A Comparative Analysis of Different Forecast Reconciliation Methods ACROSS Multiple Hierarchical Structures of Energy Consumption in Brazil

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# Overview

Accurate forecasting of energy demand is crucial for decision-makers seeking to formulate optimal strategies that balance risk reduction and socioeconomic development. This study explores a comparative analysis of multiple Hierarchical Time Series (HTS) structures of a power system and different forecast reconciliation methods in the context of energy consumption in the Brazilian National Interconnected System (SIN). Using monthly data spanning from January 2004 to December 2022, the research aims to provide insights into the accuracy of various forecasting approaches across multiple regions and classes of consumption within the Brazilian SIN. By addressing the complexities of energy consumption forecasting, particularly in a system as vast and diverse as Brazil's, this study contributes to the ongoing efforts to enhance decision-making processes in the energy sector.

**Methods**

The methodology consists of two major steps: fist, Hierarchical Time Series (HTS) structures that capture the intricacies of energy consumption across different levels of aggregation in the Brazilian National Interconnected System (SIN) are constructed. Then, multiple traditional and state-of-the-art forecast reconciliation techniques are considered to assess which forecasting approach better suits the dynamics of the Brazilian power system. Two hierarchical structures are considered: the first considers an initial division of the total electricity consumption in the Brazilian SIN across different geographical regions. Then, for each geographical region considered, subsequent divisions of classes of consumption are proposed. The second hierarchical structure proposes an initial division of total electricity consumption by classes of consumption and then by geographical regions. Past the construction phase, univariate forecast methodologies are employed to generate the initial, base forecasts for each time series in the hierarchical structures. Finally, a set of eight different forecast reconciliation methods is used aiming to generate the final, coherent forecasts of each time series across the hierarchies. The objective of such reconciliation techniques, besides providing the most accurate forecasts, is to ensure coherence in the forecasts, i.e., guaranteeing that these forecasts (i) have minimal inconsistencies or errors compared to other forecast sets and (ii) appropriate summation of their values across hierarchy levels, where the sum of time series forecasts at a given level equals the forecast value of the time series at the immediately superior level.

# Results

Significant improvements in forecast accuracy are observed when employing robust reconciliation techniques, particularly in hierarchical time series structures where regional divisions constitute the intermediate level. The results of performance metrics also suggest better forecasting performance when forecasting time series at the national, i.e., most aggregated, level of the hierarchy. Moreover, the study highlights the nuanced impact of hierarchical structure considered on the efficacy of the reconciliation methods, underscoring the importance of tailored approaches in enhancing forecast accuracy.

**Conclusions**

The findings underscore the pivotal role of reconciliation methods in enhancing forecast accuracy across multiple hierarchical structures of energy consumption series. The study also sheds light on the nuanced impact of hierarchical structure on the accuracy of reconciliation methods, emphasizing the need for tailored approaches to address the complexities inherent in energy consumption forecasting. Finally, recommendations for future research provide a roadmap for further exploration and refinement of forecasting methodologies in complex power systems like the SIN, ultimately contributing to more robust decision-making processes in the energy sector.

# References

Gross, C. W., Sohl, J. E. (1990). Disaggregation methods to expedite product line forecasting. Journal of Forecasting, 9(3):233–254.

Huber, P. J. Robust estimation of a location parameter. Ann Math Stat 1964;35(1):73–101.

Hyndman, R. J., Ahmed, R. A., Athanasopoulos, G., Shang, H. L. (2011). Optimal combination forecasts for hierarchical time series. Computational Statistics & Data Analysis, 55(9):2579– 2589.

Hyndman, R. J., Lee, A. J., Wang, E. (2016). Fast computation of reconciled forecasts for hierarchical and grouped time series. Computational statistics & data analysis, 97:16–32.

Lila, M. F., Meira, E., Cyrino Oliveira, F. L. (2022). Forecasting unemployment in Brazil: A robust reconciliation approach using hierarchical data. Socio-Economic Planning Sciences, 82:101298.

Meira, E., Cyrino Oliveira, F. L., De Menezes, L. M. (2021). Point and interval forecasting of electricity supply via pruned ensembles. Energy, 232:121009.

Meira, E., Lila, M. F., Cyrino Oliveira, F. L. (2023). A novel reconciliation approach for hierarchical electricity consumption forecasting based on resistant regression. Energy, 269:126794.

Wickramasuriya, S. L., Athanasopoulos, G., Hyndman, R. J. (2019). Optimal forecast reconciliation for hierarchical and grouped time series through trace minimization. Journal of the American Statistical Association, 114(526):804–819.

Wang L (2013). The L1 penalized LAD estimator for high dimensional linear regression. Multivariate Anal 2013;120:135–51.