

# Quantitative Investment Conference 2018

## Dynamic Factor Models and Nowcasting

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**ANALYST CERTIFICATION AND REQUIRED DISCLOSURES BEGIN ON SLIDE 20**

# Have hammer, will nail

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Done:

- DFM for hard data activity in US

- DFM for hard data activity in UK

- DFM for world aggregates (GDP, inflation, trade, IP,...)

To come:

- Hard data factors for large economies in DM and EM

- Equivalents for inflation and financial conditions

Aim:

- Global monthly indicators of prices, quantities and rates

# Quick refresher

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Basic factor model:

$$y_t^i = \lambda_i f_t + e_t^i$$

- $y^i$  is the data
- $f$  is the factor
- $\lambda^i$  is the loading
- $e^i$  is idiosyncratic, uncorrelated across  $i$

Note:  $cov(y^i, y^k) = \lambda_i \lambda_k var(f)$



Factor captures all correlation between items  
FA  $\neq$  PCA

# Intuition for estimating a latent factor

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If you know the loadings, normalized  $\sum \lambda_i^2 = 1$ :

$$\sum \lambda_i y_t^i = f_t \sum \lambda_i^2 + \sum \lambda_i e_t^i \approx f_t$$

If you know the factor, OLS:

$$\lambda_i = (\sum_t f_t^2)^{-1} (\sum_t f_t y_t^i)$$

Substitute:

$$f = \sum \text{corr}(f, y^i) \frac{\text{std}(y^i)}{\text{std}(f)} y^i$$

Solve the self-reference iteratively:

**Gibbs sampling (Bayesian)** or EM algorithm (classical)

# Current framework in UBS Global team

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Main model:

$$y_t^i = \tau_t^i + \Lambda^i(L)f_t + c_t^i \quad \text{Factor-ARMA}$$

Processes:

$$\tau_t^i = \tau_{t-1}^i + u_t^i \sim N(0, w^i) \quad \text{Stochastic trend}$$

$$f_t = \phi f_{t-1} + \omega_t \sim N(0, \lambda_t q) \quad \text{T-distribution}$$

$$c_t^i = \rho^i c_{t-1}^i + e_t^i \sim N(0, e^{\eta_t^i}) \quad \text{AR errors}$$

$$\eta_t^i = \eta_{t-1}^i + v_t^i \sim N(0, r^i) \quad \text{Stochastic volatility}$$

Specific features:

$$\Lambda^i \sim \gamma^i N(0, V_\Lambda) + (1 - \gamma^i) N(0, 0.001 V_\Lambda) \quad \text{SSVS}$$

$$\gamma^i \sim B(.5)$$

$$\lambda_t \sim \Gamma^{-1}\left(\frac{\nu}{2}, \frac{\nu}{2}\right)$$

# Why the bells and whistles?

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- **Dynamic factor loadings**: capture lead-lag relationships.
- **Idiosyncratic stochastic trends**: reflect low frequency swings.
- **Idiosyncratic auto-regressive errors**: individual dynamics useful for now-casting.
- **Idiosyncratic stochastic volatility**: volatility clustering  $\approx$  time-varying IMA.
- **Factor T-distribution** (via Gamma mixture modeling): capture pesky 10-sigma events every 8 years.
- **Stochastic Search Variable Selection**: parameter shrinkage in the loadings matrix.

# Computational Issues—moving beyond KF

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Three sets of latent variables :

factor  $f$ , RW trends  $\tau^i$ , stochastic volatility  $\eta^i$

Likely overload for the Kalman filter. Use precision sampling instead (Chan Jeliazkov 2009).

Sparse matrices → draws from the full joint distribution of states

Preferable to Kalman string of conditionals.

Huh?

# A wee bit of math

In matrix form

$$Y = T + \Lambda F + C$$

where

$$H_C C \sim N(0, V)$$

$$H_F F \sim N(0, Q)$$

$$H T \sim N(0, \Omega)$$

$$H \eta \sim N(0, R)$$

$$H = \begin{pmatrix} 1 & 0 & \dots & \dots \\ -1 & 1 & 0 & \dots \\ 0 & \ddots & \ddots & 0 \\ \dots & \dots & -1 & 1 \end{pmatrix}$$

$$H = \begin{pmatrix} \Lambda_s & \Lambda_{s-1} & \dots & \dots \\ 0 & \Lambda_s & \Lambda_{s-1} & \dots \\ \dots & \ddots & \ddots & 0 \\ \dots & \dots & \Lambda_1 & \Lambda_0 \end{pmatrix}$$

$$H_C = \begin{pmatrix} 1 & 0 & \dots & \dots \\ -\rho & 1 & 0 & \dots \\ 0 & \ddots & \ddots & 0 \\ \dots & \dots & -\rho & 1 \end{pmatrix}$$

