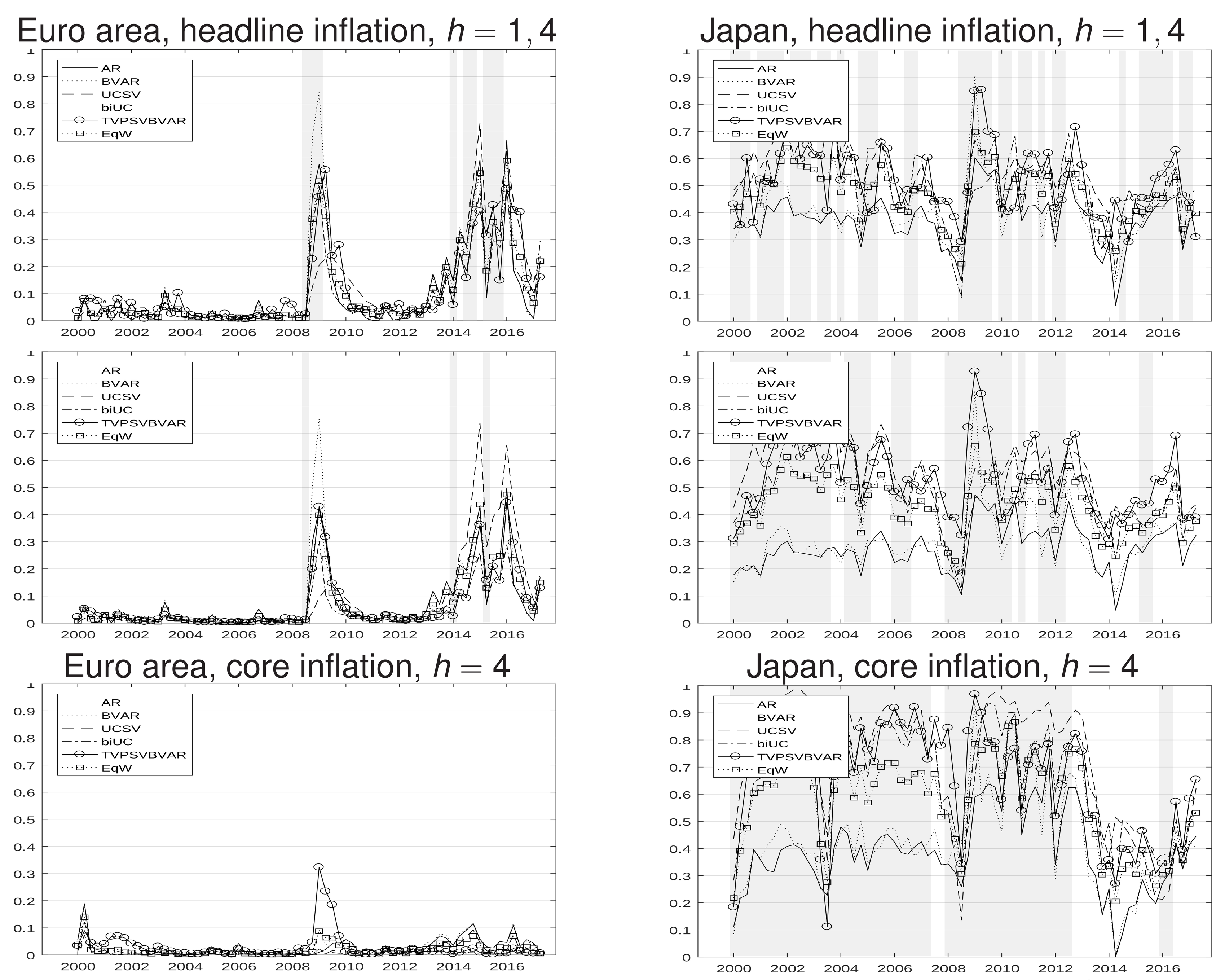
## Forecasting models

| Identifier | Description |
|---|---|
| AR | Univariate, constant-parameter AR(4) |
| BVAR | Constant-parameter BVAR(4) in inflation and GDP growth |
| UCSV | Univariate unobserved component model with time-varying trend and stoch. volatility (SV), Chan (2013) variant of Stock and Watson (2007) |
| biUC | Bivariate Trend-Cycle Model in inflation and GDP growth with SV, Chan, Koop, Potter (2016) |
| TVPSVBVAR | Time-varying-parameter VAR(4) in inflation and GDP growth with SV, Primiceri (2005) |
| EqW | Pooled density from the above models with equal weights |

