



ITISE-2026

PROGRAM

15th-17th JULY, 2026
Gran Canaria (SPAIN)

ITISE-2026 Program

Tuesday, July 14th, 2026	
18:30-20:00	REGISTRATION DESK <i>(start at 18:30h but it is open during all the conference)</i>
18:30-20:00	Upload the presentations to the room's computer (in case you haven't sent them by email). Meeting of the attendees with the Program Committee and Organizers of ITISE-2026

NOTES:

- All **Sessions A** will be held in Hotel Lopesan Villa del Conde Resort. They are **face-to-face sessions**, and they will also be shared on-line by Zoom. The **plenary lectures** are in **Session A**.
- All **Sessions B** will be held on-line (virtual) using Zoom.
- **Oral** Presentation: **15 minutes** (including questions). **Short Presentation: 8 minutes** (including questions). Depending on whether there are absent speakers, times may be adjusted.
- **Poster** authors are requested to place their posters on the panels before the start of the poster session (e.g. posters can be placed before 14:00 o'clock, before the lunch break). It is recommended to use **A0 size** and large fonts.



Session A: Located on the top floor of the main building

Wednesday, July 15th, 2026		
8:30	REGISTRATION DESK <i>(start at 8:30h but it is open during all the conference)</i>	
	All Sessions A: Oral <u>face-to-face sessions</u> . All Sessions B: Oral Virtual (will be held on-line by Zoom)	
9:00-10:00	Session A.1: Econometrics and Forecasting	Session B.1: Advanced Methods and On-line Learning in Time Series
10:00- 11:00	Session A.2: Financial Forecasting and Risk Analysis	Session B.2: Energy Forecasting
11:00-11:40	COFFEE BREAK	
11:40-13:00	Session A.3: Forecasting in Real Problems	Session B.3: Time Series Analysis and Forecasting
13:00-14:00	Session A.P1: Opening & Plenary Lecture. Prof. Eamonn Keogh Distinguished Professor, Department of Computer Science and Engineering University of California Riverside	
14:00-16:00	REST BREAK	
16:00-17:00	Session A.4: Advances in Time Series Methods	Session B.4: Time Series Applications in Energy, Finance, Transport, Health and Environmental Systems (Part I)
16:00-18:00	Session A.5: POSTER SESSION	(17:00-18:00) Virtual Session A.P2: Plenary Lecture. Prof. William A. Barnett Director at the Center for Financial Stability in New York City
	BREAK	
18:15-19:45	Session A.6: Advances in Time Series, Prediction and Data Analysis Short Presentations	Session B.5: Econometrics and Forecasting (Part I)

Thursday, July 16th, 2026		
8:45	REGISTRATION DESK <i>(start at 8:45h but it is opened during all the conference)</i>	
	All Sessions A: Oral <u>face-to-face sessions</u> . All Sessions B: Oral Virtual (will be held on-line by Zoom)	
9:00- 10:40	Session A.7: Time Series Applications in Energy, Finance, Transport, Health and Environmental Systems	Session B.6: Nonstationarity
10:40-11:15	COFFEE BREAK	
11:15-12:00	Session A.8: Advanced Econometrics Methods and Prediction	Session B.7: AI-based Forecasting
12:00-13:00	Session A.9: Robust Time Series Methods in the Time and Frequency Domains. Applications in Environmental, Health and Natural Science	Session B.8: Forecasting in Real Problems
13:00-14:00	Session A.P3: Plenary Lecture. Prof. Robert Boute Full professor Faculty of Economics and Business (FEB), KU Leuven; member of Leuven.AI - KU Leuven Institute for Artificial Intelligence	
14:00-16:00	REST BREAK	
		Session B.9: Advanced Time-Series Forecasting and Data-Driven Methods for Energy Systems and Smart Grids
16:00-17:00	Session A.10: Computational Intelligence and Sensor-Driven Time Series Analysis for Renewable Energy Forecasting	Session B.10: Econometrics and Forecasting (Part II)
17:00-18:10	Session A.11: Current Trends and Applications in Time Series Analysis Short Presentations	Session B.11: Advances in Time Series, Forecasting and Computational Methods
18:30	VISIT TO PUERTO DE MOGÁN GALA DINNER- MASPALOMAS GOLF	

Friday, July 17th, 2026		
8:45	REGISTRATION DESK <i>(start at 8:45h but it is opened during all the conference)</i>	
	All Sessions A: Oral <u>face-to-face sessions</u> . All Sessions B: Oral Virtual (will be held on-line by Zoom)	
9:00-10:00	Session A.12: Time Series for Sustainability and Environment	Session B.12: Theory, Inference, and Applications
10:00- 10:45	Session A.13: Forecasting and Planning Systems	Session B.13: Advances in Time Series Methods
10:45-11:30	COFFEE BREAK	
11:30-12:15	Session A.14: Time Series Analysis with Computational Intelligence	Session B.14: Session B.14: Time Series Applications in Energy, Finance, Transport, Health and Environmental Systems (Part II)
12:15-13:00	Session A.15: Time Series in Econometrics	
13:00 -14:00	Session A.P4: Plenary Lecture. Prof. Hossein Bonakdari Ph.D., P.Eng., esteemed professor at the University of Ottawa, Canada.	



Puerto de Mogán: The "Little Venice" of the Canaries

Located on Gran Canaria's southwest coast, **Puerto de Mogán** is a picturesque fishing village and one of the archipelago's most relaxing, family-friendly, and photogenic destinations.

Gala Dinner: After the excursion, the bus will be used again to transfer to the gala dinner, which will be held at **Maspalomas Golf Course**—an idyllic setting in the south of Gran Canaria for hosting intimate dinners or events surrounded by nature and palm trees

ITISE 2026 PROGRAM

Wednesday, July 15th, 2026

(9:00-10:00) Session A.1: Econometrics and Forecasting

Chairman: Dr. Mihai Mutascu and Dr. Juan R Trapero

Obsolescence Aware Intermittent Demand Forecasting with Enhanced mSBA Models (**Ref: 1331**)

Francesco Lolli, Antonio Maria Coruzzolo, Enrico Mizzi, Elia Balugani and Mohamed Zied Babai

The Fragility Behind the Peg: a Two Continuous-Time-Equation Framework for the Dynamics of the Currency Board (**Ref: 1451**)

Eleonora Cavallaro and Bernardo Maggi

In-sample dynamic selection of models and parameters for optimal forecast combination (**Ref: 6573**)

Pieter de Kok, Francisco Blasques and Siem Jan Koopman

Does Trade Competition with the United States Influence CO2 Emissions in China? (**Ref: 7076**)

Mihai Mutascu and Scott W. Hegerty

(9:00-10:00) Session B.1: Advanced Methods and On-line Learning in Time Series

Chairman: Dr. Ronan Timon

Recursive HMM-Based Structural Monitoring for Adaptive Financial Time Series Forecasting (**Ref: 4525**)

Lucía Calderón-García, Julio E. Sandubete and Ana Lazcano

Predictive Attribution of Urban Canopy Air Quality Drivers in an Equatorial Background Atmosphere (**Ref: 5206**)

Wan Yun Hong

Offline Changepoint Annotation to Online Changepoint Detection: A Framework for Wastewater Treatment Sensor Data (**Ref: 5560**)

Ronan Timon and James McDermott

SSA or MSSA? On the Supportiveness of a Similar Auxiliary Series for Forecasting (**Ref: 5944**)

Nina Golyandina, Nikita Fedorov, Ikbal Khasas and Alexander Khramov

(10:00-11:00) Session A.2: Financial Forecasting and Risk Analysis

*Chairman: Dr. Martin Wagner**

Time-Varying Functional Cointegration under Structural Instability (**Ref: 1383**)

Mile Bošnjak, Ivan Novak and Silviya Vlah Jerić

How far ahead can the Federal Reserve forecast? (**Ref: 1682**)

Constantin Burgi

How to create interpretable credit risk rules using data-driven segmentation (a pragmatic alternative to ML for credit risk management) (**Ref: 2656**)

Marko Zoldoš

Vector Entropy Modeling as a Tool for Monitoring and Forecasting the State of Economic Systems (**Ref: 7806**)

Alexander Tyrsin, Michail Gerasimov and Michael Beer

(10:00-11:00) Session B.2: Energy Forecasting

Chairman: Dr. Francisco Javier Cara Cañas and Dr. Lucía Calderón-García

The Impact of Photovoltaic Self-Consumption on Long-Term Electric Demand Forecasting Accuracy (**Ref: 1173**)

Ana Vendrell Blanco, Eduardo Caro, Javier Cara and Jesús Juan

Hybrid Machine Learning Approach for Short-Term Load Forecasting in Small Commercial Buildings (**Ref: 5341**)

Aitor Diez Mateo, Roberto Garay-Martinez, Cruz Enrique Borges Hernandez and Ana García Garre

Performance Analysis of Electric Load Forecasting Models under Extreme Weather Conditions (**Ref: 7295**)

Eduardo Caro, Jesus Juan, Javier Cara and Ana Vendrell

Quantifying demand for housing estates: A comparison of statistical approaches application to Türkiye (**Ref: 8608**)

Eda Ustaoglu and Suleyman Sisman

(11:40-13:00) Session A.3: Forecasting in Real Problems

*Chairman: Dr. Rafael González-Val and Dr. Miriam Marcén**

Forecasting Taily Tourism Demand 365 Days Ahead with Monthly Data:
Disaggregation, Calendar and Mobile Phone Data (**Ref: 5101**)

