

A probabilistic merit order for electricity price forecasting

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Overview

Introduction & Motivation

The classical merit order

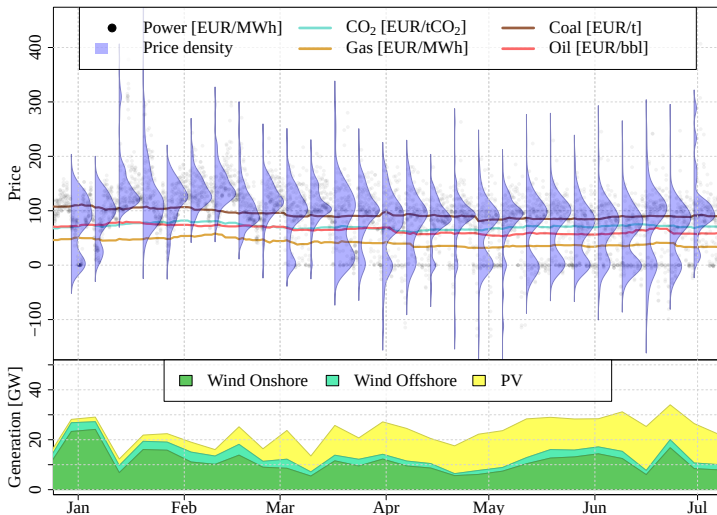
Step 1: Modeling of inputs

Step 2: Sampling & plug-in

Step 3: Calibration

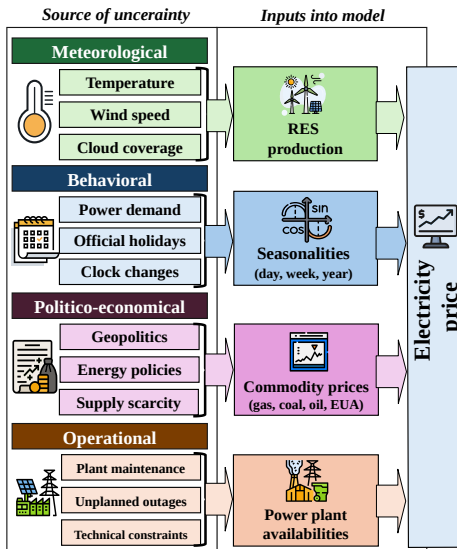
Results

German day-ahead power price distributions



► Highly complex and volatile time series, uncertainty changes

Sources of uncertainty



Data-driven and fundamental models



Data-driven models
(Statistical, econometric,
machine learning models)

Inputs:
Historical data

Outputs:
Power price

Data-driven and fundamental models



Data-driven models
(Statistical, econometric,
machine learning models)

Inputs:
Historical data

Outputs:
Power price



Fundamental models
(System simulation,
cost min, welfare max)

Inputs:
Power plant parameters
Current data
Operational constraints

Outputs:
Power price
Operational plans

Overview

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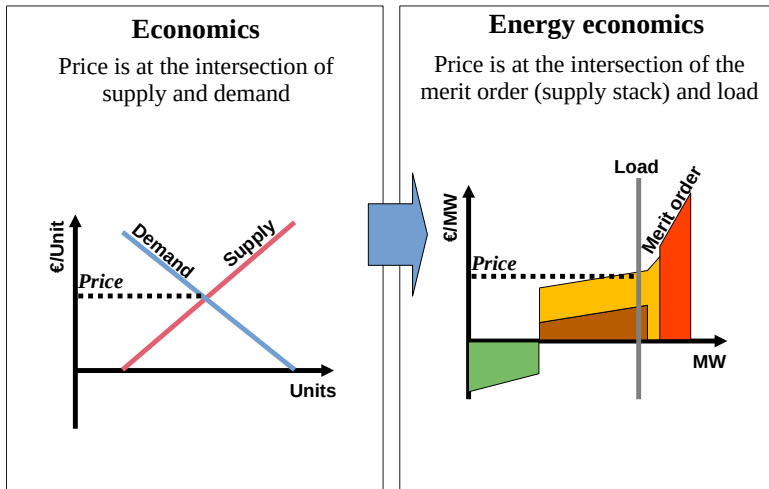
Step 1: Modeling of inputs

Step 2: Sampling & plug-in

Step 3: Calibration

Results

Simple fundamental model: the classical merit order

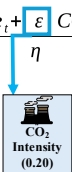


Constructing the merit order

$$VarCost_t = \frac{GasPrice_t + \varepsilon \ CO_2Price_t}{\eta} + OtherCost_t$$

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CO₂ Intensity (0.20)