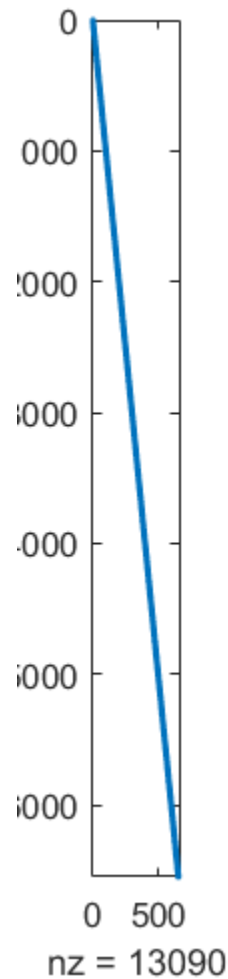
$$V, Q, R, \Omega = \begin{pmatrix} \Sigma_x & 0 & \dots & \dots \\ 0 & \Sigma_x & 0 & \dots \\ 0 & \ddots & \ddots & 0 \\ \dots & \dots & 0 & \Sigma_x \end{pmatrix}$$



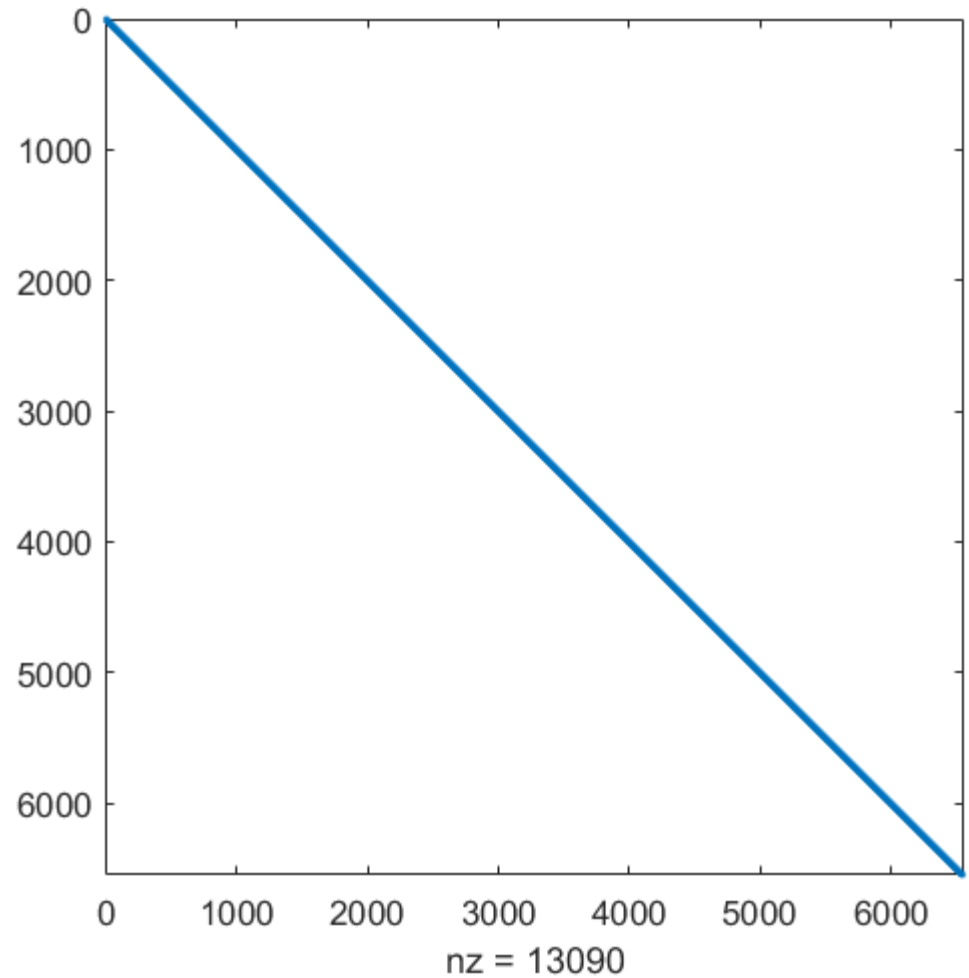
# Matrices are far simpler than you think

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$\Lambda =$



$H, R, Q, V, \Omega =$



Source: UBS calculations

# Why precision is key in the joint distribution

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Likelihood function:  $Y - T|F \sim N\left(\Lambda F, (\mathbf{H}_c' \mathbf{V}^{-1} \mathbf{H}_c)^{-1}\right)$

Prior:  $F \sim N\left(\mathbf{0}, (\mathbf{H}_F' \mathbf{Q}^{-1} \mathbf{H}_F)^{-1}\right)$

Posterior:  $F|Y - T \sim N(F^*, P^{-1})$

with: 
$$P = \Lambda' \mathbf{H}_c' \mathbf{V}^{-1} \mathbf{H}_c \Lambda + \mathbf{H}_F' \mathbf{Q}^{-1} \mathbf{H}_F$$
$$F^* = P^{-1} \Lambda' \mathbf{H}_c' \mathbf{V}^{-1} \mathbf{H}_c (Y - T)$$

ALL MATRICES IN  $P$  ARE SPARSE BAND MATRICES

# The secret ingredient

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Easy to invert sparse precision matrix with Cholesky:

$$P = C' C$$

Draw latent factor *jointly* (with backslash operator):

$$F = C \backslash (C' \Lambda' H_c' e^{-\eta} H_c (Y - T) + N(0, I))$$

Easy to program.