Martin Wagner

Hybrid Model for Long-Term and Short-Term Power Demand Forecasting
in HPC Data Centers (**Ref: 5441**)

*Stefano Rinaldi, Chiara Franzoni, Salvatore Dello Iacono, Lavinia
Chiara Tagliabue, Robert Birke and Silvia Meschini*

Absenteeism Forecasting using State Space models (**Ref: 6104**)

Juan R. Trapero, Diego J Pedregal, Pablo García and Caroline Biron

Attribution Consistency in Time-Series Foundation Models (**Ref: 7117**)

*Raphael Schilling, Ferdinand Heinrich, Florens Fraidling and Franz
Wenninger*

Deep Learning-Based Models for Enhancing Air Quality Forecasting in
the UAE (**Ref: 9412**)

Hana Sulieman and Siva Durga Adduri

(11:40-13:00) Session B.3: Time Series Analysis and Forecasting

Chairman: Dr. Guohua Lu and Dr. Marco Ciro Liscio*

Forecasting GDP Growth in the Arab World Using ARIMA and ETS
Models: A Comparative Time-Series Analysis (**Ref: 1886**)

Adam Daouk, Ali Al Rifai, Pascale Bou Chahine and Seifedine Kadry

Comparative Analysis of Machine Learning Models for Mo-torcycle Sales
Forecasting in the Peruvian Market (**Ref: 4160**)

Kalpdrum Passi and Jose Alonso Vasquez Pasco

Market Regime Transitions and Investor Behavioral Dynamics: A Hidden
Markov Model Approach to Regime-Conditional Asset Allocation (**Ref: 6300**)

Songqing Zhao

Forecasting State-Level Unemployment with Hybrid Statistical and
Neural Time Series Models under Normal and Shock Conditions (**Ref: 7659**)

Nellie Chen, Guohua Lu and Eugene Pinsky

CADE-GA: Context-Adaptive Deep Ensemble Meta-Learning via Genetic Algorithms for Time Series Forecasting (**Ref: 2325**)

Zeeshan Malik, Reham Yousef and Ali Abusnina

**(13:00-14:00) Opening Ceremony. Plenary Talk:
Prof. Eamonn Keogh**

Distinguished Professor, Department of Computer Science
and Engineering University of California Riverside

(16:00-17:00) Session A.4: Advances in Time Series Methods

Chairman: Dr. Indeevara Perera and Dr. Jose-Luis Molina Gonzalez

The Forgotten Beginning: Backcasting for Optimal SSOE Initialisation (**Ref: 0652**)

Ivan Svetunkov and Kandrika Pritularga

Bootstrap Specification Tests for Multivariate GARCH Processes (**Ref: 0711**)

Indeevara Perera

Simultaneous Inference Bands for Autocorrelations (**Ref: 1675**)

Uwe Hassler, Marc-Oliver Pohle and Tanja Zahn

Multiscale Comparison of Nonparametric Trending Coefficients (**Ref: 3172**)

Marina Khismatullina and Bernhard van der Sluis

**(16:00-17:00) Session B.4: Time Series Applications in Energy,
Finance, Transport, Health and Environmental Systems (Part I)**

Chairman: Dr. Rodrigo Schons Arenhart and Dr. Eduardo Caro Huertas

Forecasting MBTA Transit Dynamics: A Performance Benchmarking of Statistical and Machine Learning Models (**Ref: 2478**)

Sai Siddharth Nalamalpu, Kaining Yuan, Aiden Zhou and Eugene Pinsky

Analyzing Fishing Fleet Time-Series Dynamics in pre and post-Covid Periods (**Ref: 2884**)

Eugene Pinsky, Harini Saravaran and Kunal Sivakumar

Churn Prediction: A Hybrid Approach with Transactional Data and Topic Extraction via LLMs (**Ref: 4410**)

Estevan Mendes, Álvaro Veiga and Karla Figueiredo

The impact of minimum wage on industrial employment in Brazil: a time series analysis using the Kaitz index (**Ref: 6457**)

Rodrigo Schons Arenhart, Adriano Mendonça Souza and Daniel Arruda Coronel

(17:00-18:00) Plenary Talk (Virtual, by Zoom):

Prof. William A. Barnett

Prof. William A. Barnett, is the Oswald Distinguished Professor of Macroeconomics at the University of Kansas, Director at the Center for Financial Stability in New York City, and Director of the Institute for Nonlinear Dynamical Inference.

Title of the presentation: Economic Bifurcation and Chaos

(16:00-18:00) Session A.5: Poster Session

*Chairman: Dr. Fernando Rojas and Dr. Ciro Rodriguez León**

Short-Term Price Forecasting in the Spanish Continuous Intraday Market Using a Hybrid LSTM+ARX Model (**Ref: 0618**)

Juan Manuel Roldan Fernandez, Jesus Manuel Riquelme-Santos and Manuel Burgos-Payan

Adoption trajectories and early signals of AI scaling: Evidence from 30 enterprise interviews (**Ref: 0957**)

Peter Štetka and Nora Grisáková

Board Effectiveness and European Bank Performance What Role of Corporate Social Responsibility? (**Ref: 0973**)

Djebali Nesrine and Amri Chadha

Machine Learning Analysis of Surface Temperature, Precipitation, and Land Use Dynamics; A GIS Based Eco-Thermal Assessment of Swat District, Pakistan (**Ref: 1049**)

Muhammad Qasim, Muhammad Abubakar and Wajid Rashid

A Dynamic Profit Maximization Model for the Expansion of AI Infrastructure under Monopoly Conditions (**Ref: 1101**)

Nora Grisáková and Peter Štetka

The Impact of AI on the Forecast Work of Planners (**Ref: 1307**)

Gabriel David Pinto

Integrating Machine Learning and Econometric Techniques for Enhanced Forecasting Accuracy: Evidence from Macroeconomic Time Series (**Ref: 1365**)

Nadeem Iqbal and Zeeshan Akmal

Forecasting Short-Horizon Energy Loss for Wind Farm Maintenance: A Mobility-Based Decision Framework (**Ref: 1535**)

Filippo Petroni

Does income diversification matter for bank stability? A threshold analysis for MENA banks (**Ref: 1785**)

Nesrine Djebali

Recursive Way to Get the Cross-Entropy Rate to Evaluate Data Model Dissimilarity in a State-Space Framework (**Ref: 2231**)

Eric Grivel

The Impact of the Spanish Civil War on the Stationarity of Fertility Rates (**Ref: 2393**)

Rafael González-Val and Miriam Marcén

A Multidimensional Framework for Regional Energy-Economic Transformation (**Ref: 2527**)

Ignacio Rojas-Valenzuela, Victor Gonzalez Argudo, Fernando Rojas and Olga Valenzuela

The Moderating effect of the shadow economy on the relationship between foreign trade and economic Growth: A Panel ARDL analysis in Developing Countries (**Ref: 3258**)

Khalil Mhadhbi

The Regional and Distributional Consequences of Tax Pass-Through: The Case of Germany's Fuel Tax Discount (**Ref: 3292**)

Manuel Frondel

RainHealth©: A Machine-Learning Prototype for Early Hydro-Sanitary Risk Assessment in Reservoirs under Extreme Rainfall Events (**Ref: 4409**)

José Luis Molina González, Santiago Zazo del Dedo, Fernando Espejo Almodovar, Carmen Patino Alonso and Juan Carlos García Prieto

Time-Series Modeling and Forecasting of Drug-Eluting Bioactive Glass/Polymer Coatings for Metallic Implants (**Ref: 4485**)

Laura Floroian and Liviu Dogar

Human Capital and Regional Growth in Kazakhstan: The Role of Spatial Spillovers (**Ref: 4582**)

Nazym Ainakul, Aziza Zhuparova and Saule Nurymova

Estimating Intervention Impacts When Timing Is Unclear: An AR-LagDT Model with Distributed Lags (**Ref: 4621**)

Wen Chen, Xiangliang Zhang and Kunpeng Wu

A Recursive Probit Model for Dynamic Discrete-Continuous Choices: The Case of Vehicle Ownership and Use Over Time (**Ref: 4726**)

Cinzia Cirillo, Asal Mehdi Tabrizi and Yan Liu

A Data-Driven Framework for Short-Term Visibility Nowcasting at Indira Gandhi International Airport Using Multi-Horizon Gradient Boosting Models (**Ref: 4731**)

Neeti Singh

Day-Ahead Electricity Price Forecasting Using Gradient Boosting Decision Tree Models: A Case Study of the Croatian Market (**Ref: 4793**)

Damir Jakus, Josip Vasilj, Joško Novaković and Danijel Jolevski

From Quarterly Labor Market Surveys to Official Statistics: Does the Method Matter in the Era of AI? (**Ref: 4799**)

Fatma Ezzahra Laadhari and Adel Karaa

Analysis of Climate Trends in the Haouz Region Through Reference Evapotranspiration Time Series (**Ref: 5161**)

El Houcine El Moussaoui, Saïd Khabba, Salah Er-Raki and Abderrahman Lahrouni

Introducing Robust Least-Squares Methods in the Detrended Fluctuation Analysis (**Ref: 5671**)

Eric Grivel and Pierrick Legrand

Digital Transformation in Islamic Finance: Enhancing Business Performance Through FinTech Innovation (**Ref: 5755**)