Constructing the merit order

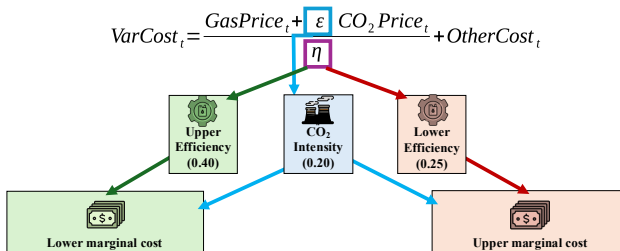
$$VarCost_t = \frac{GasPrice_t + \boxed{\varepsilon} CO_2 Price_t}{\boxed{\eta}} + OtherCost_t$$

Upper Efficiency (0.40)

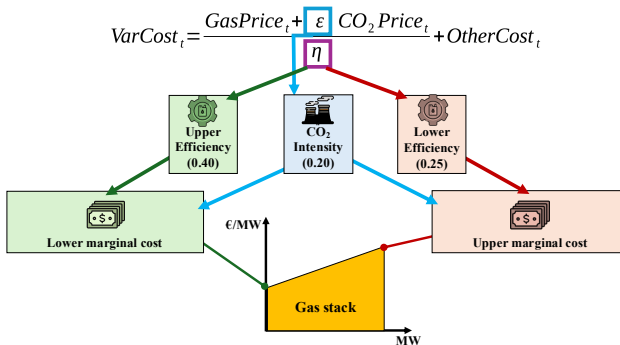
CO₂ Intensity (0.20)

Lower Efficiency (0.25)

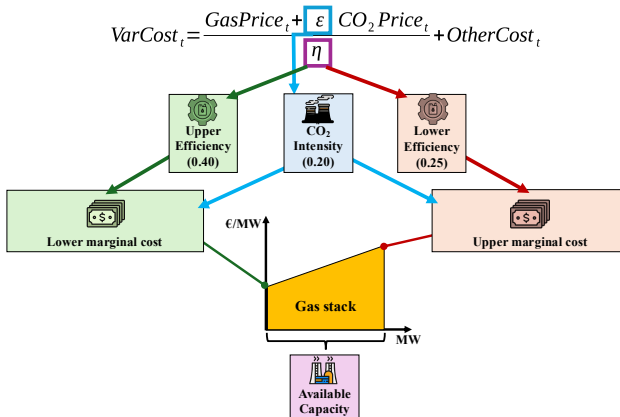
Constructing the merit order



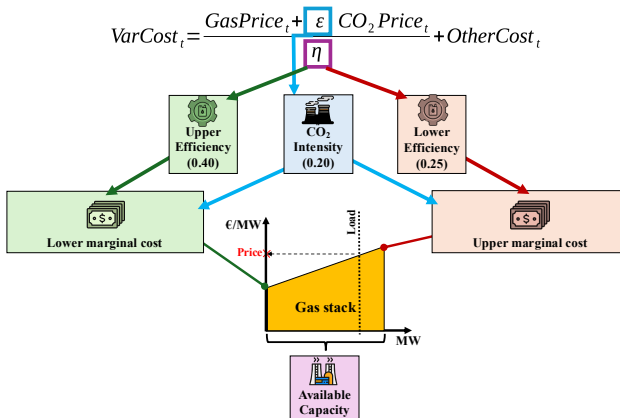
Constructing the merit order



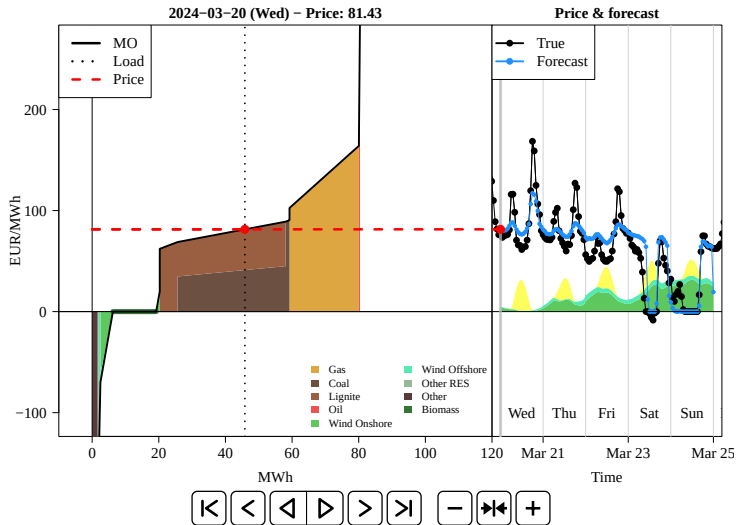
Constructing the merit order



Constructing the merit order



Modelling the price with the merit order



Proposal

To our knowledge, this is the first fully probabilistic fundamental model for electricity price forecasting.

