The inventory impact of including macroeconomic leading indicators in global SCM

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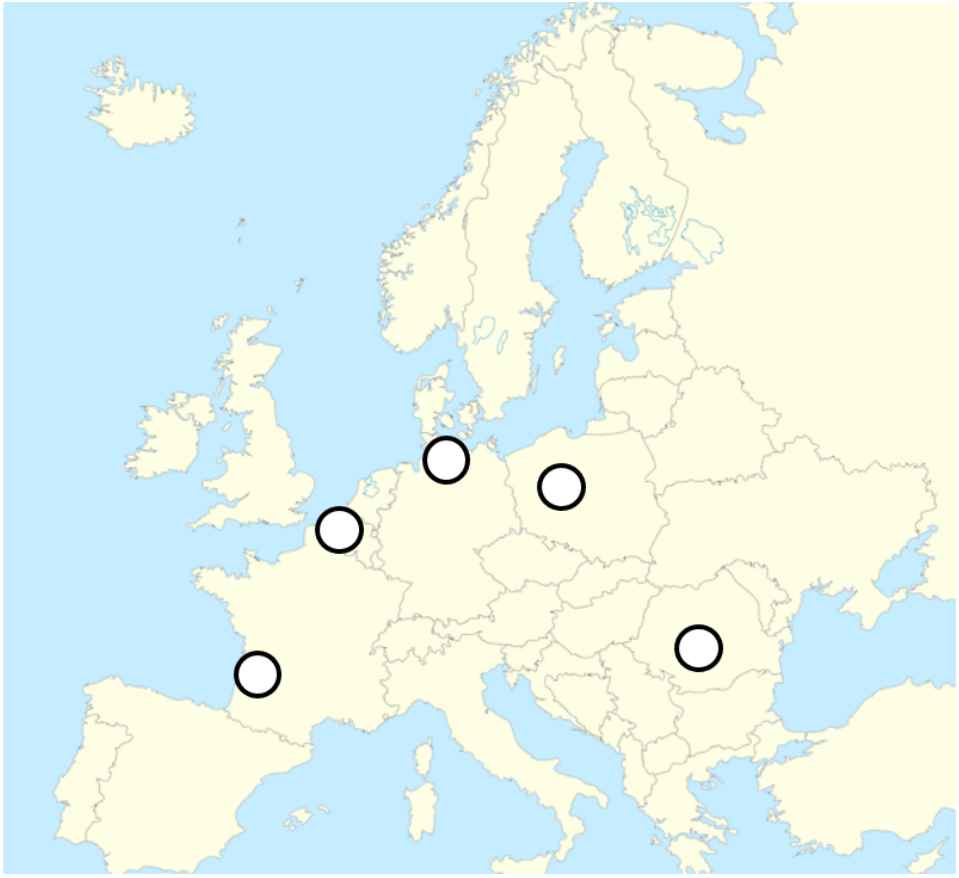
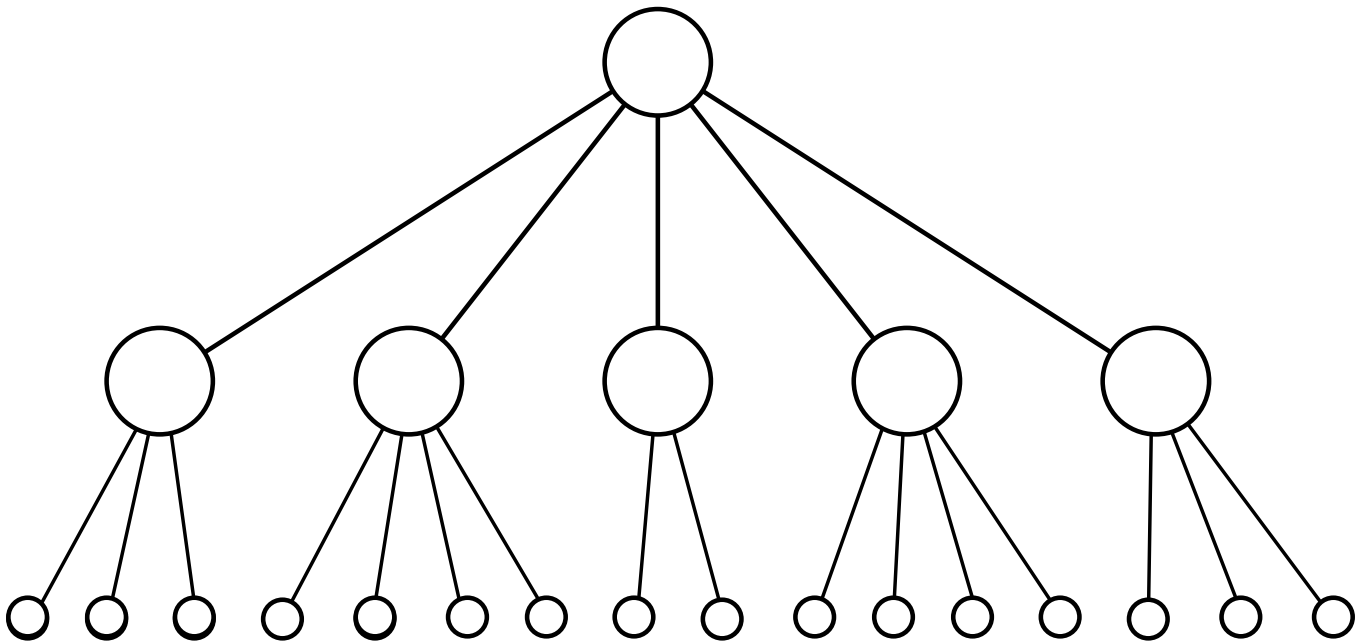
The company's production plants are distributed over Europe