Ahmad Amin, Syed Mgafur Ahmad and Mahadi Hasan Miraz

An Adaptive Online Framework for Non-Stationary Time Series Forecasting via Multi-Scale Gated Transformers (**Ref: 5796**)

Bachir Kaddar and Hadria Fizazi

Extracting running-in dynamics from operational time series using long short-term memory networks (**Ref: 5837**)

Theodor R. van Caspel, Gabriel Thaler and Rodolfo C. C. Flesch

Forecasting MASI and MASI ESG Indices: Evaluation and Limitations of the BiLSTM Model (**Ref: 6679**)

Oumaima Hamou, Mohamed Oudgou and Abdeslam Boudhar

Calibration of the AquaCrop Model by Using Micrometeorological Times Series to Optimize Pea Irrigation in Semi-Arid Region (**Ref: 6779**)

Lamia Jallal, Saïd Khabba, Salah Er-Raki, Jamal Ezzahar, Oumaima Kaissi, Zoubair Rafi and Abdelghani Chehbouni

Development of a Multi-Model Ensemble Simulator with Bayesian Optimization for Robust Prediction of Multivariable Water Quality in Drinking Water Treatment Processes (**Ref: 6894**)

Graphical Lasso for Measuring Associations in Elliptically Symmetric Distributions: An EM Approach (**Ref: 7400**)

Gyorgy Terdik

A Finsler-Based Extension of the Gini Index for Concentration Analysis on Riemannian Spaces (**Ref: 7854**)

Leonardo Moreno

Integrated Frameworks for Solar Photovoltaic Power Forecasting: Advanced Methodologies, Hybrid Machine Learning, and Input Data Calibration (**Ref: 7879**)

Ignacio Rojas-Valenzuela, Victor Gonzalez Argudo, Fernando Rojas and Olga Valenzuela

Broken Adaptive Ridge in Time Series: the TS-BAR (**Ref: 8171**)

Gianluca Cubadda, Luca Margaritella and Orest Prifti

Persistence Analysis of Physiological Time Series of Subjects with Different Chronic Disease Risk Profiles (**Ref: 8468**)

Jose Alberto Zamora-Justo, Pilar Ortíz-Vilchis, José Luis Del-Rio-Correa and Alejandro Muñoz-Diosdado

A Review of Cryptocurrency Price Prediction Using Machine Learning: Advantages, Challenges, and Future Scope (**Ref: 8529**)

Hossein Tabasi

Exchange rate prediction using machine learning techniques (**Ref: 8546**)

Simiso Msomi

CampusLearn+ Free Classroom For Extra Growth (**Ref: 8555**)

Swaroop Gulhane, Shivam Gujar and Rohan Dhotre

Private ownership vs Informality in developing countries: The corruption Conundrum (**Ref: 8810**)

Njoya Loudi and Dama Die Marcel

Time Series Forecasting of International Tourism Demand in Georgia: Evidence for Sustainable Planning (**Ref: 8963**)

Sopiko Tevdoradze, Zurab Mushkudiani, Natia Surmanidze and Giorgi Khidesheli

Measuring salience in macroeconomic time series (**Ref: 9162**)

Francesca Papagni and Emilio Zanetti Chini

Crack patterns using machine learning predictions on damaged unreinforced masonry walls (**Ref: 9165**)

Dorin Radu, Marijana Hadzima Nyarko, Karlo Emmanuel Nyarko, Ercan Isik and Eleonora Desnica

Does speed bump resolve the problems of mini flash crashes? Evidence from NYSE American (**Ref: 9196**)

Bo Liu

Multi-Objective Hyperparameter Optimization for Recursive Ensemble Demand Forecasting (**Ref: 9709**)

Amine Hedroug

Carbon Pricing and Its Uneven Impacts: Evidence from the EU ETS (**Ref: 9746**)

Nerea Gómez Fernández and Juan-Francisco Albert

Disaggregated Electricity Demand Forecasting using Machine Learning for the Day-Ahead Market and Energy Communities (**Ref: 9767**)

Jesus Riquelme

TS2Vec-Ensemble: An Enhanced Self-Supervised Framework for Time Series Forecasting (**Ref: 9848**)

Ganeshan Niroshan

A Pipeline for Electricity Forecasting under Data Scarcity, Fragmentation, and Nonstationarity (**Ref: 5374**)

José Juan Hernández-Gálvez, Stefano Sanfilippo, José Juan Hernández Cabrera, Jose Évora-Gómez, Octavio Roncal-Andrés and Mario Caballero-Ramírez

Early Detection of Crowd-Flow Anomalies in Urban Time Series Using Conv1D-LSTM and Dynamic Thresholding (**Ref: 7756**)

Rafael Rodrigo-Guillen, Higinio Mora-Mora, Jorge Azorin-Lopez and David Gil

(18:15-19:45) Session A.6: Advances in Time Series, Prediction and Data Analysis (Short Presentations)

Chairman: Dr. Hugo Morais and Dr. Diego Carvalho do Nascimento

Deep Learning-Based Imputation of Irradiance Time Series Enhanced by Numerical Data (**Ref: 1237**)

Mónica Moreno Revelo, Juan Bernardo Gómez Mendoza, Javier Revelo Fuelagán and Diego H. Peluffo Ordoñez

On the development of vector autoregressive fractional unit Root integrated moving average (VARFURIMA) model: a Bivariate case (**Ref: 1286**)

Tasi'U Musa, Musa Garba Abubakar, Hussaini Garba Dikko, Abubakar Usman, Sanusi Jibrin Alhaji and Jamilu Garba

Context-Aware Neural Circuit Policies for Non-Stationary Industrial Energy Time Series via Error-Decorrelation Partitioning (**Ref: 2803**)

Giulia Palma and Antonio Rizzo

Measuring and preventing ESG risks: integrating qualitative and quantitative data through artificial intelligence (**Ref: 2893**)

Jean-Michel Sahut

Secondary Substation Power Demand Forecast to Support Distribution Network Operation (**Ref: 3836**)

Inês Moreira, Lucas Pereira, Pedro Carvalho and Hugo Morais

Robust Factor Analysis of Rank-Decomposition-Based Matrix Factor Model for High-Dimensional Time Series (**Ref: 4056**)

Qiang Xia

Thermal performance optimization of bio-based masonry blocks using numerical simulation and surrogate modeling (**Ref: 4741**)

Ibrahim Kachalla, Joelle Al Fakhoury and El Moustapha Bouha

Irregular Immigration and Smuggling at the Serbian Romanian Border: A Wavelet Approach (**Ref: 9340**)

Iliuta Cumanasu and Cristina Strango

Determinants of Urban Recommendability: Identifying Key Smart City Drivers (**Ref: 9516**)

Jelena Stanković, Vesna Janković-Milić, Ivana Marjanović and Marina Stanojević

Machine Learning-Based Prediction of Mini Flash Crashes (**Ref: 9980**)

Bo Liu, Ke Xu and Xinwei Zheng

Crash Severity Prediction Using Temporal Weather and Roadway Data in Cold Regions (**Ref: 3177**)

Osama Abaza

(18:15-19:15) Session B.5: Econometrics and Forecasting (Part I)

Chairman: Dr. Akshay Murthy and Dr. Kalpdram Passi

Determinants of European Union Public Support for Development Aid: A Generalized Ordered Logistic Regression Analysis of Eurobarometer Data (1993–2019) (**Ref: 2861**)

Daniele Bregoli, Marco Ciro Liscio and Paolo Sospiro

Comparing Standard Deviation with Alternative Volatility Metrics in Financial Time-Series Forecasting and Trading with Bollinger Bands (**Ref: 8448**)

Akshay Murthy, Jonathan Yan and Eugene Pinsky

Estimating Earth's Temperature Response with Trans- formed and Augmented OLS (**Ref: 8811**)

Justin Sun

Forecasting Daily Price Movements of ETFs Using a Bayesian-Optimized Dynamic Sliding Window Size Approach (**Ref: 1027**)

Hossein Pirayesh and Jose M Sallan

Thursday, July 16th, 2026

(9:00-10:40) Session A.7: Time Series Applications in Energy, Finance, Transport, Health and Environmental Systems

Chairman: Dr. Ebrahim Ghaderpour and Dr. Michail Gerasimov

A Comprehensive Study on Short-Term Oil Price Forecasting Using Econometric and Machine Learning Techniques (**Ref: 1082**)

Gil Cohen

Identification and Quantification of Complex Nonlinear Dynamics in Biological Recordings (**Ref: 2003**)

Valeri Makarov, Ricardo Muñoz and Julia Makarova

Group-Based Blood Glucose Forecasting in Type 1 Diabetes: Bridging the Gap Between General and Personalized Models (**Ref: 5526**)

Ciro Rodriguez-Leon, Maria Dolores Aviles-Perez, Oresti Banos, Miguel Damas, Javier Medina, Manuel Munoz-Torres, Hector Pomares, Miguel Quesada-Charneco and Claudia Villalonga

Short-Term Traffic Speed Prediction and Pattern Discovery Using Sensor Data (**Ref: 6415**)

Ali Hadi, Muhammad Munim Shafi, Asadullah Safi, Aristeidis Mystakidis and Christos Tjortjis

Battery Ageing Prediction: Information-Driven Data Analysis and Model Parametrisation (**Ref: 6820**)

