Incorporating macro-economic leading indicators in inventory management

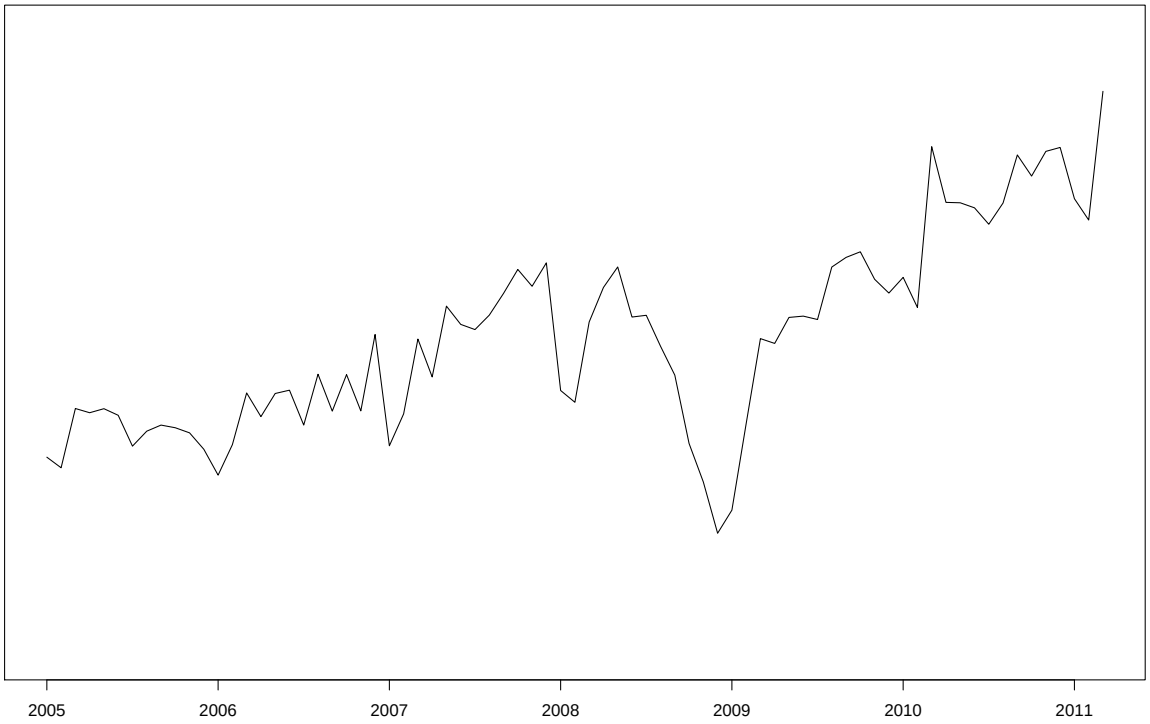
Yves R. Sagaert, Stijn De Vuyst, Nikolaos Kourentzes,
El-Houssaine Aghezzaf, Bram Desmet

Department of Industrial Management, Ghent University

26/08/2016

Motivation

When will the next economic crisis hit? Where? For how long?



Traditional univariate forecasting techniques do not incorporate context information

Research Question

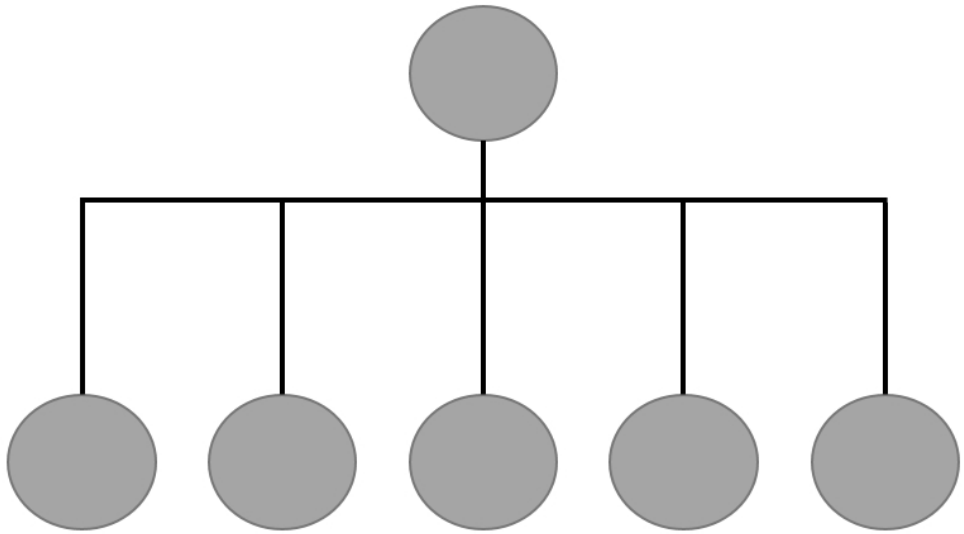
Long term sales forecasting are formulated using