- Models are estimated recursively with Bayesian MCMC methods
- Out-of sample path forecast densities are computed

## Main results

### Estimated deflation probabilities




- Note: shaded areas show observed values $y^o_{\mathcal{D}}$, i.e. a bar in period $T$ indicates that $\sum_{i=1}^h \pi^o_{T+i} < 0$

### Scores for binary outcomes

Headline inflation

| | Euro area | | Japan | | Euro area | | Japan | | Euro area | | Japan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| horizon | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ |
| | Log Score | | | | Brier Score | | | | Asymmetric Score | | | |
| AR | -0.32 | -0.26 | -0.76 | -0.95 | -0.09 | -0.06 | -0.28 | -0.36 | -0.21 | -0.21 | -0.37 | -0.49 |
| BVAR | -0.30 | -0.27 | -0.73 | -0.91 | **-0.08** | -0.07 | -0.27 | -0.34 | -0.20 | -0.20 | -0.36 | -0.46 |
| UCSV | -0.31 | -0.26 | -0.72 | -0.70 | -0.09 | -0.06 | **-0.26** | **-0.25** | -0.20 | -0.20 | **-0.34** | -0.33 |
| biUC | -0.29 | **-0.21** | -0.73 | -0.74 | -0.09 | **-0.05** | **-0.26** | -0.27 | **-0.19** | **-0.16** | -0.35 | -0.35 |
| TVPSVBVAR | -0.31 | -0.22 | -0.72 | **-0.69** | -0.10 | **-0.05** | **-0.26** | **-0.25** | -0.20 | -0.17 | **-0.34** | **-0.32** |
| EqW | **-0.28** | -0.22 | **-0.71** | -0.74 | -0.09 | **-0.05** | **-0.26** | -0.27 | -0.18 | -0.17 | **-0.34** | -0.35 |

Core inflation

| | Euro area | | Japan | | Euro area | | Japan | | Euro area | | Japan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| horizon | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ | $h=1$ | $h=4$ |
| | Log Score | | | | Brier Score | | | | Asymmetric Score | | | |
| AR | -0.02 | -0.03 | -0.62 | -0.80 | 0.00 | 0.00 | -0.21 | -0.30 | -0.02 | -0.03 | -0.25 | -0.34 |
| BVAR | -0.02 | -0.03 | -0.60 | -0.75 | 0.00 | 0.00 | -0.21 | -0.28 | -0.02 | -0.03 | -0.25 | -0.31 |
| UCSV | -0.02 | **-0.01** | **-0.53** | **-0.45** | 0.00 | 0.00 | **-0.18** | **-0.15** | -0.02 | **-0.01** | -0.24 | **-0.19** |
| biUC | **-0.01** | **-0.01** | -0.54 | -0.48 | 0.00 | 0.00 | **-0.18** | -0.16 | **-0.01** | **-0.01** | **-0.23** | **-0.19** |
| TVPSVBVAR | -0.03 | -0.03 | -0.58 | -0.49 | 0.00 | 0.00 | -0.20 | -0.16 | -0.03 | -0.03 | -0.27 | -0.20 |
| EqW | -0.02 | -0.02 | -0.55 | -0.54 | 0.00 | 0.00 | **-0.18** | -0.18 | -0.02 | -0.02 | **-0.23** | -0.21 |

## Summary & conclusions

- Deflation is a rare event in the Euro area and difficult to forecast, deflation probabilities are lower and less volatile than in Japan
- In the Euro area, deflation probabilities for core inflation are negligible compared to headline inflation
- In Japan, deflation probabilities for core inflation are much higher than for headline inflation
- Time-varying-parameter models and density pool generally outperform constant-parameter models; gains are more pronounced for higher forecast horizons

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