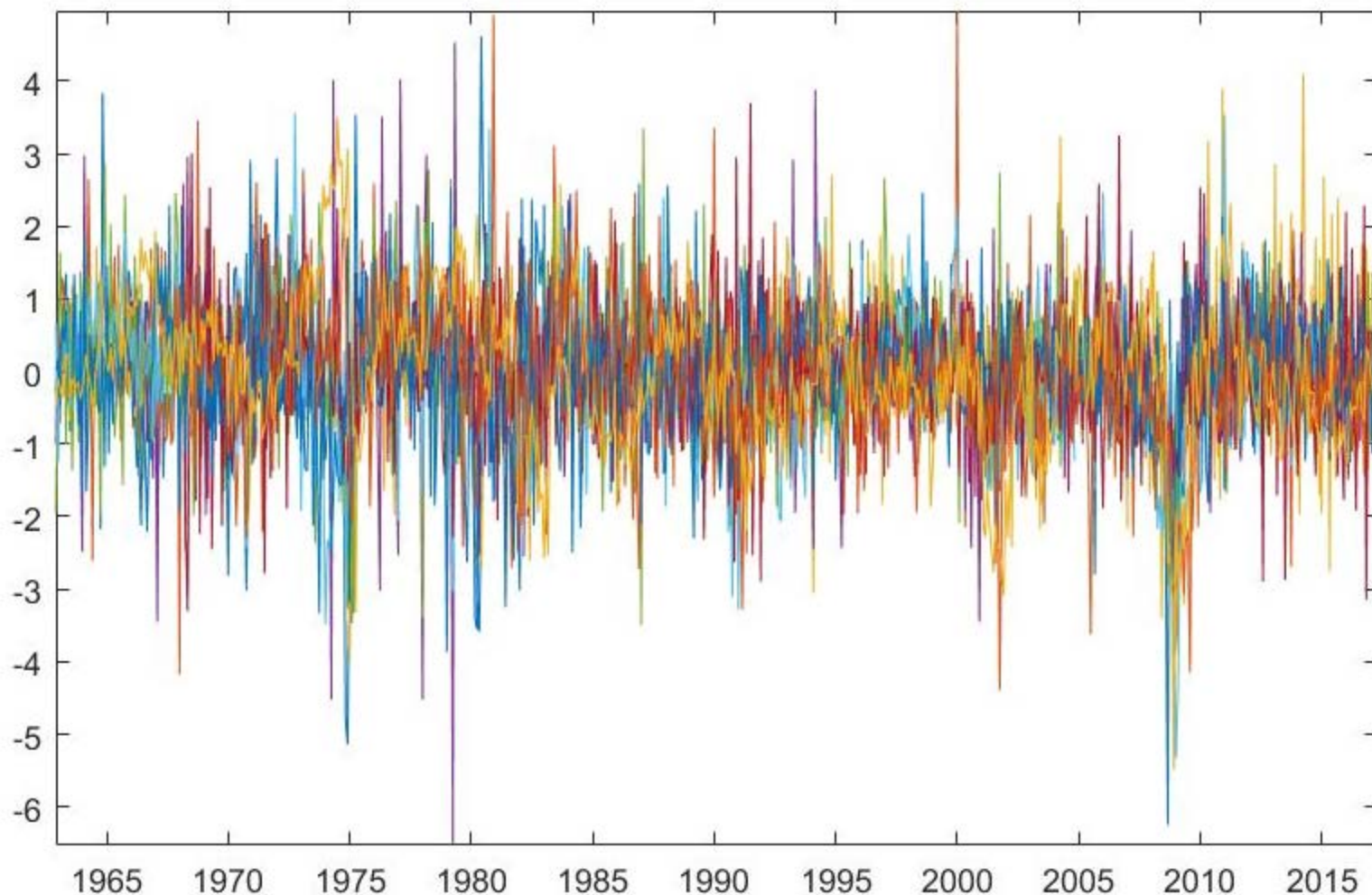
Precision sampling is 2~3 times faster than the Kalman filter, for one state. Here, 3 states!

No numerical instability coming from inverting variances from conditional distributions.