- Historical data patterns (level, trend, seasonality, ...)
- Promotions
- Judgemental adjustments:
  - Collaborative input from clients
  - Newspapers and industry magazines
  - Rumors in the corridors

  Judgemental input is known to be biased and inconsistent (Fildes and Goodwin 2007, Trapero et al. 2013)
- Information of exogenous leading indicators
  - Capturing market sentiment in external big data (Russom et al. 2011)

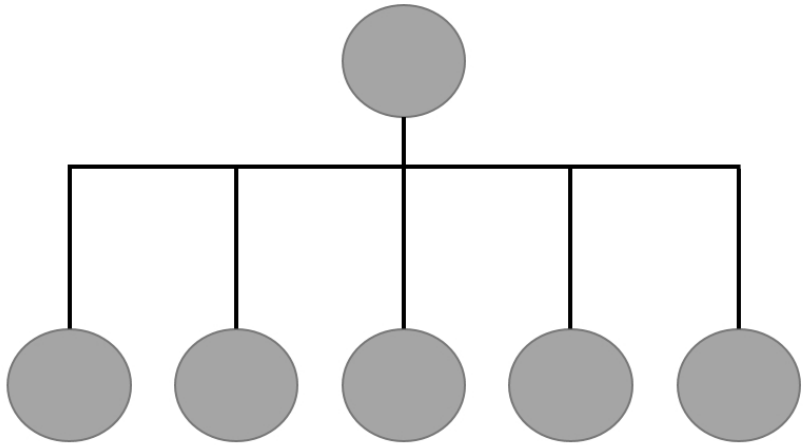
Research Question

- Can macro-economic indicators improve sales forecasts?



- What is the real impact on the supply chain inventory?

Experiment design



Incorporating leading indicator information

- Tactical level
- Plant level
- Top-down level

Evaluation: MAPE and MdAPE

Models

Benchmark models

- Naive model
- Holt-Winters model
- Exponential Smoothing

LASSO model

$$\hat{Y}_i = \beta_0 + \sum_{k=1}^{S} \beta_k D_k + \sum_{j=1}^{P} \beta_i x_{ij} \tag{1}$$

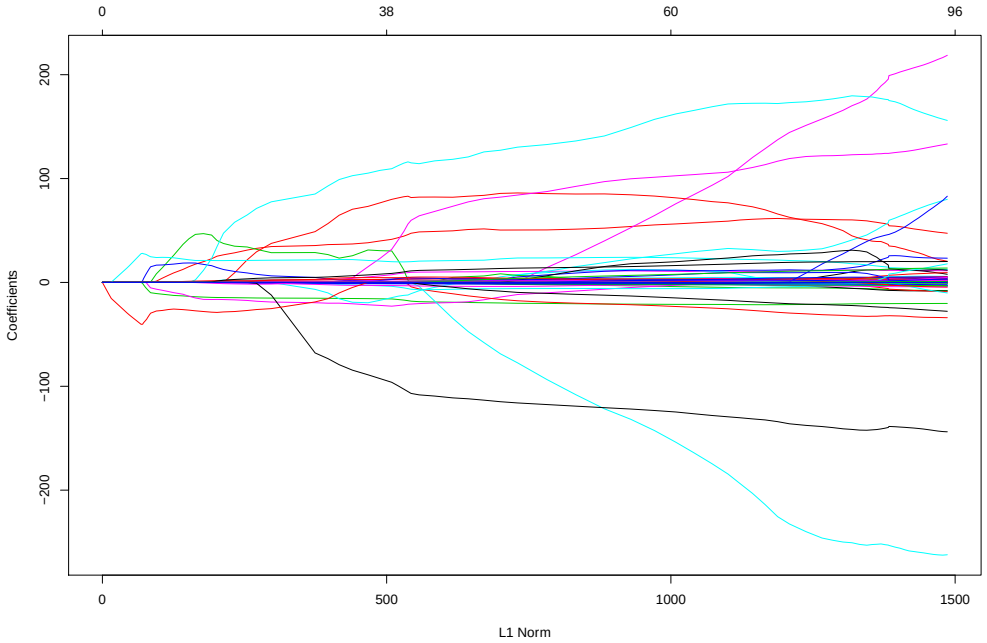
Cost function:

$$\sum_{i=1}^{n} \left(y_i - \beta_0 - \sum_{p=1}^{P} \beta_p x_{ip} \right)^2 + \lambda \sum_{p=1}^{P} |\beta_p| \tag{2}$$

LASSO

Least Absolute Shrinkage Selection Operator (Tibshirani, 1996)

- Shrinkage and variable selection
- Selecting λ through cross-validation



LASSO

Working paper:
Sagaert Y. R., Aghezzaf E.H., Kourentzes N. and Desmet B. Tactical sales forecasting using a very large set of macroeconomic indicators. European Journal of Operational Research.

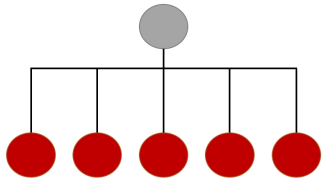
- MAPE improvement 18.8% on 1-12 months ahead
- Set of 67,851 indicators
- Unconditional Forecasting
- Final model: 10-15 indicators selected
  - Employment in automobile
  - National passenger car registrations
  - Consumer Prices Index for solid fuel prices

Data

Sales data of 5 plants of a global manufacturer

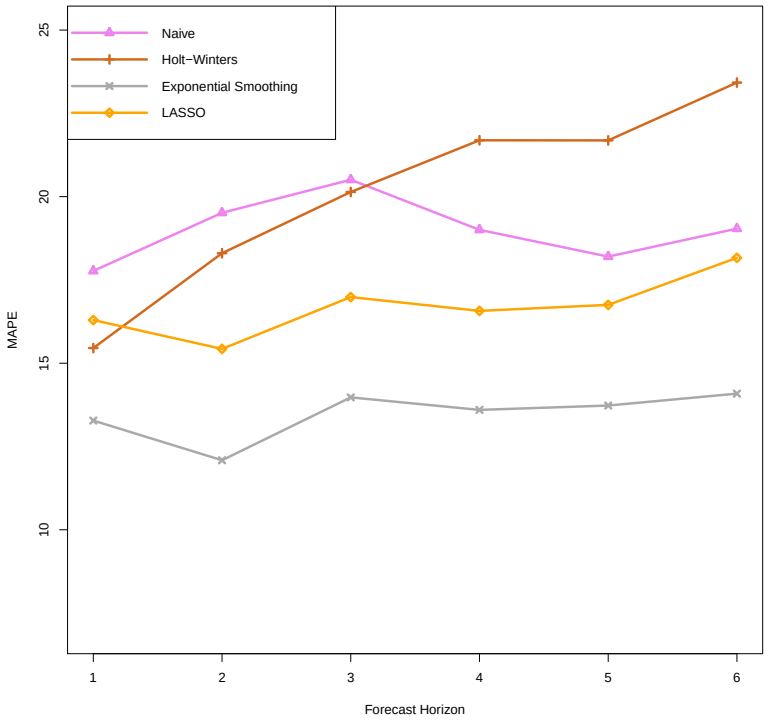
- Train period: 2005 - 2012
- Test period: 2013 - 2014
- Forecast horizon h=1..6
- Rolling origin evaluation