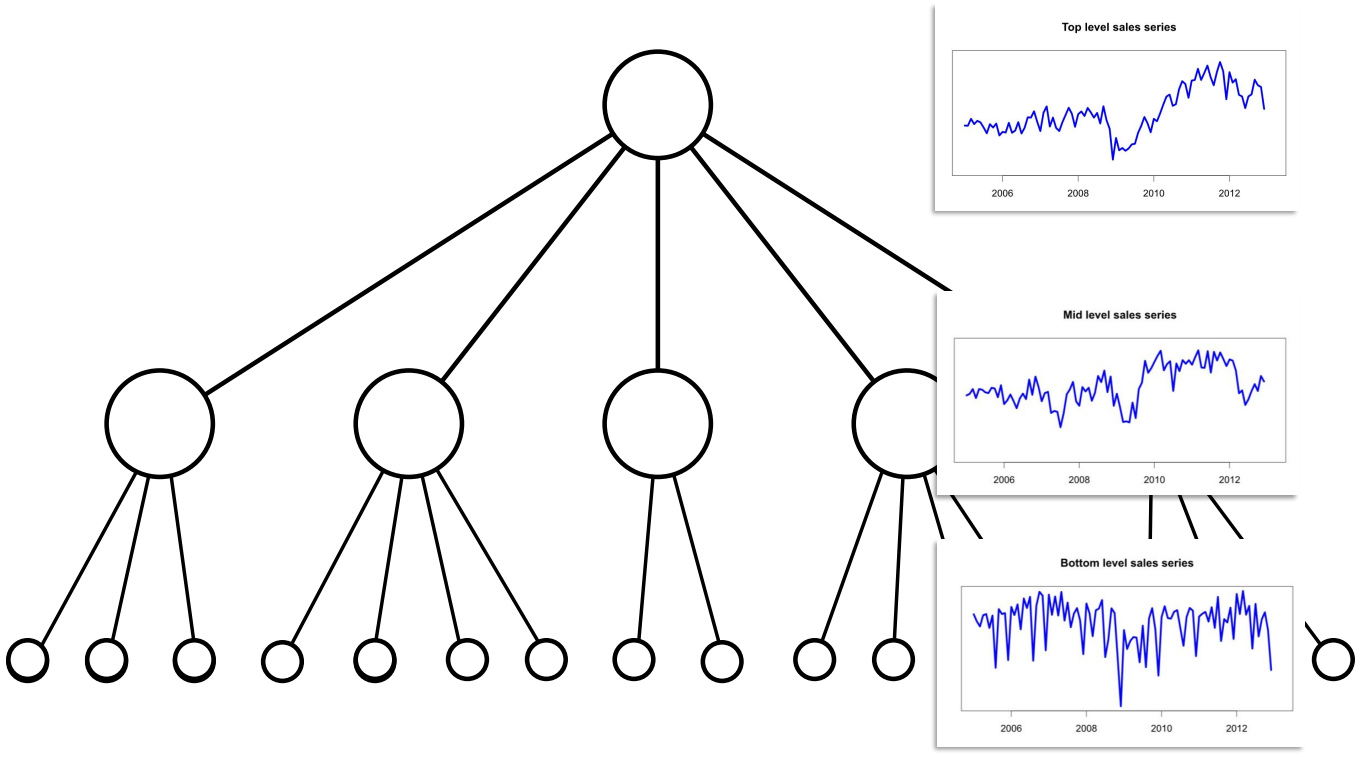


The sales data of a product family can be aggregated from Stock-Keeping-Unit (SKU) to plant level to Europe market level



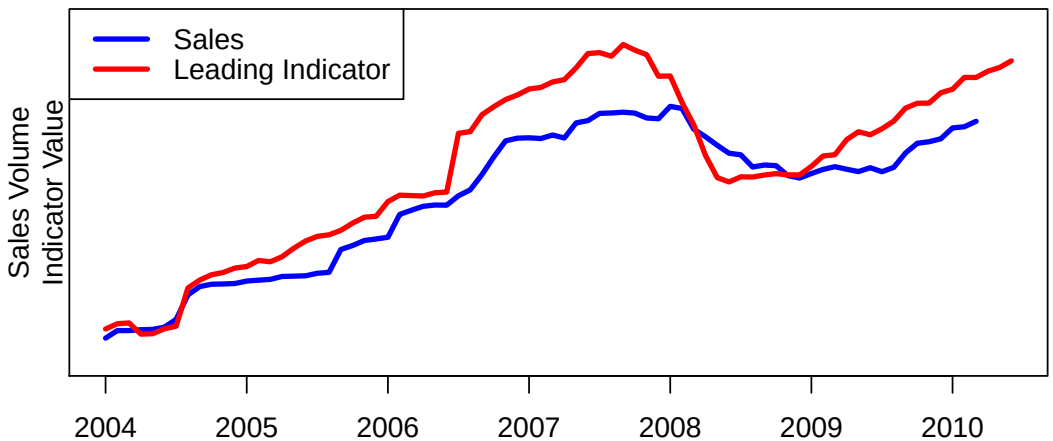
Motivation: leading indicators for European market