# Example: building a factor from hard activity data

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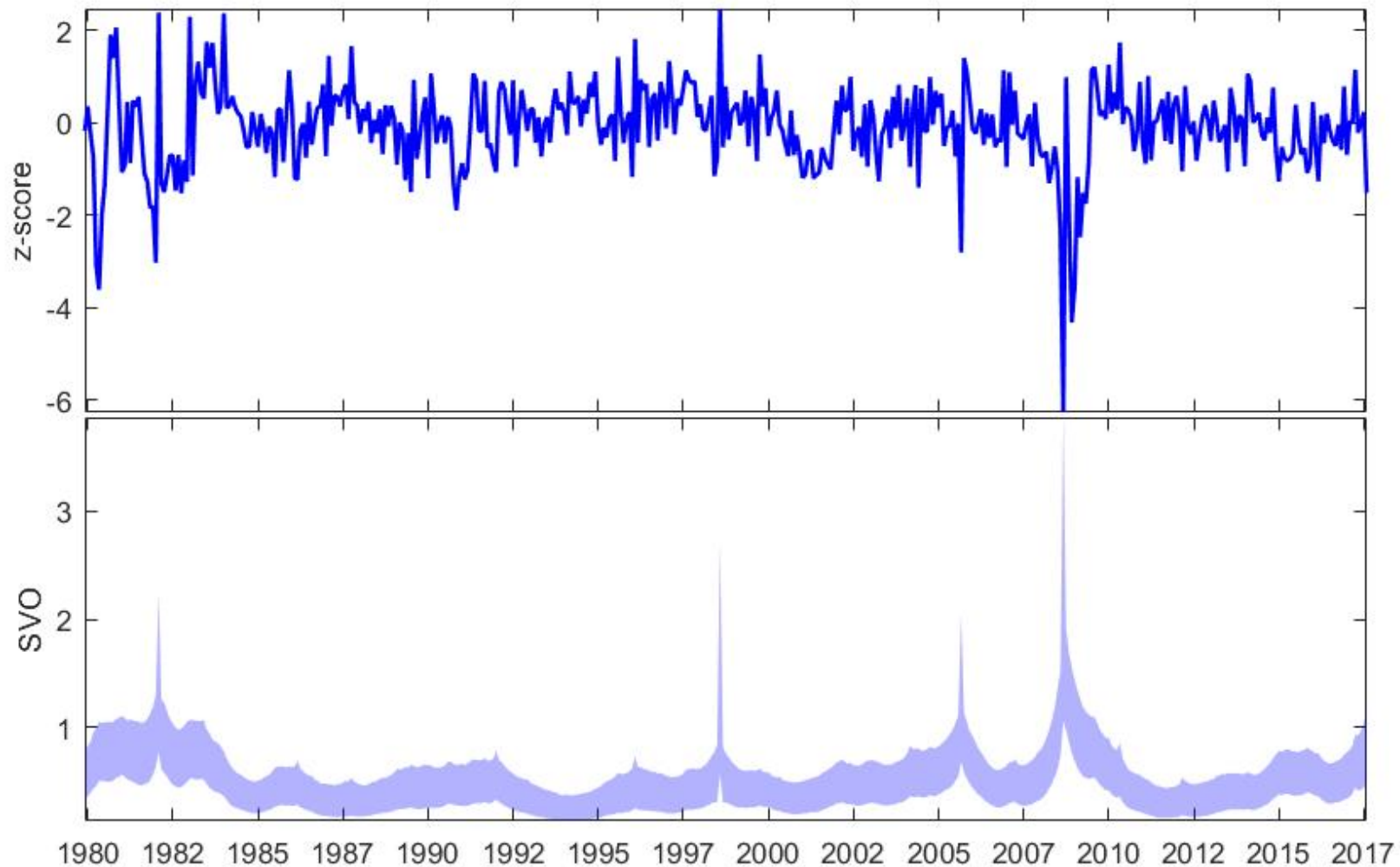
The raw data:



Source: Haver, UBS calculations

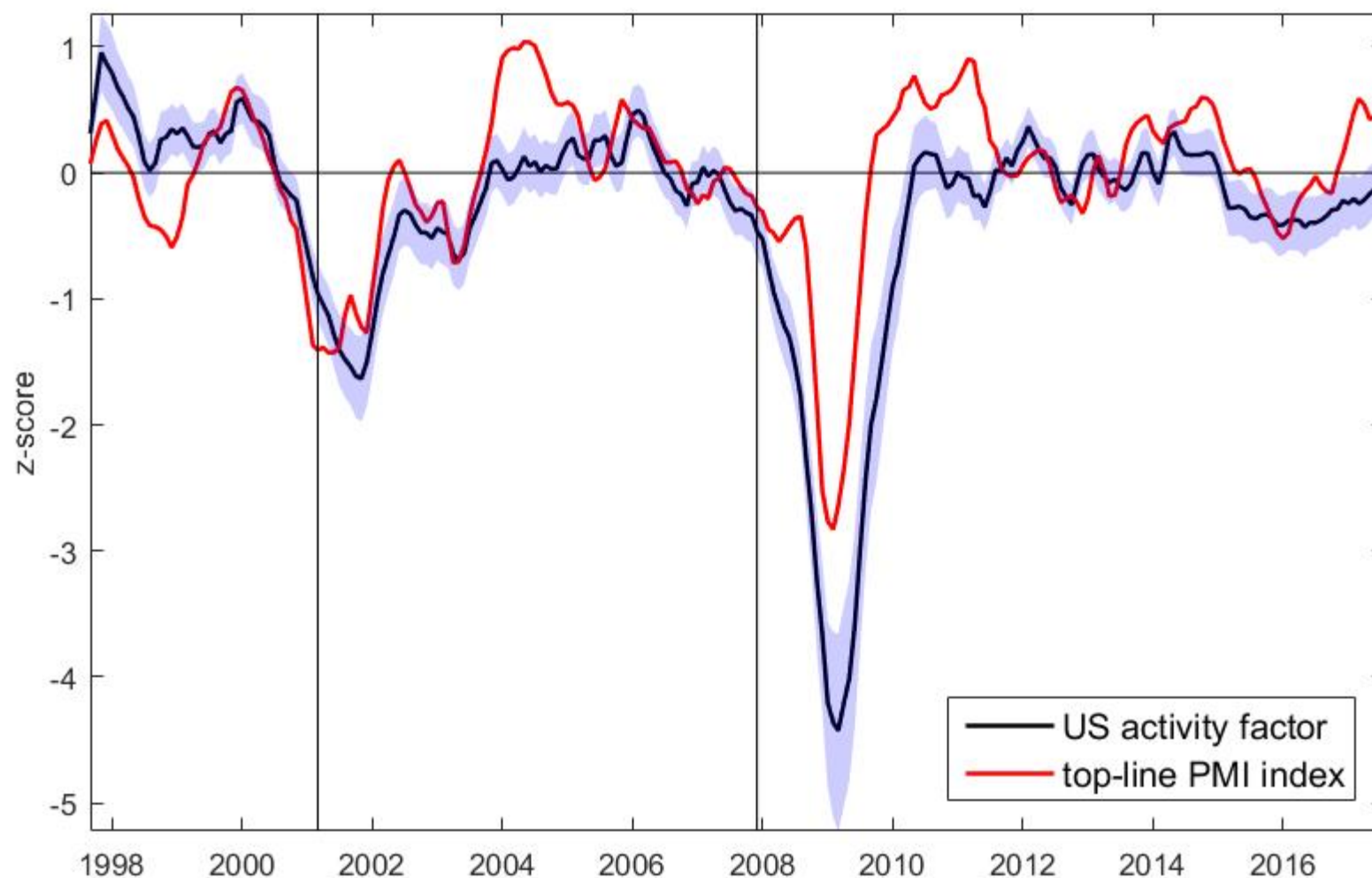
# Dealing with volatility clustering and outliers