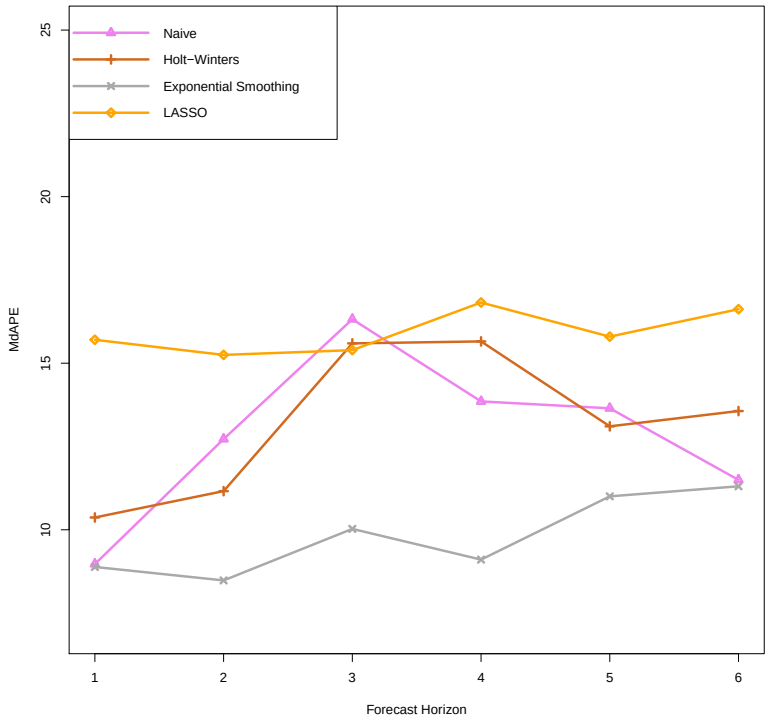
Empirical results: forecasting accuracy



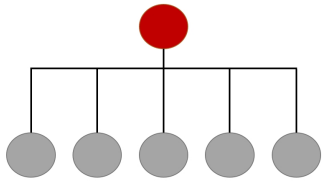
Lower level

	MAPE	MdAPE
Naive	19.0	12.8
Holt-Winters	20.1	13.2
Exponential smoothing	13.5	9.8
LASSO	16.7	15.9