Christoph Hametner, Genario Oliveira and Stefan Jakubek

Short-term sea level forecasting using data-driven models and lunar phase information (**Ref: 6934**)

Pierdomenico Dutillo and Francesco Lisi

Addressing Parameter Estimation Bias in Kalman Filtering Using GMM (**Ref: 8583**)

Marco Costa and Magda Monteiro

(9:00-10:40) Session B.6: Nonstationarity

*Chairman: Dr. Mark Leischner**

Refinements of reservoir neural networks for chaotic time series forecasting (**Ref: 0211**)

Roman Vysotskiy, Anton Kovantsev and Shahd Hammoud

Adaptive Feudal Trader with Dynamic Goal Latent Space for Algorithmic Trading (**Ref: 0500**)

Mark Leischner and André Bauer

Impact of Data Quality on School Enrollment Forecasting for Brazil's National Textbook Program (PNLD) (**Ref: 3875**)

Victor Brasileiro, Marcelo Falcão, Breno Duarte, Romildo Escarpini, Luciano Cabral, Dalgoberto Pinho, Laisa Sousa, Rafael Silva, Nicholas Cruz, Lenardo Silva and Bruno Pimentel

Linear and non-linear ARDL estimation of Global Innovation and Economic Growth in Vietnam (**Ref: 4235**)

Quang Phung Duy, Huyen Nguyen Khanh, Quyen Hoang Nam, Thinh Nguyen Huu Thinh, Thao Pham Thi Phuong and Dang Nguyen Hai

BeTiSe: A Comprehensive Benchmark Dataset for Time Series Stationarity and Structural Analysis (**Ref: 4723**)

Kerem R Gür, P. Cemre Yazıcı, Pelin Erkaya, Yağmur Türkmen, Berke Baytak, Ismail Güzel, Pınar Karagöz and Ceylan Yozgatlıgil

Confidence bands for local non-stationarity detection (**Ref: 5470**)

Alessandro Cardinali

A Non-Stationary BINAR(1) Model with 2 Poisson-Weighted Exponential Innovations (**Ref: 9578**)

Yuvraj Sunecher, Naushad Mamode Khan, Muhammed Rasheed Irshad and Hendrik Willem Pretorius

(11:15-12:00) Session A.8: Advanced Econometrics Methods and Prediction

Chairman: Dr. Grzegorz Dudek and Dr. Khalil Mhadhbi

Maximum Likelihood Estimation for Multivariate All-Pass Time Series Models (**Ref: 3023**)

Yixin Li

Estimation and Inference In Multiple-Regime Threshold CCC-GARCH(1, 1) Model (**Ref: 5462**)

Anastasiia Kazovskaia

Maximum entropy bootstrap for time series using generalized maximum entropy (**Ref: 9892**)

Pedro Macedo, Jorge Cabral and Vera Afreixo

(11:15-12:00) Session B.7: AI-based Forecasting

Chairman: Dr. Beatriz Royo

School Demand Forecasting System based on Gradient Boosting with Walk-Forward Validation (**Ref: 0476**)

Lucas Praxedes, Lenardo Silva, Rafael Silva, Breno Duarte, Nicholas Cruz, Dalgoberto Júnior, Laisa Sousa and Bruno Almeida

Improving the Prediction of Homicides with a Lumpy and Erratic Pattern, through Deep Learning and Data Augmentation (**Ref: 6093**)

Martín Solís and Luis-Alexander Calvo-Valverde

Neural network models and Lotka-Volterra models in the assessment and forecasting of industry growth sustainability (**Ref: 6129**)

Nailia Gabdrakhmanova

(12:00-13:00) Session A.9: Robust Time Series Methods in the Time and Frequency Domains. Applications in Environmental, Health and Natural Science

Chairman: Dr. Valderio Anselmo Reisen and Dr. Tom Vanwallegghem

Least-Squares Cross-Wavelet Analysis of Snow-Temperature Interactions and Spatial Trends in the Alps (**Ref: 1274**)

Ebrahim Ghaderpour, Hanieh Dadkhah, Paolo Mazzanti, Francesca Bozzano and Gabriele Scarascia Mugnozza

Constraint-Aware Multivariate Time Series Forecasting for Day-Ahead Photovoltaic Generation: a Case Study (**Ref: 7523**)

Octavio Roncal Andrés, Jose Juan Hernandez Cabrera, Mario Caballero, José Juan Hernández Gálvez, Ana María Placido Castro and José Évora

Propagating Input Uncertainty in Irregular Clinical Time Series (**Ref: 9355**)

Juan Carlos Santana-Santana, José Juan Hernández-Gálvez, José Juan Hernández-Cabrera and José Évora-Gómez

Operations Management in retail with Industrial Statistics: an overview
bridging Big Data forecasting and causal TS relation (**Ref: 9979**)

Diego Nascimento

(12:00-13:00) Session B.8: Forecasting in Real Problems

Chairman: Dr. Anton Kovantsev

Testing for the Asymmetric Optimal Hedge Ratios: With an Application
to Bitcoin (**Ref: 0205**)

Abdulnasser Hatemi-J

Obtaining personalized predictions from a randomized controlled trial on
Alzheimer's disease (**Ref: 1230**)

Dennis Shen

Global risk of dengue outbreaks and the impact of El Nino events (**Ref: 1788**)

Martial Ndeffo, Sina Mokhtar and Dana Pittman

Forecasting Raw Material Price Volatility in SMEs: A Lightweight Hybrid
Approach Using Open Data and Explainable Models (**Ref: 6124**)

Beatriz Royo and Maria Teresa De la Cruz

(13:00-14:00) Plenary Talk:

Prof. Robert Boute

Full professor Faculty of Economics and Business (FEB),
KU Leuven; member of Leuven.AI - KU Leuven Institute
for Artificial Intelligence; member of LIM - KU Leuven
Institute for Mobility

Title of the presentation: Integrating Forecasting and Inventory
Decisions Using AI/ML

**(14:15-16:00) Session B.9: Advanced Time-Series Forecasting
and Data-Driven Methods for Energy Systems and Smart Grids**

*Chairman: Dr. Challa Krishna Rao and Dr. Phemelo Seaketso**

Dynamic Pricing-based Home Energy Management for Islanded Operation with Integrated Distributed Energy Resources (**Ref: 1692**)

Challa Krishna Rao, Tamminana Lokanadha Rao, Sarat Kumar Sahoo, Swetha Irugatla, Pappu Baladhitya, Kuchetti Krishna Rao and Vanjarapu Venkata Rao

Design of a Smart IoT based Diabetic Detection System Using Photoplethysmogram (**Ref: 3107**)

Challa Krishna Rao, Bibhuti Bhusan Rath, Dannana Sailaja, Talabattula Lakshmi Durga Bhavani, Potnuru Revathi and Gunta Mukkala Sri Ram Akash

Performance analysis of BKA-Optimized FONPID Controller for Frequency Regulation in Renewable-Integrated Airport Microgrids (**Ref: 3167**)

Kumaraswamy Simhadri, Banaja Mohanty, B.V.S Acharyulu and Kanaka Raju Kalla

smart energy monitoring system for household applications using ESP32 micro controller (**Ref: 3856**)

Bevara Srikanth, Konni Sivadatta, Namballa Bhavani, Palla Mahesh and Ashok Ganga

An IoT Framework For Peak Load Prediction Using Deep Learning Techniques (**Ref: 4099**)

Sreenubabu Dasari, Vasanthi Ravada, Sai Gowtham Vulli, Tejeswar Nadiseti, Rajesh Jada and Tarun Kumar Kondaka

Reliable Prediction of Solar Global Tilted Irradiance Using TabNet with SHAP-Based Interpretability and Uncertainty Quantification (**Ref: 4337**)

Kanaka Raju Kalla, D.Ravi Kishore and D.Vijaya Kumar

An Intelligent Simulation-Based Fault Diagnosis Approach for Power Systems Using Attention-Enhanced Residual Learning with Bayesian Hyperparameter Optimization (**Ref: 4558**)

Ashok Ganga, D Ravi Kishore and D Vijaya Kumar

(16:00-17:00) Session A.10: Computational Intelligence and Sensor-Driven Time Series Analysis for Renewable Energy Forecasting

*Chairman: Dr. Peter Glösekötter and Dr. Ignacio Rojas**

Conceptual Design and Preliminary Analysis of a Resource-Constrained Measurement Device Using Nitrogen Vacancy Centers (**Ref: 1656**)

Frederik Hoffmann, Ann-Sophie Bülter, Jonas Homrighausen, Ludwig Horsthemke, Marina Peters, Markus Gregor, Ignacio Rojas Ruiz and Peter Glösekötter

Data-Driven State-of-Charge Estimation for Rechargeable Zinc-Air Batteries Using LSTM with EIS-Based Feature Engineering (**Ref: 1822**)

Jan-Ole Thranow, Felix Winters, Andre Loechte, Markus Gregor, Peter Glösekötter and Ignacio Rojas Ruiz

Comparing FCNN and LSTM Architectures for Magnetic Field Prediction Using an All-Optical NV Diamond Setup (**Ref: 4922**)

Ann-Sophie Bülter, Ludwig Horsthemke, Glen Neiteler, Frederik Hoffmann, Sarah Kirschke, Tilman Sanders, Markus Gregor, Ignacio Rojas Ruiz and Peter Glösekötter