Example for Industrial Production:



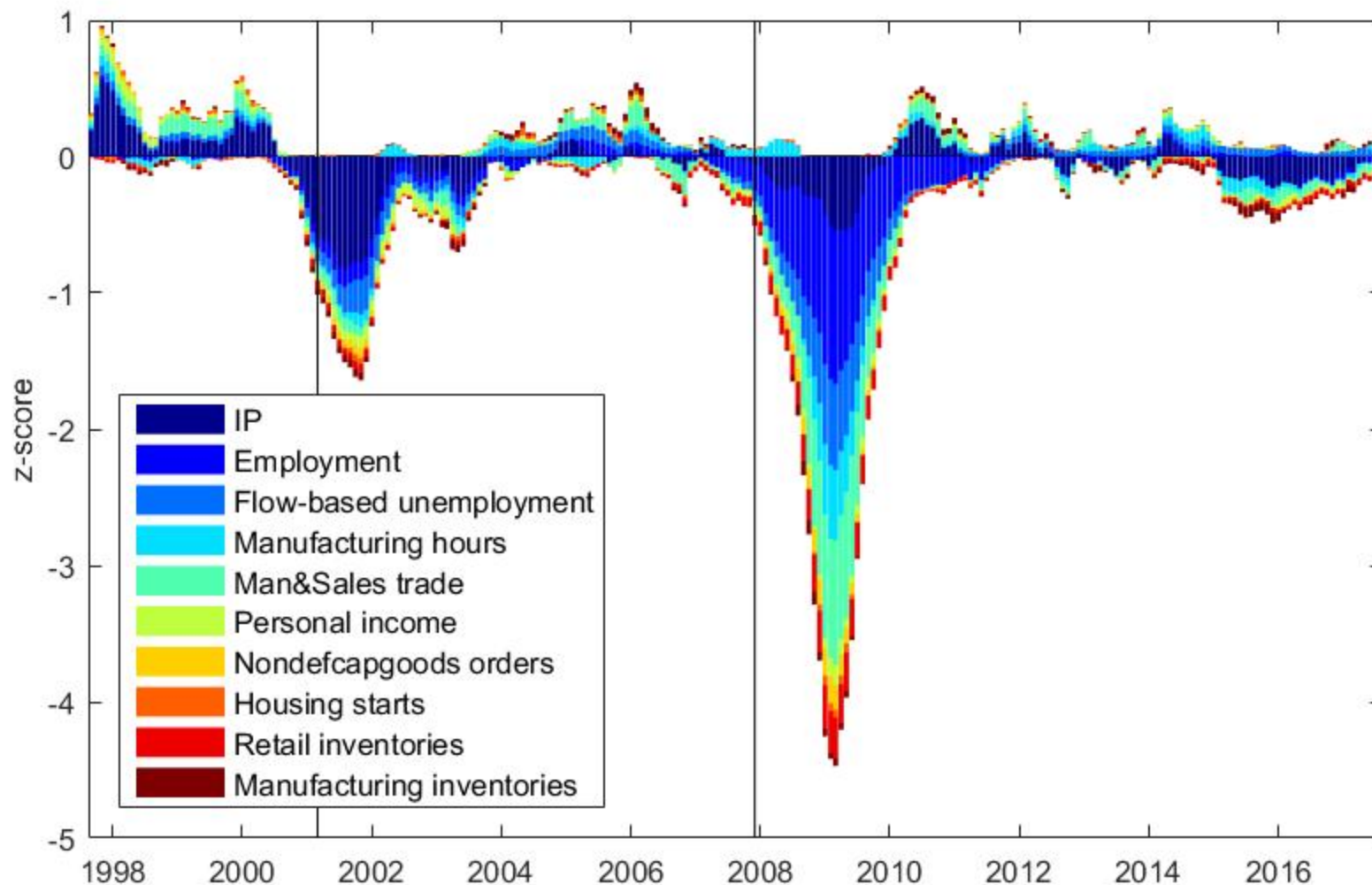
Source: Haver, UBS calculations

# Comparing the factor with