3 steps:

1. Generate probabilistic forecasts for inputs
2. Sampling and put into a fundamental merit-order model $\Rightarrow$ price outcomes
3. Calibrating the model parameters to historical data

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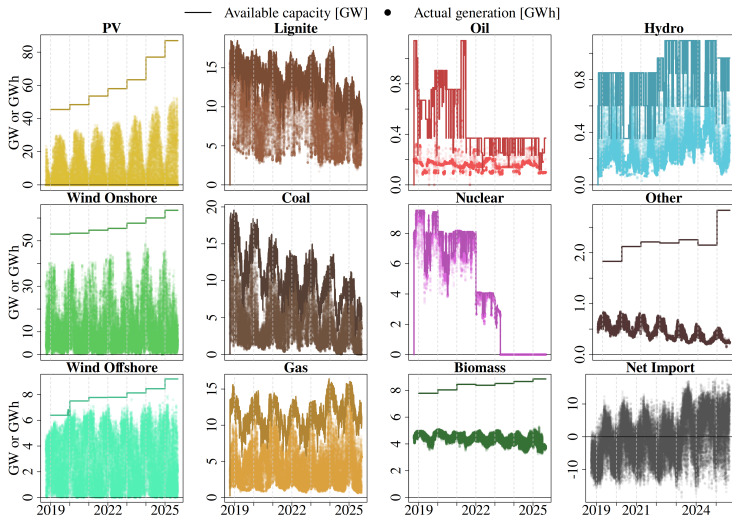
Step 1: Modeling of inputs

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Step 3: Calibration

Results

Power plant availabilities



Distributional forecasting of inputs (GAMLSS framework)

- ▶ for each input variable y_{t+1} model each parameter of its distribution distribution $\mathcal{D}$ given regressors $\mathbf{X}_t$

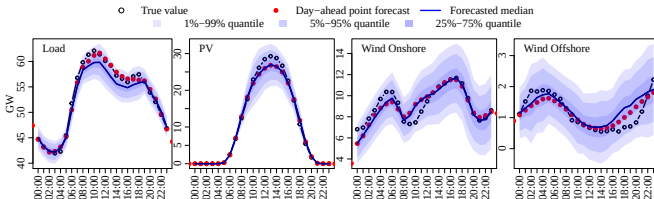
$$y_{t+1} \mid \mathbf{X}_t \sim \mathcal{D}\left(\theta_{t+1}^{(1)}, \dots, \theta_{t+1}^{(n)}\right), \quad (1)$$

$$g_i\left(\theta_{t+1}^{(i)}\right) = \mathbf{X}_t \beta^{(i)}, \quad i = 1, \dots, n,$$

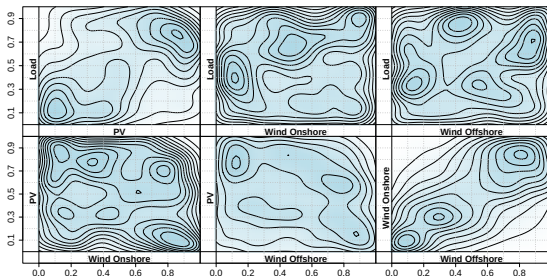
- ▶ e.g. $\mathcal{D} = \mathcal{N}$, $g(\cdot)$ is a link function

Input forecasting - results

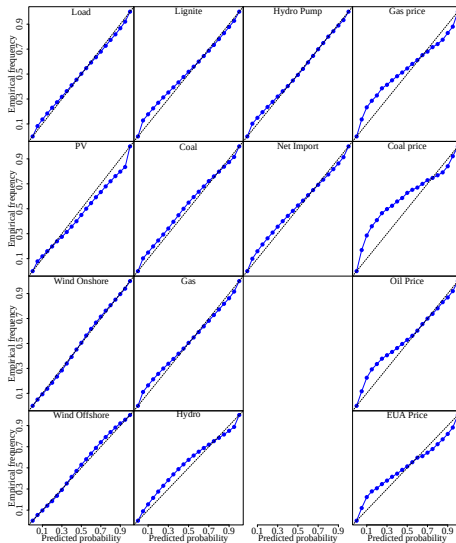
► Results



► Dependency modelling via empirical copula:



Calibration



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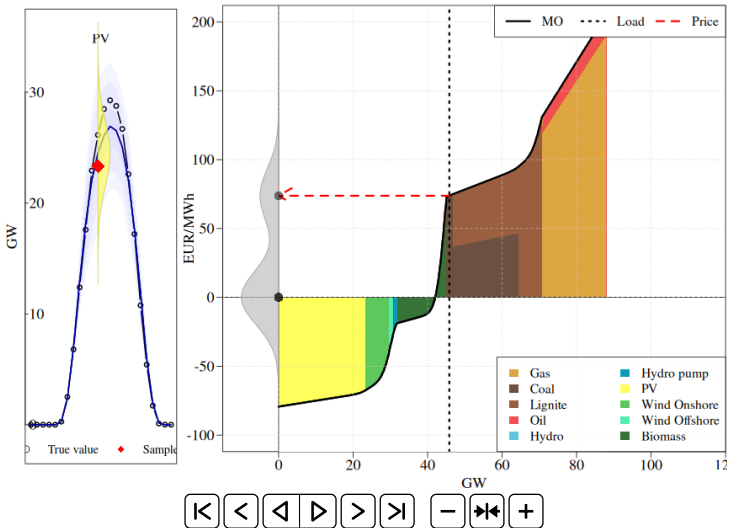
Step 1: Modeling of inputs

Step 2: Sampling & plug-in

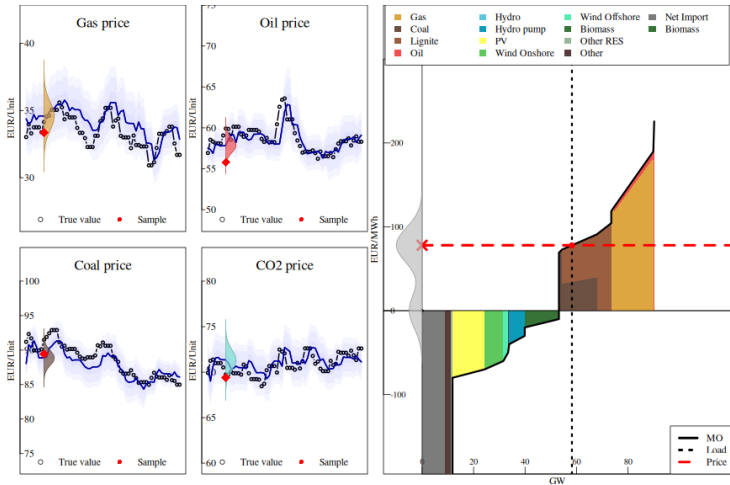
Step 3: Calibration

Results

Effects - RES



Effects - Fuels



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Results

Estimating the parameters

- Parameters of the merit order model in:
 $\Theta^{\text{MO}} = \{\text{Efficiencies, CO2 intensities, } \dots\}$
- Estimate the parameters Θ^{MO} by minimizing CRPS:

$$\hat{\Theta}^{\text{MO}} = \arg \min_{\Theta^{\text{MO}}} \left(\frac{1}{N} \sum_{t=1}^N \text{CRPS} \left(\underbrace{\text{MO}_t(\text{Load}_t; \Theta^{\text{MO}})}_{\text{Price}_t}, \text{Price}_t \right) \right) \quad (2)$$

s.t. $\Theta^{\text{L}} \leq \Theta^{\text{MO}} \leq \Theta^{\text{U}}$

- Efficiencies treated as hyperparameters (weights) to be estimated
- Solved using black-box Bayesian stochastic optimization (R package mlrMBO).

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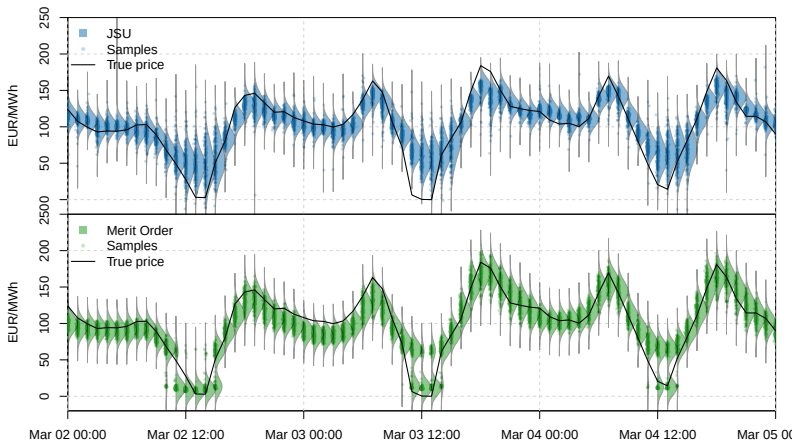
Results

Errors

	RMSE	MAE	CRPS
Naive	41.47	25.98	20.46
JSU	29.19	18.21	14.04
Data-Driven MO	25.81	17.28	13.92

Table 1: Model Error Comparison

Distribution



Link

► Previous work:

**A data-driven merit order:
Learning a fundamental electricity price model**



<https://arxiv.org/abs/2501.02963>

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