Sequential LSTM Modeling for Short-Term PV Power Forecasting (**Ref: 7665**)

Fereshteh Jafari, Joseph Moerschell and Kaspar Riesen

(16:00-17:00) Session B.10: Econometrics and Forecasting (Part II)

*Chairman: Dr. Norman Swanson and Dr. Justin Sun**

Consistent Estimation, Variable Selection, and Forecasting in Factor-Augmented VAR Models (**Ref: 0941**)

Norman Swanson and John Chao

Visualizing Time-Series Dynamics of GDP Growth and Gini Inequality Index Across Countries (**Ref: 2098**)

Aayan Ali and Eugene Pinsky

The Effect of Monetary and Macro variables on Capital adequacy Ratio: Evidence from South Africa (**Ref: 4362**)

Kanayo Ogujiuba and Lethabo Maponya

Nonlinear Energy and Security Effects in Cryptocurrency Markets: Evidence from Traditional and Green Cryptocurrencies (**Ref: 7865**)

Wassim Mannai, Malek Abaab, Layth Sliman and Kamel Helali

Price Shocks and Carbon Emissions: Asymmetric Effects of Oil Markets and Cryptocurrency Mining on Global CO Dynamics (**Ref: 8186**)

Hajer Chibani, Maha Kalai, Layth Sliman and Kamel Helali

(17:00-18:10) Session A.11: Current Trends and Applications in Time Series Analysis. (Short Presentations)

*Chairman: Dr. Ling Shiqing**

Random coefficient AR(2) in continuous time (**Ref: 1238**)

Milena Hoyos, Karoll Gómez-Portilla and Daniela Cárdenas-Sánchez

Eigen-transform Tests for Mean Vectors in High-Dimensional Time Series Dependent Data (**Ref: 3858**)

Xiaoran Wu and Shiqing Ling

Practice-Oriented Quantile Forecast Validation for Distribution Grid Load Exceedance Prevention (**Ref: 5530**)

Ties van der Heijden, Pascal Sado, Gertjan Kok, Bart Pleiter and Pedro Vergara Barrios

Machine Learning-Based Forecasting of Monthly Gold Prices for Strategic and Investment Decision-Making (**Ref: 5693**)

Lawrence Madziwa, Prosper Chimunhu and Thabo Falayi

Trustworthy Explanations for an Uncertain World: Relative Forecast Interpretability (**Ref: 6759**)

Yves R. Sgaert, Kandrika Pritularga and Nikolaos Kourentzes

Forces of Change Wild Cards in Medium-Term Projections (**Ref: 7842**)

Konstantina Papaioannou, Anna-Maria Kanzola and Panagiotis E. Petrakis

irreversibility: A Python Package for Assessing and Manipulating the Time Irreversibility of Real-World Time Series (**Ref: 8590**)

Massimiliano Zanin

Any-quantile probabilistic forecasting of short-term electricity demand: Fusing uncertainties from diverse sources (**Ref: 8909**)

Slawek Smyl, Boris Oreshkin, Paweł Pełka and Grzegorz Dudek

(17:00-18:30) Session B.11: Advances in Time Series, Forecasting and Computational Methods (Short Presentations)

Chairman: Dr. Layth Sliman and Dr. Eda Ustaoglu**

Decomposing Volatility in the microstructure turbulent Nordic/Baltic Power Market A Multifactor Stochastic Volatility Approach (**Ref: 2292**)

Per B Solibakke

Time Series Analysis of Agricultural Drought Impacts on Rainfed Cereal Yields: Enhancing Drought Impact Assessment Through Yield Detrending in Morocco (**Ref: 3062**)

Youness Ablila, Abdelhakim Amazirh, El Houssaine Bouras, Maria Jose' Escorihuela, Said Khabba, Jose Antonio Martinez Casasnovas and Salah Er-Raki

Alternating heads of state and structural transformation in sub-Saharan Africa: a panel VAR analysis (**Ref: 4253**)

Fabrice Nzepang

Detecting random coefficients in periodic regression models (**Ref: 4883**)

Regui Slimane

Predictability of Stock Returns: A Multi-Criteria Portfolio Selection with a Refined TOPSIS (**Ref: 8224**)

Eero Pätäri, Sheraz Ahmed, Pasi Luukka and Julian Scott Yeomans

Assessing the determinants of banking stability in the MENA region: what role for economic and financial freedom? (**Ref: 8320**)

Nesrine Djebali

Covariate-Aware Deep Learning for Injector Core Return Forecasting (**Ref: 0624**)

Yash Shah

Partial Envelope and Reduced-Rank Partial Envelope Vector Autoregressive Models (**Ref: 2646**)

Wiranthe Herath and Yaser Samadi

Forecasting Urban Housing Tenure Patterns in Iran Using Deep Neural Network Modeling (2024–2033) (**Ref: 8353**)

Nasibeh Esmaili and Gholamreza Ghaffari

Friday, July 17th, 2026

(9:00-10:00) Session A.12: Time Series for Sustainability and Environment

Chairman: Dr. Nagarajan Deivanayagampillai and Dr. Eric Grivel

Hydrological balance as a tool for a better water management strategy for assessing the hydrological dynamics of a large regulated lake in Northern Italy (**Ref: 4293**)

Alessandro Gorini, Maria Chiara Magnano, Andrea Fenocchi, Helmi Saidi and Marzia Ciampitiello

Assessing climate variability and extreme events for water resource management in the Lake Maggiore basin (**Ref: 5811**)

Maria Chiara Magnano, Alessandro Gorini, Andrea Fenocchi, Helmi Saidi and Marzia Ciampitiello

Spectral Fidelity of Diffusion Models for Surface Solar Irradiance Downscaling: Why Regime-Conditioned Evaluation Matters? (**Ref: 5877**)

Jose Gomez, Yves-Marie Saint-Drenan, Yehia Eissa and Philippe Blanc

Can AI Foundation Models Predict Aquifer Decline? Benchmarking TimeGPT Against Traditional Forecasting in Southern Spain's Endangered Wetlands (**Ref: 6570**)

Tom Vanwalleghe

(9:00-10:00) Session B.12: Theory, Inference, and Applications

*Chairman: Dr. Albert Antwi and Dr. Mateusz Zareba**

Assessing Online Change Point Detection in Noisy Environments: A Case Study on Synthetic and Real Crime Data (**Ref: 0322**)

Allan Bolaños-Barrientos and Martín Solís

Timing Matters: Fuzzy Logic Optimization of Portfolios Using Weekly and Monthly Recommendations (**Ref: 2431**)

Anna Łyczkowska-Hanćkowiak and Aleksandra Wójcicka-Wójtowicz

Assessing Climate Change Trends and Extremes in the Euro-Atlantic Sector: A Time Series Forecasting Framework Using Stratospheric Polar Vortex and Jet Stream Dynamics (1979–2024) (**Ref: 4036**)

Jakub Smaga and Mateusz Zareba

Seasonal phase modelling of heavy rainfall patterns in Semi-Arid regions
Using the von Mises Distribution (**Ref: 4239**)

Albert Antwi, Alexander Boateng and Daniel Maposa

(10:00-10:45) Session A.13: Forecasting and Planning Systems

Chairman: Dr. Krzysztof Drachal and Dr. Enrico Mizzi*

Model Predictive Control for Battery Storage in Net-Load Levelling: A
Comparison of MILP and Heuristic Strategies under Perfect and Learned
Forecasts (**Ref: 7852**)

Anthony Faustine and Lucas Pereira

Quantum Machine Learning for Time Series Forecasting of Energy Price
Trends for Community Networks (**Ref: 5705**)

Jiří Tomčala

Boost Fisher Scoring for Robust Parameter Estimation in Contaminated
State-Space Models (**Ref: 3294**)

F. Catarina Pereira, A. Manuela Gonçalves and Marco Costa

(10:00-10:45) Session B.13: Advances in Time Series Methods

Chairman: Dr. Alessandro Cardinali

Developing a Hybrid Modelling Framework Integrating Linear Statistical
Models and Non-Linear Machine Learning to Capture Temporal
Structures and Complex Dynamics (**Ref: 5899**)

Phemelo Seaketso, Martin Chanza and Modisane Seitshiro

Analysis of Extreme Nitrogen Dioxide Concentrations in European Capitals (**Ref: 9296**)

Marta Ferreira

A Simulation study of Stabilized Logistic Predictions Under Separation (**Ref: 9932**)

Alessandro Cardinali

Real Infection Spreading Rates for the COVID-19 pandemic in Ukraine
estimated with the Use of the Novel Reproduction Number (**Ref: 7046**)

Igor Nesteruk

**(11:30-12:15) Session A.14: Time Series Analysis with
Computational Intelligence**

Chairman: Dr. Eros Gian Alessandro Pasero and Dr. Lucas de Sousa Pereira Pereira

The Role of Preprocessing in High-Frequency Time Series Data Applications on the Edge (**Ref: 0407**)

Florens Fraidling, Arham Bin Tariq and Franz Wenninger

AI-Driven Smart Beta: Combining Crash Prediction Vetoes and Momentum for Retail Investors' Downside Protection (**Ref: 2883**)

Alessandro Casella, Vincenzo Randazzo and Eros Pasero

Towards Explainable Vision-Based Photovoltaic Nowcasting: Performance Analysis and Visual Incident Interpretation (**Ref: 6801**)