soft data



Source: Haver, UBS calculations

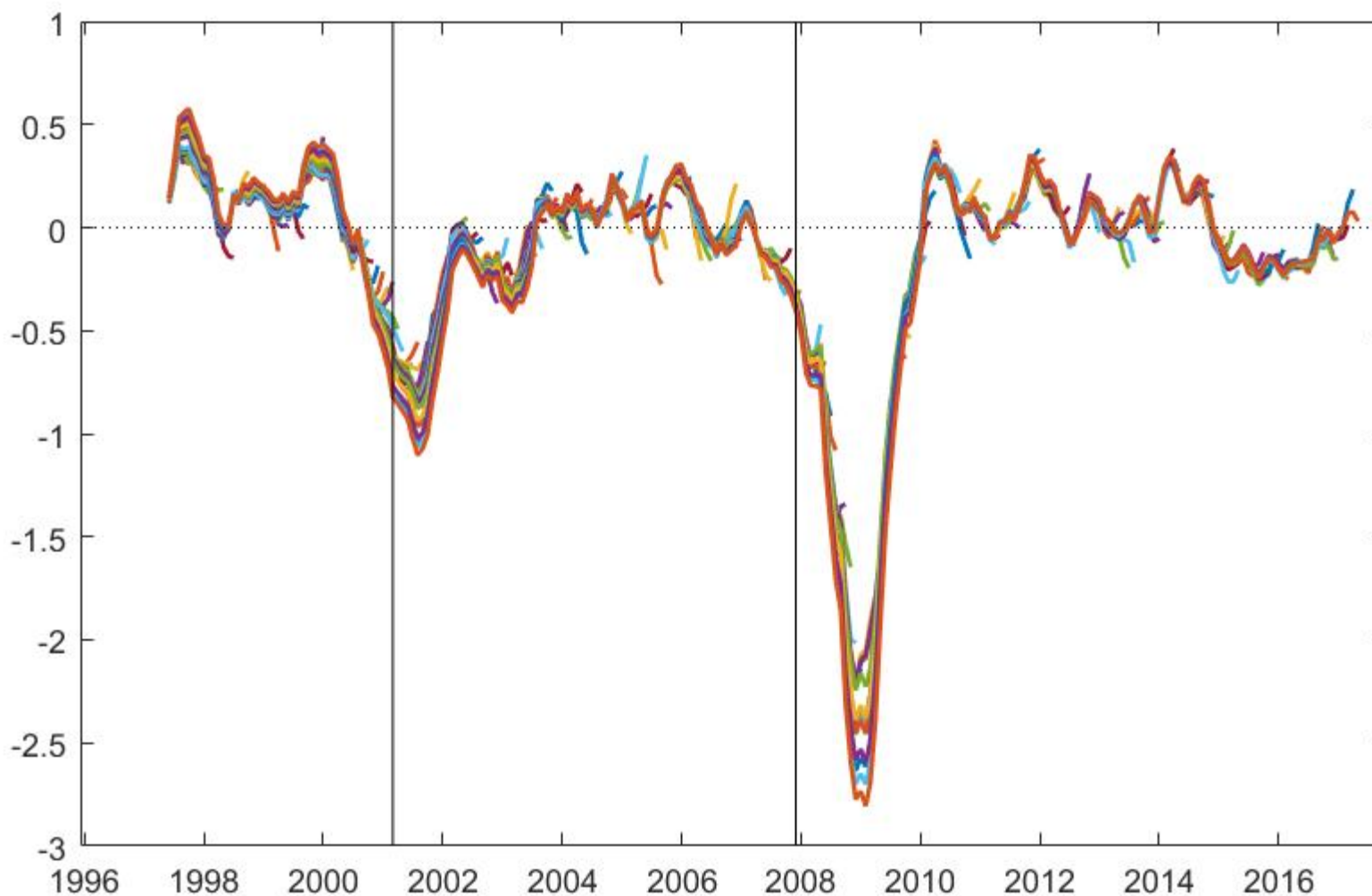
# Historical contributions are easy to extract