The time series on different aggregation levels have different properties.
Macroeconomic leading indicators can be identified on the top level.



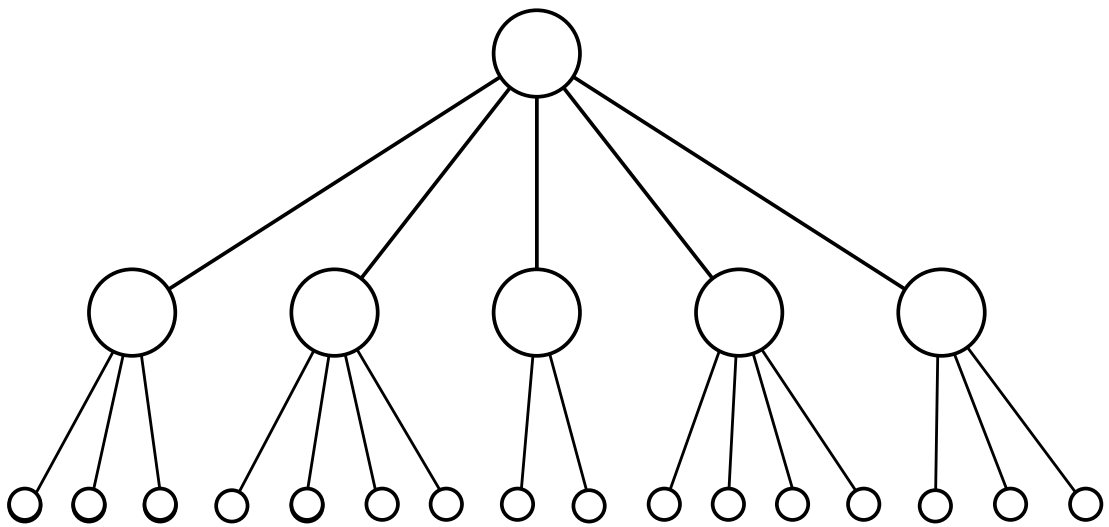
Sagaert et al.(2017) identifies relevant leading indicators via LASSO:

- Select from an extremely large set of potential indicators $(p \gg n)$
- Determine the appropriate leading effect
- Use conditional forecasts only so as to not need to forecast indicators



Benefit for SKU level planning?

- Leading indicators are identified at the aggregate level
- Inventory impact occurs at the lowest level



- Synthetos et al.(2010) conclude that a 1% MAPE reduction can translate into inventory reductions of 15% – 20%
- Babai et al.(2013) argue that forecast accuracy improvements do not necessarily imply inventory cost savings and/or a service level increase.
- Barrow et al.(2016) assess the forecast distribution through inventory evaluation
- Ali et al.(2017) note that minimising MSE does not imply saving costs on supply chain level

Hierarchical forecasting can be used to translate the impact of an improved top level forecast on the SKU level.

Wickramasuriya et al.(2018) propose reconciliation via

$$\tilde{y}_h = S(S'W^{-1}S)^{-1}S'W^{-1}\hat{y}_h \tag{1}$$

where S is the structural matrix and W is the matrix of the covariance of the errors.

Hyndman et al.(2016) proposes error variance scaling for W, using the in-sample one step ahead error variance of time series methods in each node .

LASSO is designed to underfit the in-sample data and therefore using in-sample MSE in the hierarchical forecasting for the reconciliation will be problematic. The MSE for Lasso and other methods are not qualitatively comparable.

Kourentzes (2018, working paper) showed that one can replace in-sample MSE with cross-validated errors and gain in performance. Cross-validated errors between LASSO and ETS are comparable, so we can reconcile now.

In-sample MSE

- Estimate the model on the training data
- Calculate the one step ahead in-sample MSE without re-estimating the model over a rolling origin

Cross-validated MSE

- Estimate the model on the training data
- Keep the model specification
- Split the training sample in base set and cross-validation set
- Re-estimate the model over a rolling origin, and calculate the one step ahead forecast and MSE
- We "mix" training and validation due to the limited sample size