Aurora Polo-Rodríguez, Jafari Fereshteh, Joseph Moerschel, Limei Zhang, Ignacio Rojas and Javier Medina Quero

(11:30-13:00) Session B.14: Time Series Applications in Energy, Finance, Transport, Health and Environmental Systems (Part II)

Chairman: Dr. Estevan Mendes

Bitcoin's halving events and the fractal nature of mining energy consumption (**Ref: 3977**)

Lucas Mussoi, Fernanda Müller and Marcelo Scherer Perlin

Incorporating Temporal Stock Price Patterns into Portfolio Optimization (**Ref: 4131**)

Pankaj Kumar, Disha Gupta and Kavya Kumari

Optimization Sensitivity in ARFIMA and FIGARCH Models for Precious Metals (**Ref: 4350**)

Modisane Seitshiro and Christian Fanevasoa

Forecasting Territorial Accessibility and Sustainability Impacts of Transport Infrastructure: Evidence from Mainland Portugal (**Ref: 5036**)

Rui Alexandre Castanho and José Manuel Naranjo Gómez

Discrete Multivariate Copula based Model fitting to Longitudinal Count Data (**Ref: 5380**)

Yuvraj Sunecher, Naushad Mamode Khan and Vandna Jowaheer

Trade Integration in the Adriatic-Ionian Region: A Structural Gravity Approach to Macro Regional and Functional Regionalisation (**Ref: 7940**)

Daniele Bregoli, Donato Iacobucci, Paolo Sospiro and Marco Ciro Liscio

(12:15-13:00) Session A.15: Time series in Econometrics

Chairman: Dr. Mile Bosnjak and Dr. Pieter de Kok*

Forecasting commodities prices with an enhanced Bayesian Dynamic
Mixture Models (**Ref: 1097**)

Rajat Dogra and Krzysztof Drachal

Score Autoregressive (ScAR) Models (**Ref: 2967**)

Emilija Dzuverovic, Andrew Harvey and Dario Palumbo

A Shrinkage Factor-Augmented VAR for High-Dimensional Macro-Fiscal
Dynamics (**Ref: 8540**)

Dimitra Kyriakopoulou

(13:00-14:00) Plenary Talk:

Prof. Hossein Bonakdari

Ph.D., P.Eng., esteemed professor at the University of
Ottawa, Canada

ITISE 2026. Abstracts

[0205] Abdulnasser Hatemi-J (Department of Economics and Finance, United Arab Emirates University). *Testing for the Asymmetric Optimal Hedge Ratios: With an Application to Bitcoin.*

Abstract. — Reducing financial risk is of paramount importance to investors, financial institutions, and corporations. Since the pioneering contribution of [1], the optimal hedge ratio based on futures is regularly utilized. The current paper suggests an efficient method for testing the null hypothesis of a symmetric optimal hedge ratio against the asymmetric alternative one within a multivariate setting. If the null is rejected, the position dependent optimal hedge ratios can be estimated via the suggested model. This approach is expected to enhance the accuracy of the implemented hedging strategies compared to the standard methods since it accounts for the fact that the source of risk depends on whether the investor is a buyer or a seller of the risky asset. An application is provided using spot and futures prices of Bitcoin. The results strongly support the view that the optimal hedge ratio for this cryptocurrency is position dependent. The investor that is long in Bitcoin has a much higher conditional optimal hedge ratio compared to the one that is short in the asset. The difference between the two conditional optimal hedge ratios is statistically significant, which has important repercussions for implementing risk management strategies.

[0211] Roman Vysotskiy (ITMO University), Anton Kovantsev (ITMO University) and Shahd Hammoud (Higher Institute for Applied Sciences and Technology, Damascus, SYR). *Refinements of reservoir neural networks for chaotic time series forecasting.*

Abstract. The well-established technique of reservoir neural networks still attracts researchers' attention due to its ability to model the processes with nonlinear and chaotic dynamics better than the other techniques. Here, we have found that Fourier transform of the input data may refine the forecasting quality. As reservoir neural networks are still not much involved in the problem of economics and finance analysis, we use examples from this area. Since Benoit B. Mandelbrot published "The (Mis)Behavior of Markets" in 2004, the nonlinear dynamics, chaotic and fractal peculiarities of these processes have been recognized, and we may suspect that the specific tools which were invented for dealing with such systems could also be useful in economics problems. The results are promising. Moreover, we propose a way to distinguish the processes for which reservoir models could perform more accurate forecasts. Therefore, in our research, the reservoir network with the Fourier layer and polynomial expansion is presented.

[0278] Challa Krishna Rao (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India), B Manmadha Kumar (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India), Sarat Kumar Sahoo (Parala Maharaja Engineering College Berhampur, Odisha), Yernagula Deekshitha (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India), Killamsetty Pranitha (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India), Lakkoju Harika (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India) and Bagadi Chiranjeevi (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhrapradesh, India). *A Cost Effective Fast Cell Balancing Technique for Lithium-Ion Batteries using a Single DC–DC Converter with Direct Energy Transfer.*

Abstract. A novel quick lithium-ion battery balancing method with a single DC-DC converter for facilitating the direct energy transfer process in low and high voltage cells is introduced in this research work. Cost effectiveness in the design of the switch network is achieved by the use of relays in switching the cells. A control circuit including an MCU and a battery management IC is used for the sensing of cell voltages and hence the overall battery protection. The validity of the performance efficiency of this technology is justified by the creation of a prototype circuit setup by the employment of twelve lithium-ion batteries that consumes an incredible balance time of 48 minutes during the charging process with a maximum efficiency of 89.85%. The efficiency of the proposed balancing circuit based on balance time and implementation cost is justified over the existing technology. Hardware details regarding Battery Management Systems in static and EV applications are considered in the article. This article helps in the determination and measurement of crucial parameters while designing a Battery Management System based on its implementation scenarios with a snapshot description regarding the existing trends in state-of-the-art technology. Implementation details regarding the battery packs based on the commercial models for EVs are discussed in this article. Implementation details regarding the measurement of critical parameters like temperature, voltage, and current and balance control strategies are considered in this article.

[0322] Allan Bolaños-Barrientos (Technological Institute of Costa Rica) and Martín Solís (Technological Institute of Costa Rica). ***Assessing Online Change Point Detection in Noisy Environments: A Case Study on Synthetic and Real Crime Data.***

Abstract. This study benchmarks 16 online change-point detection algorithms using both a synthetic dataset and a real dataset. The synthetic dataset enables the analysis of algorithm performance across different scenarios with high and low levels of noise in the time series. The real dataset is composed of crime count time series that also exhibit both high and low noise levels. The results show that `ssm_canary` and `ocpdet_two_sample_test` are the best options under low-noise conditions, while `online_gaussian` combined with `ocpdet_two_sample_test` performs best under high-noise conditions. For the real dataset, the best F1 scores are approximately 0.40 (achieved by `ssm_canary`), which is not encouraging when high accuracy in criminal activity detection is required.

[0407] Florens Fraidling (Fraunhofer EMFT, Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT), Arham Bin Tariq (Technical University of Munich (TUM)) and Franz Wenninger (Fraunhofer EMFT, Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT). ***The Role of Preprocessing in High-Frequency Time Series Data Applications on the Edge.***

Abstract. High-frequency time series data applications generate data volumes that quickly exceed the strict memory and computational limits of ultra-low-power microcontrollers, making end-to-end deep learning approaches impractical for embedded machine learning. To address the resource bottleneck, this paper evaluates the trade-off between monolithic end-to-end inference and a two-stage preprocessing based embedded ML pipeline. We introduce a Minimal Spectrogram approach that leverages the Fast Fourier Transformation and spectral binning to compress the raw vibration data into a compact 2D time-frequency representation. We benchmark customized 1D and 2D Convolutional Neural Networks on a STM32 microcontroller to compare raw time-domain data based inference against the preprocessing-assisted frequency-domain pipeline. The profiling results reveal that the end-to-end time-domain model exhibits severe underfitting. The preprocessing supported pipeline achieves sufficient classification accuracy while reducing the total memory consumption and computational complexity. We conclude that explicit signal preprocessing is not merely an optional optimization but a strict necessity. By shifting workload from the model to highly optimized digital signal processing methods, the resource bottleneck of microcontrollers can be mitigated, enabling efficient, always-on high-frequency time-series data analysis in embedded ML applications.

For our experiments, we use a publicly available rotational machine dataset containing the rotation speed (RPM) measurements and synchronized accelerometer vibration signals sampled at 25.6 kHz. We extract labeled event sequences corresponding to RPM changes, reflecting typical machine execution patterns. Since the raw data representation is too large for a typical resource constrained microcontroller, we propose a compact Minimal Spectrogram Approach. Calculating the FFT on short input time windows reduce the temporal resolution. Adjacent frequency bins are then averaged into frequency buckets to further shrink the frequency dimensions while preserving event-relevant information.

We deployed the preprocessing pipeline and the trained models on an STM32 microcontroller and benchmarked latency, energy consumption, memory footprint, and computational complexity. The proposed feature extraction approach achieved up to ~80% dimensionality reduction and enabled compact 2D Convolutional Neural Networks with a ≤ 500 kB memory footprint, reaching up to ~93% accuracy on the test data. These results show that preprocessing makes high-frequency event detection feasible in embedded ML applications, while introducing additional engineering effort and domain knowledge for parameter selection and tuning.