Source: Haver, UBS calculations

# Pseudo-real time estimates of the factor

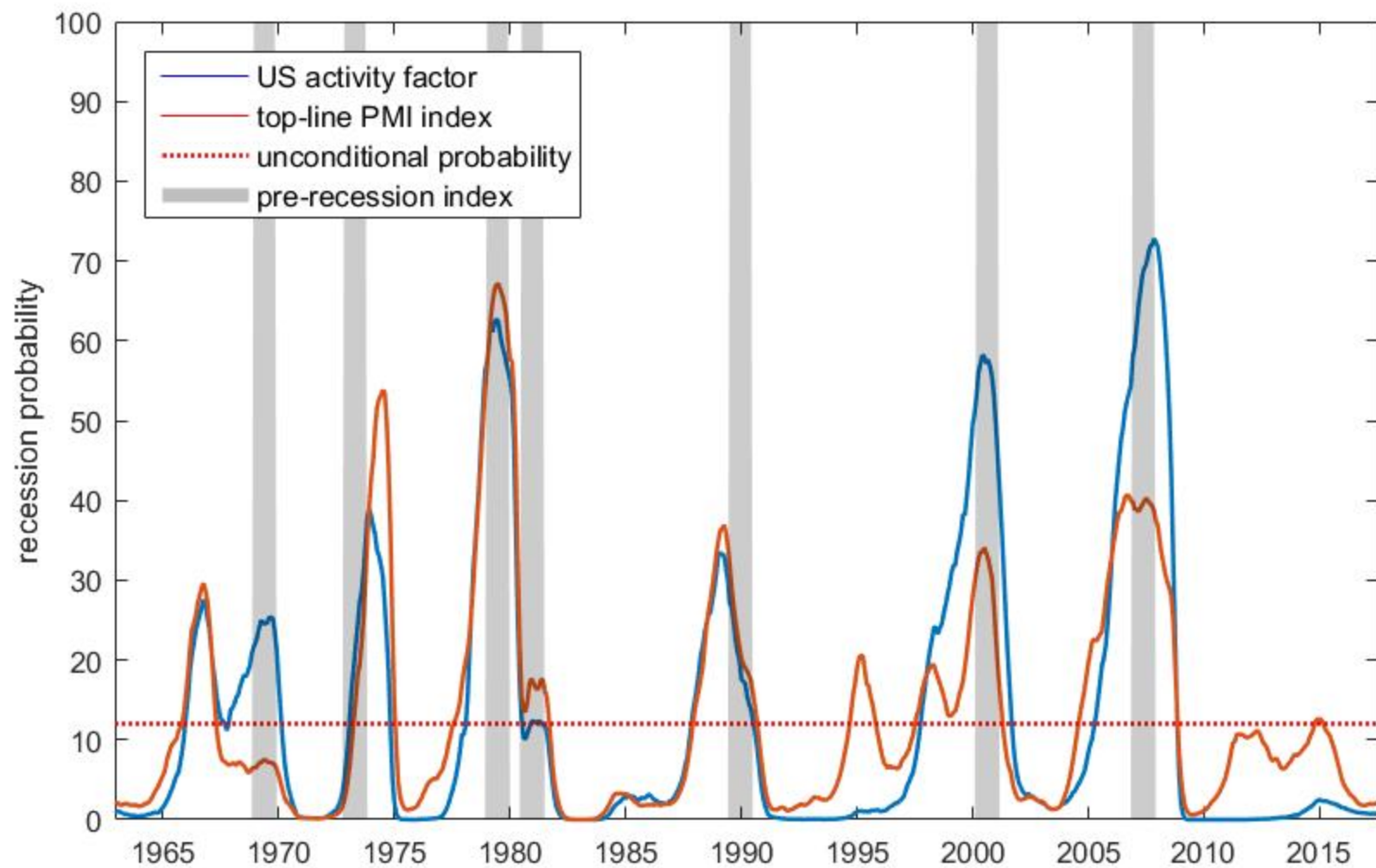
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Source: Haver, UBS calculations