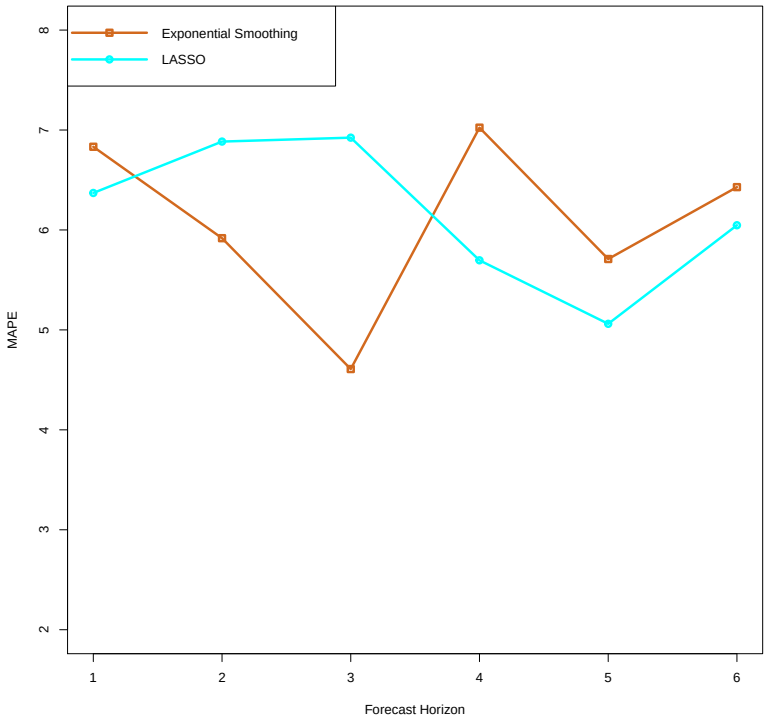


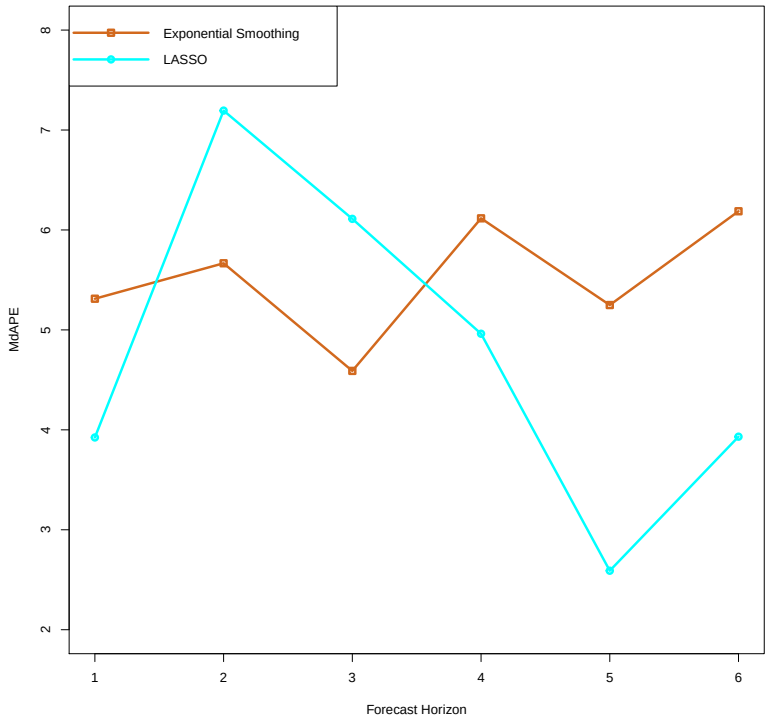
Empirical results: forecasting accuracy



Higher level

	MAPE	MdAPE
Exponential smoothing	6.1	5.5
LASSO	6.2	4.8



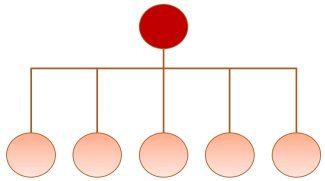


Reconciliation hierarchical forecasting

The hierarchy is captured in the summing matrix
Reconciliation incorporates $1/MSE$ of each forecast

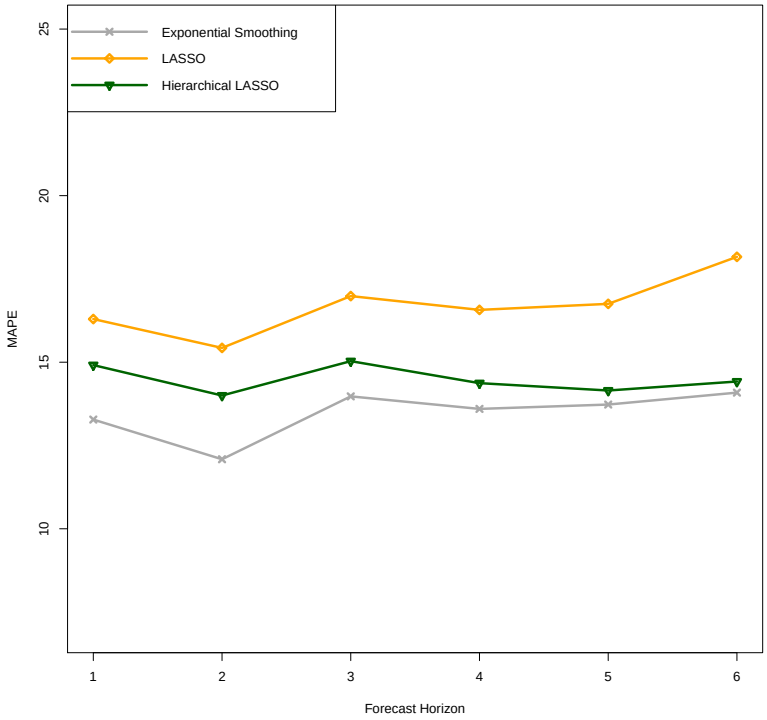
$$\begin{bmatrix} \hat{Y}_{Tot} \\ \hat{Y}_A \\ \hat{Y}_B \\ \hat{Y}_C \\ \hat{Y}_D \\ \hat{Y}_E \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{Y}_{A,r} \\ \hat{Y}_{B,r} \\ \hat{Y}_{C,r} \\ \hat{Y}_{D,r} \\ \hat{Y}_{E,r} \end{bmatrix}, \tag{3}$$