Experimental Design

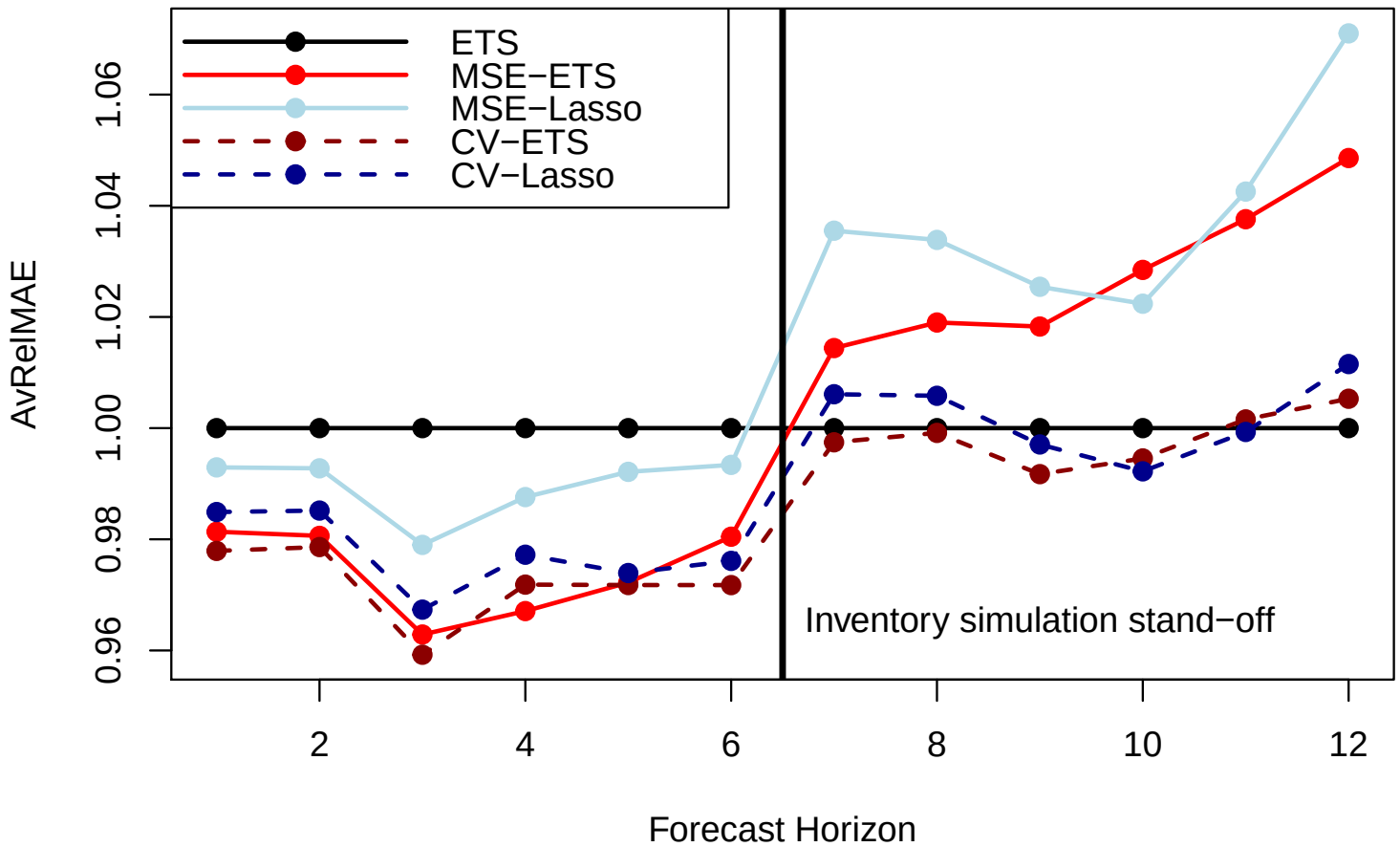
- Company case of a B2B tire manufacturer
- Train (96 months) and test set (18 months)
- Over 1000 indicators and 12 leading effects
- Evaluation over rolling origin
- Models:
  - ETS on SKU level (benchmark model in AvgRelMAE)
  - Hierarchy with LASSO on top level, ETS on mid & SKU level
  - Hierarchy with ETS on all 3 levels
- Average Relative Mean Absolute Error (Davydenko & Fildes, 2013)

$$AvgRelMAE = \left(\prod_{i=1}^{m} r_i^{n_i} \right)^{\frac{1}{\sum_{i=1}^{m} n_i}}, \; r_i = \frac{MAE_i^f}{MAE_i^b}. \qquad (2)$$

Evaluation:

- We review 14 main SKU time series of 5 production plants
- We evaluate forecast accuracy on forecast horizons 1 to 12
- The inventory simulation has a 5 months stand-off