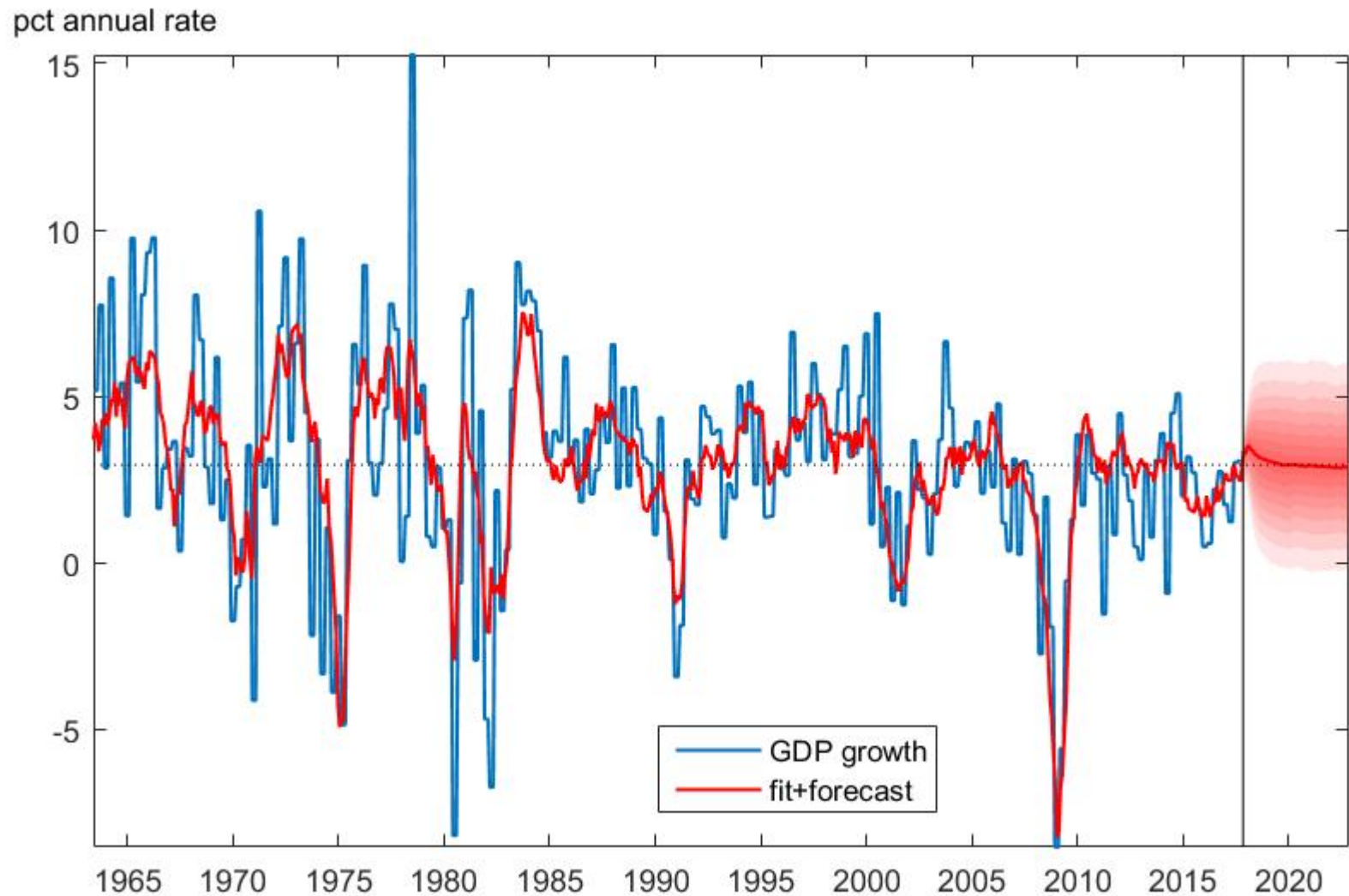


# Turning point forecasting



Source: Haver, UBS calculations

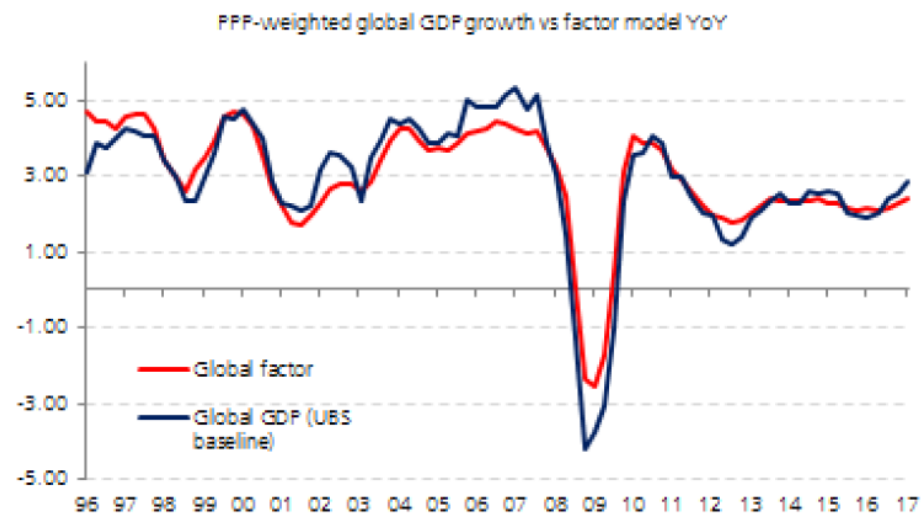
# Nowcasting



Source: Haver, UBS calculations

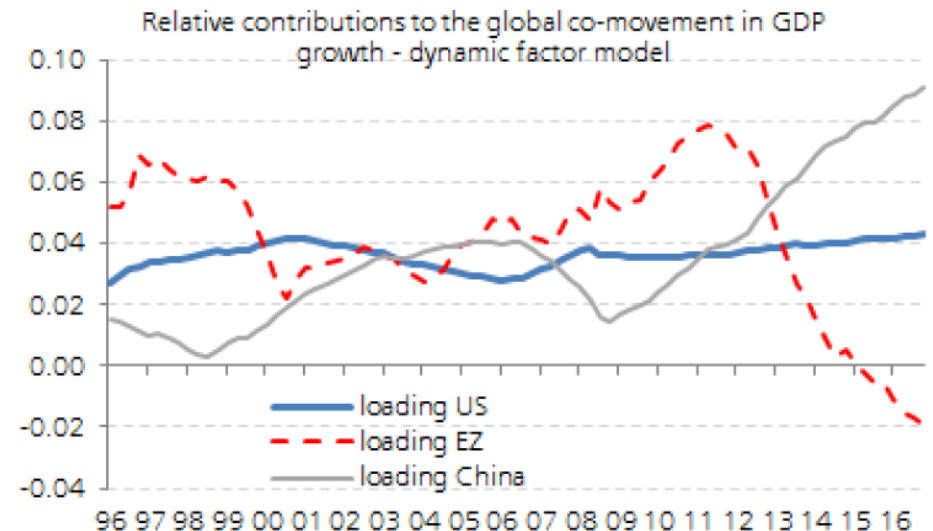
# A different view on world aggregates

Figure 62: PPP weighted global GDP growth vs factor weighted GDP growth



Source: Haver, UBS calculations

Figure 63: Relative contributions to the global co-movement in GDP growth for the G3



Source: Haver, UBS calculations

# Conclusion

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So much to do. So little time.

Thank you.

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