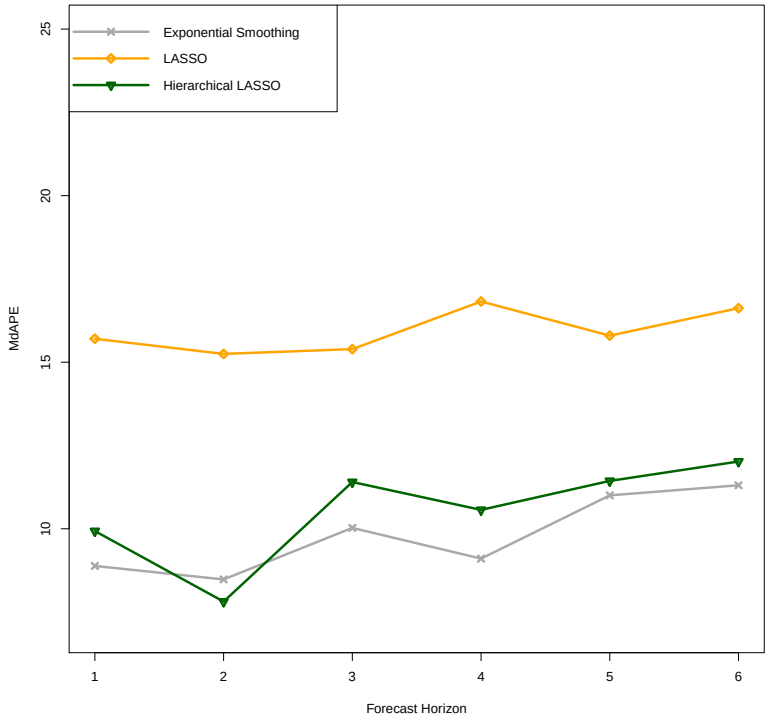
Empirical results: forecasting accuracy



Reconciled lower level

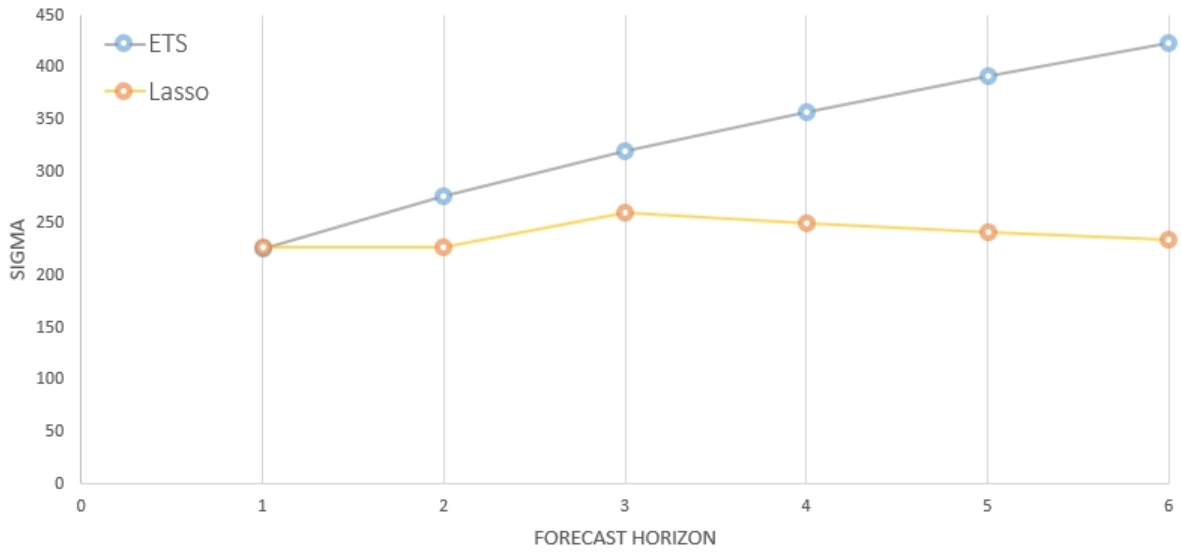
	MAPE	MdAPE
Exponential smoothing	13.5	9.8
LASSO	16.7	15.9
Hierarchical LASSO	14.5	10.5





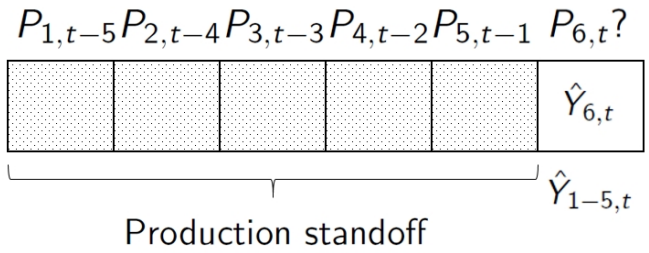
Uncertainty: iterative vs direct forecasting

Reformulated LASSO model for each horizon allows for empirical estimation of σ_h



Direct forecasting: independent across horizons
Iterative forecasting: covariances inflate variance