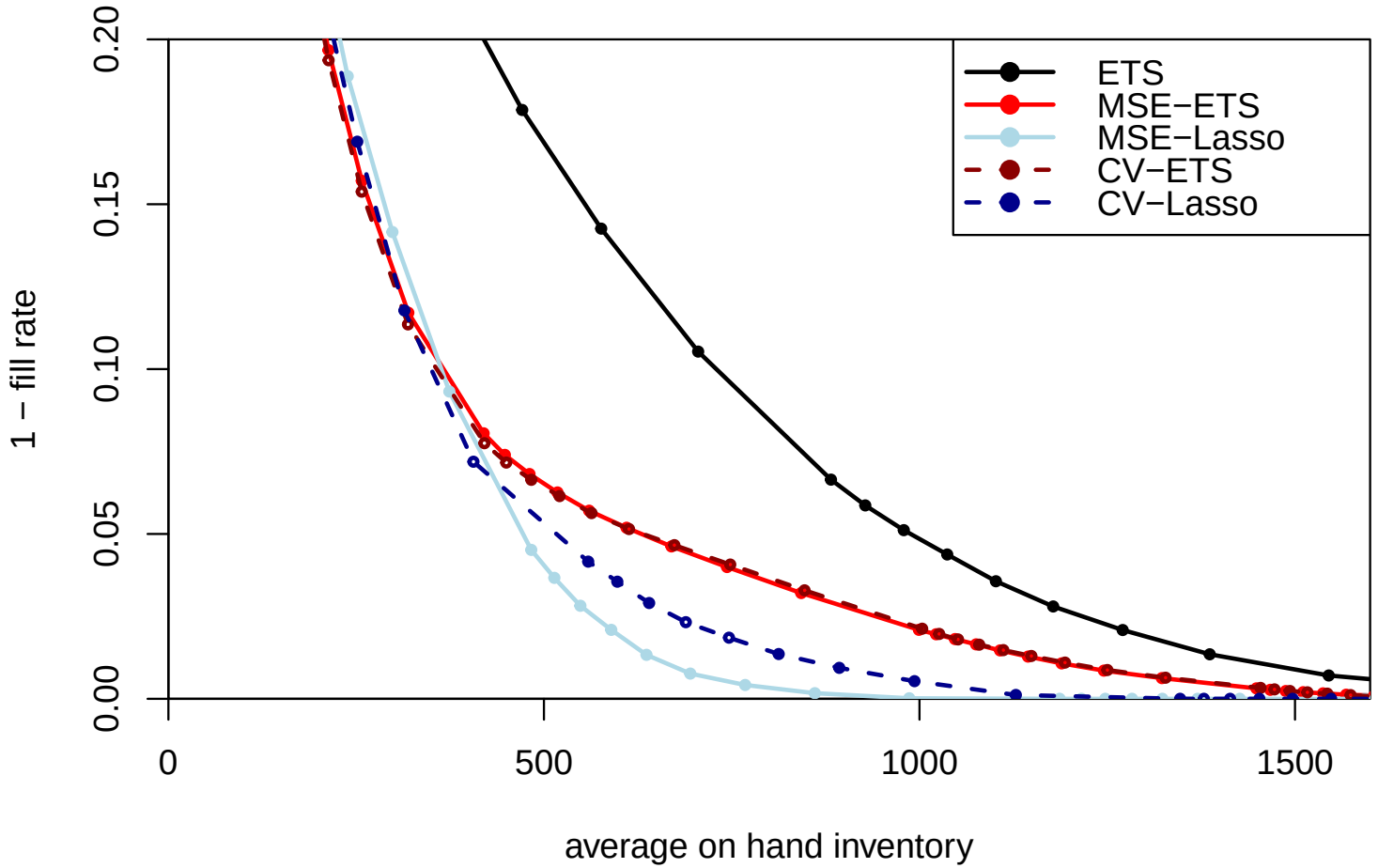
Reconciled forecasting results



Results:

- The LASSO hierarchical approach is better than benchmark ETS
- The ETS hierarchy is better than the LASSO hierarchy
- Cross-validated MSE improves accuracy over the in-sample MSE approach, for both hierarchical models

Inventory simulation results



Results:

- The hierarchical approaches perform better than benchmark ETS
- LASSO hierarchy performs better on high service levels / fill rates
- ETS hierarchy is marginally better for lower fill rates
- Cross-validated MSE and in-sample MSE reconciliation have an equal inventory performance for the ETS hierarchy
- In-sample MSE reconciliation performs better than cross-validated MSE for the LASSO hierarchy for high fill rates

We investigated whether LASSO on tactical level can benefit SKU planning decisions. For lower fill rates LASSO does not offer an advantage, but at high fill rates it does.

Conclusions:

- Although LASSO forecasts improve accuracy over ETS on top level, the benefit on SKU planning level is not apparent in terms of accuracy.
- Hierarchical has clear benefits on inventory compared to base forecasts.
- Using cross-validated errors for the reconciliation improves LASSO forecasts.

Questions?

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