[0476] Lucas Praxedes (Federal Rural University of the Semiarid Region), Lenardo Silva (Federal Rural University of the Semiarid Region), Rafael Silva (Federal University of Alagoas), Breno Duarte (Federal University of Alagoas), Nicholas Cruz (Federal University of Alagoas), Dalgoberto Júnior (Federal University of Alagoas), Laisa Sousa (National Fund for Educational Development) and Bruno Almeida (Federal University of Alagoas). ***School Demand Forecasting System based on Gradient Boosting with Walk-Forward Validation.***

Abstract. Efficient resource allocation in public education intrinsically depends on accurate enrollment demand forecasting. This work proposes a Data Science approach to forecast enrollments in Brazilian basic education, using microdata from the School Census from 2011 to 2021. GPU-accelerated Machine Learning techniques were employed, specifically Gradient Boosting (XGBoost and LightGBM) combined via Voting Ensemble. The study applied rigorous temporal cross-validation (TimeSeriesSplit) to minimize data leakage problems and utilized context-specific feature engineering, including student-teacher ratios and demand acceleration. The results demonstrated high precision in regular teaching stages ($R^2 > 0.97$) but revealed high hidden volatility in vocational education when subjected to honest temporal validation. Interpretation via SHAP values indicated that historical inertia is the dominant factor in stable grades, while exogenous factors predominate in elective series, offering public managers a transparent tool to differentiate between structural demands and conjunctural fluctuations.

[0500] Mark Leischner (Illinois Institute of Technology) and André Bauer (Illinois Institute of Technology). ***Adaptive Feudal Trader with Dynamic Goal Latent Space for Algorithmic Trading.***

Abstract. This paper introduces the Adaptive Feudal Trader with Dynamic Goal Latent Space (AFT-DGLS) framework, a novel hierarchical reinforcement learning architecture designed for robust portfolio management. We address the fundamental challenges of market non-stationarity and temporal credit assignment by decomposing the investment process into a "feudal" structure of strategic and tactical roles. The system features a high-level controller that sets a continuous 8-dimensional goal vector on a strategic pulse of ΔT days, effectively guiding a layer of specialized soft actor-critic agents. These specialists are conditioned on market regimes identified by a Hidden Markov Model, allowing the architecture to isolate and master distinct market covariance structures.

Validation on an out-of-sample period across a 14-asset universe of global indices and commodities, following an extensive 15-year training horizon (2009--2023), demonstrates significant risk-adjusted superiority. Utilizing the baseline configuration of $\Delta T = 120$ days, the AFT-DGLS agent achieved a Sharpe Ratio of 3.584, representing a 109% improvement over a passive equal-weight benchmark and a 52% improvement over a single-asset buy-and-hold strategy. The resulting Calmar Ratio of 10.061 further confirms the framework's ability to navigate volatile market regimes, providing a robust, goal-conditioned solution for portfolio optimization in non-stationary environments.

[0618] Juan Manuel Roldan Fernandez (Universidad de Sevilla), Jesus Manuel Riquelme-Santos (Universidad de Sevilla) and Manuel Burgos-Payan (Universidad de Sevilla). ***Short-Term Price Forecasting in the Spanish Continuous Intraday Market Using a Hybrid LSTM+ARX Model.***

Abstract. The liberalisation of electricity markets in Europe has created highly volatile short-term price signals that challenge market agents seeking to optimise dispatch and trading decisions. The Spanish Continuous Intraday Market (MIC) operates on a near-real-time basis and exhibits price dynamics that differ substantially from those of the Day-Ahead Market (DAM), driven by last-minute adjustments in renewable generation, load, and system imbalances. Accurate forecasting of MIC prices at short horizons—typically two or more hours ahead—is therefore of practical and economic relevance for generators, retailers, and aggregators that participate in intraday sessions.

This work addresses the problem of predicting the hourly weighted-average MIC price at a forecast horizon of $t+2$ hours, using data collected throughout the year 2024 at a 15-minute resolution. The dataset contains around 100 candidate exogenous variables covering day-ahead marginal prices (MARGINALPDBC), the first three Intraday Auction (IDA) session prices, solar photovoltaic and wind generation forecasts, system demand forecasts, and calendar features (hour of day, day of week) encoded cyclically to preserve their periodic nature. Preliminary analysis revealed a strong positive correlation between the MIC price and the DAM price as well as the IDA auction prices, motivating their inclusion as primary drivers in the predictive models.

A systematic model comparison was performed across three families of approaches. First, classical autoregressive (AR) models with different lag structures were evaluated as linear baselines. Second, Multilayer Perceptron (MLP) networks with various architectures and input configurations were trained to capture non-linear static relationships. Third, Long Short-Term Memory (LSTM) networks—including walk-forward (rolling-origin) variants—were explored for their ability to model sequential dependencies in the price series. In total, more than twenty model configurations were evaluated. The best-performing approach was a hybrid architecture that combines an Autoregressive model with Exogenous inputs (ARX) as a linear base component with a stacked LSTM network that refines the ARX residuals. The ARX layer captures immediate linear relationships and short-range dynamics, while the LSTM layer models complex temporal dependencies and corrects systematic biases of the linear component, allowing the hybrid model to leverage complementary strengths of both paradigms.

The hybrid LSTM+ARX model was evaluated over all 24 anchor hours of the day using a rolling-origin test protocol on the 2024 dataset. The model achieves R^2 values above 0.90 across all forecast anchors, with the best results observed in the early morning and late evening hours where MIC prices are more predictable. A representative case study at anchor hour $t=12:00$ predicting the price at $t=14:00$ yields an RMSE of 8.96 €/MWh, a relative RMSE of 14.02%, a MAE of 6.52 €/MWh, and an R^2 of 0.96, confirming that the model captures the vast majority of price variance. The highest forecast errors are observed around peak demand hours (17:00–19:00), consistent with the elevated price volatility associated with renewable generation uncertainty during those periods. Overall, the hybrid model consistently outperforms the pure AR, MLP, and standalone LSTM baselines across all evaluation metrics.

The results demonstrate that combining linear autoregressive modelling with deep sequential learning is a robust and interpretable strategy for intraday electricity price forecasting. The ARX component provides a strong and transparent linear prior that exploits the tight coupling between the MIC price and closely related market signals, while the LSTM component adds the capacity to encode non-linear temporal structures that a linear model cannot represent. This architecture is well suited to the operational context of the MIC, where forecasts must be updated continuously with a rolling window of recent observations. Future work will explore extended forecast horizons ($t+3$ to $t+6$), the incorporation of real-time network constraint indicators, and the application of attention mechanisms and Transformer-based architectures to further improve accuracy during high-volatility periods.

[0624] Yash Shah (Sr. Quality Specialist). *Covariate-Aware Deep Learning for Injector Core Return Forecasting.*

Abstract. Forecasting fuel injector core returns is a foundational planning activity for heavy-duty diesel remanufacturers; however, current industry practice relies heavily on classical univariate methods such as Seasonal ARIMA and exponential smoothing, often supplemented by manual adjustments. These approaches fail to incorporate critical leading indicators, including diesel prices, freight activity, fleet utilization, defect reporting signals, and broader macroeconomic conditions.

This paper proposes a novel covariate-driven probabilistic forecasting framework for heavy-duty diesel remanufacturing core returns. We benchmark DeepAR and the Temporal Fusion Transformer (TFT) against five classical and machine learning baselines using a multi-year, multi-SKU industrial dataset. The framework integrates publicly available covariates from sources such as NHTSA, EIA, BTS, and FRED, while enforcing a strict temporal data discipline to prevent information leakage.

Experimental results demonstrate that the Temporal Fusion Transformer significantly outperforms all baseline methods, particularly at longer forecast horizons, while providing improved probabilistic calibration. The analysis further reveals that external covariates become the dominant source of predictive signal. Specifically, retail diesel price, the Freight Transportation Services Index, and NHTSA fuel-system complaint counts emerge as the most influential predictors of future core return volumes.

Finally, a newsvendor-style cost model establishes a direct link between probabilistic forecast accuracy and inventory decision-making, highlighting the operational value of improved forecasting in remanufacturing systems.

[0652] Ivan Svetunkov (Lancaster University) and Kandrika Pritularga (Lancaster University). *The "Forgotten" Beginning: Backcasting for Optimal SSOE Initialisation.*

Abstract. ETS and ARIMA are popular models, frequently used in modern forecasting. However, the academic literature has historically focused on the study of optimisation of smoothing parameters over the critical issue of initial state vector specification. This is an important problem, especially in a small sample size, because the starting state might influence the final forecast accuracy. We modify the backcasting initialisation procedure, proposed originally by Box and Jenkins, specifically tailoring it for the State Space models. A central contribution of this work is the development of an endogenous method for estimating the efficient number of degrees of freedom (df) coming from the initialisation. We demonstrate that the df penalty is not static but functions as a gradient between full estimation of states and no estimation at all. Furthermore, we investigate how this refined initialisation affects the estimation of residual variance, to ensure its unbiased estimate. The proposed methodology is validated through a series of Monte Carlo simulations assessing parameter consistency, followed by an empirical application to real-world datasets to demonstrate its practical utility in improving forecasting performance.

