

Electricity energy price forecasting based on hybrid multi-stage heterogeneous ensemble: Brazilian commercial and residential cases

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Agenda

- Introduction
- Objectives and Contribution
- Datasets
- Methodology
- Results
- Conclusion
- References





Introduction









Objective

Proposes a hybrid heterogeneous ensemble learning model to forecasting Brazilian electricity prices multi-step-ahead (one, two, and three-months-ahead).

> Hybrid approach is composed by Complementary Ensemble Empirical Mode Decomposition (CEEMD), Coyote Optimization Algorithm (COA), and heterogeneous ensemble of components





Proposition of a self-adaptive decomposition approach for electricity price forecasting

Contributions

The first use of the combination of CEEMD and COA approaches.

Evaluation of decomposed homogeneous and heterogeneous ensemble learning models for electricity price forecasting.





Datasets - Brazilian Electricity energy price (R\$/MWh)



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Methodology

- Pre-process: CEEMD
- Optimization: COA
- Heterogeneous models:
 - **ELM** (Extreme Learning Machine)
 - **GP** (Gaussian Process)
 - **GBM** (Gradient Boosting Machine)
 - **RVM** (Relevance Vector Machine)
- Performance measures and statistical test

TABLE V Models adopted by each component in each dataset

Dataset	Component		Forecasting Horizon	l	
		One-month-ahead	Two-months-ahead	Three-months-ahead	
Commercial	IMF ₁	ELM	ELM	ELM	
	IMF_2	GP	ELM	RVM	
	IMF ₃	GBM	GP	GBM	
	Residue	GP	GP	GP	
Residential	IMF ₁	GP	GP	RVM	
	IMF_2	GP	ELM	GBM	
	IMF ₃	ELM	ELM	RVM	
	Residue	GP	GP	GP	



Flowchart of proposed framework





Decomposed Data

Commercial Case

Residential Case

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Results – Fyneriment 1

TABLE VI

PERFORMANCE MEASURES OF PROPOSED AND COMPARED MODELS USED TO FORECASTING BRAZILIAN ELECTRICITY PRICE MULTI-STEP-AHEAD

		Forecasting Horizon						
Dataset	Model	One-month-ahead		Two-months-ahead		Three-months-ahead		
		MAE	RRMSE	MAE	RRMSE	MAE	RRMSE	
	Proposed	9.1191	0.0272	12.5722	0.0415	14.0000	0.0501	
Commercial	COA-CEEMD-GP	9.8200	0.0295	12.6248	0.0417	14.2700	0.0510	
	COA-CEEMD-ELM	38.0209	0.1289	68.6489	0.2489	83.8030	0.2926	
	COA-CEEMD-GBM	108.6709	0.3490	109.1811	0.3500	109.6404	0.3500	
	COA-CEEMD-RVM	303.1389	0.9202	314.3207	0.9431	322.8980	0.9522	
	Proposed	8.9811	0.0305	11.0507	0.0381	13.2598	0.0460	
Residential	COA-CEEMD-GP	9.0935	0.0310	11.1217	0.0390	13.2872	0.0473	
	COA-CEEMD-ELM	35.0976	0.1146	52.1548	0.1786	60.5261	0.2000	
	COA-CEEMD-GBM	103.2843	0.3175	103.5004	0.3174	104.3387	0.3176	
	COA-CEEMD-RVM	310.2537	0.9146	327.5563	0.9344	334.7754	0.9444	





Results – Experiment 2

TABLE VII

PERFORMANCE MEASURES OF PROPOSED AND COMPARED MODELS USED TO FORECASTING BRAZILIAN ELECTRICITY PRICE MULTI-STEP-AHEAD

	Model	Forecasting Horizon						
Dataset		One-month-ahead		Two-months-ahead		Three-months-ahead		
		MAE	RRMSE	MAE	RRMSE	MAE	RRMSE	
	Proposed	9.1191	0.0272	12.5722	0.0415	14.0000	0.0501	
Commercial	GP	10.1264	0.0366	13.0655	0.0487	15.4955	0.0577	
	ELM	61.8013	0.2107	51.7893	0.1774	66.5200	0.2331	
	GBM	109.7469	0.3525	110.3789	0.3529	111.0765	0.3531	
	RVM	320.8700	0.9463	331.5674	0.9605	334.7101	0.9640	
	Proposed	8.9811	0.0305	11.0507	0.0381	13.2598	0.0460	
Residential	GP	9.4405	0.0342	12.1558	0.0451	14.4413	0.0552	
	ELM	52.9344	0.1721	95.2086	0.3413	91.7472	0.3177	
	GBM	105.467	0.3231	106.5075	0.3258	106.9078	0.3259	
	RVM	325.8226	0.9275	348.0082	0.9558	360.2490	0.9681	







Results - Diebold-Mariano test

TABLE VIII

STATISTIC OF DM TEST FOR STATISTICAL COMPARISON OF PROPOSED APPROACH VERSUS OTHER MODELS

	Forecasting Horizon							
Model	One-month-ahead		Two-mon	hts-ahead	Three-months-ahead			
	Commercial	Residential	Commercial	Residential	Commercial	Residential		
COA-CEEMD-ELM	-5.93***	-5.95***	-4.83***	-4.14***	-3.71***	-3.31***		
COA-CEEMD-RVM	-11.78***	-11.73***	.7 27***	<u>.7 49***</u>	-5.87***	-6.06***		
COA-CEEMD-GP	-1.99*	-1.63*	-0.19	-0.86	-1.31*	-1.34*		
COA-CEEMD-GBM	-8.79***	-8.87***	-5.17***	-5.11***	-4.04***	-3.96***		
ELM	-7.05***	-7.01***	-4.90***	-4.87***	-4.49***	-3.84***		
RVM	-12.78***	-12.41***	-7.85***	-8.35***	-6.10***	-6.95***		
GP	-1.91*	-1.12*	-1.45*	-1.41*	-1.99**	-1.95**		
GBM	-8.98***	-8.91***	-5.22***	-5.15***	-4.06***	-4.00***		

Note: ***1% significance level; **5% significance level; * 10% significance level.



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Results – Predicted versus Observed electricity prices

Commercial case

Residential Case

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Conclusion

Hybrid multi-stage heterogeneous ensemble model was proposed to forecast multi-step-ahead (one, two, and three-months-ahead) Brazilian commercial and residential electric energy prices. (i) The political, climatic and demand factors were not taken into account in the data analysis; (ii) The proposed model was not able to capture the variability of an extreme observation for the set of data referring to the price of residential electricity; and (iii) The parameters of COA optimizer were selected by trial and error.





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Conclusion

Heterogeneous ensemble achieved better forecasting accuracy than homogeneous ensembles COA-CEEMD heterogeneous models is better than nondecomposed models regarding forecasting accuracy



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