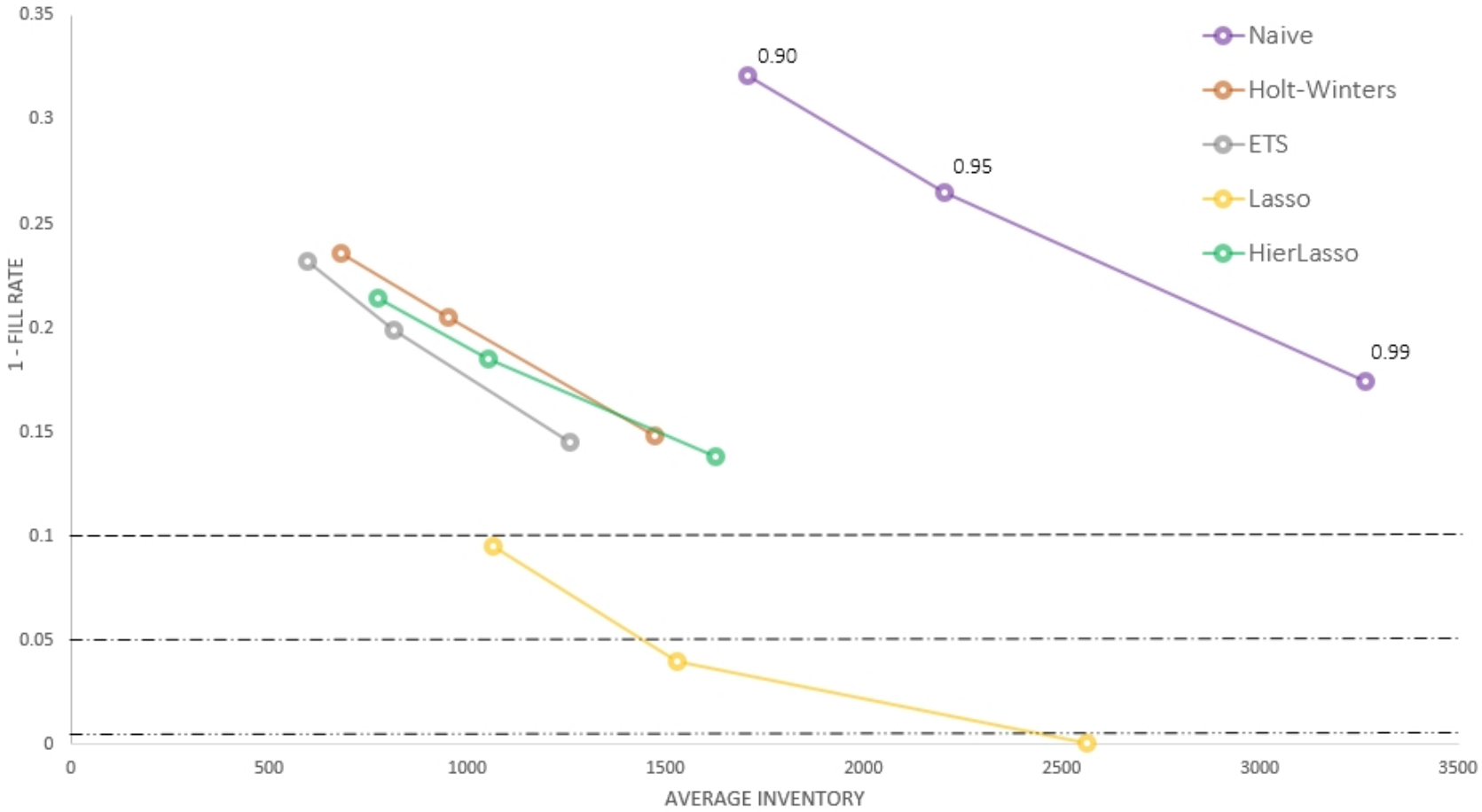
Inventory simulation



Simulation parameters

- Production standoff t+6
- Service level: 0.9, 0.95, 0.99
- Inventory policy: Make to stock

Average inventory per service level



Conclusion

- LASSO has an improved forecasting accuracy on long-term
- On short horizons, LASSO leads to service level and inventory improvements

Questions?

Thank you for your attention !

Yves R. Sagaert - yves.sagaert@ugent.be