[0711] Indeewara Perera (University of Sheffield). *Bootstrap Specification Tests for Multivariate GARCH Processes.*

Abstract. Modelling volatility and dependence in multivariate financial time series is central to many applications in financial econometrics, including risk management, portfolio allocation, and derivative pricing. Multivariate GARCH models are widely used to capture time-varying conditional variances and correlations. Statistical inference in these models relies critically on the correct specification of the innovation distribution, as different assumptions have distinct implications for tail behaviour and the overall shape of the return distribution. Misspecification can lead to biased parameter estimates and misleading conclusions about risk and dependence structures, such as underestimating the Value at Risk. This paper develops bootstrap specification tests for evaluating distributional assumptions in multivariate GARCH models. The proposed methodology is based on transforming multivariate data into univariate data using the marginal and conditional cumulative distribution functions specified by the null model. This transformation produces m independent uniform random variables under the null hypothesis for an m -dimensional process. Test statistics are constructed using scalar-indexed empirical processes that measure deviations between the empirical distribution of these transformed variables and the uniform distribution. When the parameters of the assumed distribution are known, the limiting distribution of the test statistics is pivotal and can be characterised using Brownian bridge processes. In practice, however, model parameters are estimated, which introduces additional sampling variability and leads to non-pivotal asymptotic distributions that depend on the true distribution and the estimator used. To address this issue, the paper proposes a bootstrap procedure that is shown to be asymptotically valid irrespective of the presence of nuisance parameters. The procedure involves drawing random samples from the estimated multivariate distribution to compute bootstrap test statistics and p-values. This approach is shown to be consistent, with the bootstrap p-value approximating the true p-value under the null hypothesis and converging to zero under the alternative. A simulation study involving both IID samples and Constant Correlation GARCH processes demonstrates that the new tests perform well in finite samples. A real data example illustrates the testing procedure.

[0941] Norman Swanson (Rutgers University) and John Chao (University of Maryland). *Consistent Estimation, Variable Selection, and Forecasting in Factor-Augmented VAR Models.*

Abstract. We introduce a completely consistent method for variable selection with high dimensional datasets. The method is presented in a framework where latent factors are estimated for the purpose of dimension reduction, and is meant to serve as a complement to extant methods. We argue that the method is of particular interest in empirical settings where there may be many irrelevant predictor variables. The reason for this is that situations where there are "too many" irrelevant variables can lead to inconsistent factor estimates.

Interestingly, our method yields a consistent estimate of the number of such irrelevant variables, which can aid the applied practitioner in assessing the strength of the underlying factor structure for a particular application.

We also show that when factors constructed using our variable selection method are inputted into the forecast equation simplified by a factor augmented vector autoregressive (FAVAR) model for the purpose of forecasting, the

conditional mean forecast equations can be consistently estimated. Monte Carlo results are presented indicating that the variable selection method performs well in finite samples. The paper also contains two empirical illustrations, where

we compare forecasts constructed from factor-augmented forecast equations using our variable selection procedure with two alternative methods for factor construction - the conventional PCA procedure, which does not pre-screen the variables, and a

hard thresholding method that is widely used in the empirical literature. Overall, we find that our method to outperform both of these alternative procedures in a majority of the cases that we study across different target variables,

forecast horizons, and data window specifications (i.e., recursive or rolling).

[0957] Peter Štetka (Bratislava University of Economics and Business) and Nora Grisáková (Bratislava University of Economics and Business). ***Adoption trajectories and early signals of AI scaling: Evidence from 30 enterprise interviews.***

Abstract. This paper examines artificial intelligence (AI) adoption as a dynamic organizational process rather than a single technological decision. Drawing on 30 in-depth semi-structured interviews with Slovak firms that had adopted AI, the study identifies dominant adoption trajectories and early signals associated with further AI scaling, to provide a qualitative foundation for future forecasting-oriented and maturity-oriented research. The analysis combines thematic analysis and the framework method and is theoretically informed by the Technology–Organization–Environment framework and Diffusion of Innovations. The findings suggest three main trajectories of AI adoption: bottom-up experimentation, top-down strategic adoption, and iterative scaling in AI-oriented firms. Across these trajectories, seven early signals of scaling readiness emerge: explicit adoption goals, pilot or iterative testing, the creation of ownership, broader process or product integration, future-oriented expansion plans, the ability to balance growth with risk control, and organizational learning under technological un-certainty. The paper contributes to current research on enterprise AI adoption by showing that AI implementation develops through distinct temporal patterns and that qualitative interview evidence can be used to identify leading indicators of subsequent scaling.

[0973] Djebali Nesrine (Faculty of Law, Economics and Management of Jendouba) and Amri Chadha (Faculty of Law, Economics and Management of Jendouba). ***Board Effectiveness and European Bank Performance What Role of Corporate Social Responsibility?***

Abstract. This paper examines the impact of board effectiveness on the financial performance of European banks, while investigating the role of corporate social responsibility over the period 2014–2023. Using a panel dataset of 44 European banks and an empirical approach based on the System Generalized Method of Moments, the findings indicate that board remuneration and the presence of a CSR committee significantly enhance bank performance, particularly in terms of return on assets. In contrast, gender diversity, board size, and the frequency of board meetings are found to negatively affect bank performance, suggesting the existence of coordination costs and decision-making inefficiencies within bank boards.

When return on equity is used as a performance measure, the results show that board remuneration, gender diversity, and the number of board meetings exert a negative effect on performance, reflecting different dynamics between asset profitability and equity efficiency. Overall, the findings highlight the importance of board structure and CSR engagement in shaping the financial performance of European banks and provide useful insights for policymakers and decision-makers in designing effective corporate governance frameworks.

[1027] Hossein Pirayesh (Universitat Politècnica de Catalunya) and Jose M Sallan (Universitat Politècnica de Catalunya). ***Forecasting Daily Price Movements of ETFs Using a Bayesian-Optimized Dynamic Sliding Window Size Approach.***

Abstract. Forecasting price movements accurately is vital for profitable investment, and even minor improvements in prediction accuracy can yield significant profits. This study focuses on enhancing prediction accuracy of price movement through a novel approach using dynamic sliding window sizes. Traditional methods often assume that larger datasets produce better prediction accuracy. We challenge this belief by proposing that training machine learning models with data more relevant to the current market regime leads to better results. The optimal sliding window size for predicting each data point is determined by Bayesian optimization, which allows the prediction model to train with the most relevant historical data to improve its predictive capability. Support Vector Machine (SVM) is used as the predictive model, trained with a feature set comprising a diverse range of 39 technical indicators designed to capture various aspects of the market, tested on data from 156 ETFs over five years. The results demonstrate that the dynamic sliding window size method significantly improves the accuracy of price movement predictions compared to baseline models that use fixed sliding window sizes. The proposed model achieves statistically significant enhancements across all evaluation metrics, including accuracy outperforming fixed-sliding window counterparts. These findings highlight the importance of adaptive data selection in time-series forecasting, offering a robust, scalable, and scientifically rigorous methodology to advance the predictive capabilities of machine learning models in dynamic and volatile financial environments.

[1049] Muhammad Qasim (University of Swat, Pakistan), Muhammad Abubakar (University of Swat, Pakistan) and Wajid Rashid (University of Swat, Pakistan). ***Machine Learning Analysis of Surface Temperature, Precipitation, and Land Use Dynamics; A GIS Based Eco-Thermal Assessment of Swat District, Pakistan.***

Abstract. Climate change, defined as the long-term alteration in temperature and precipitation patterns, drives significant ecological and land cover transformations, particularly in vulnerable mountainous regions such as the Swat Valley, Pakistan. This study investigates the spatiotemporal relationship between climatic variability and land use/land cover (LULC) change in Swat District from 2000 to 2024. Using multi-temporal Landsat 5 and Landsat 8 imagery, supervised classification based on the Random Forest algorithm was performed to map seven major LULC classes: water, forest, built-up, agriculture, ice/snow, rangeland, and bare land. In parallel, variations in land surface temperature (LST) and precipitation over the 24-year period were analyzed to assess their correlation with LULC dynamics.

The results reveal a substantial increase in LST accompanied by a marked decline in forest and ice/snow cover, amounting to losses of approximately 2.9 and 3.7 million pixels, respectively. Precipitation patterns also exhibited notable alterations, including declining snowfall frequency and increasingly irregular rainfall events. Built-up areas expanded significantly under population pressure and temperature-induced landscape transformation, while agricultural lands declined due to urban encroachment and land reallocation.

Overall, spatial-temporal analyses demonstrate a strong interdependence between climatic variability and land use change in the Swat Valley. The findings underscore that climate should not be viewed merely as a passive backdrop influencing land systems but as an active driver rapidly restructuring them. This study enriches the growing body of research on climate–land interactions and provides valuable insights to support evidence-based land management and climate adaptation strategies in mountainous regions.

[1082] Gil Cohen (Western Galilee Collge). ***A Comprehensive Study on Short-Term Oil Price Forecasting Using Econometric and Machine Learning Techniques.***

Abstract. This paper investigates the short-term predictability of daily crude oil price movements by employing a multi-method analytical framework that incorporates both econometric and machine learning techniques. Utilizing a dataset of 21 financial and commodity time series spanning ten years of trading days (2015–2024), we explore the dynamics of oil price volatility and its key determinants. In the forecasting phase, we applied seven models. The meta-learner model, which consists of three base learners (Random Forest, gradient boosting, and support vector regression), achieved the highest R² value of 0.532, providing evidence that our complex model structure can successfully outperform existing approaches. This ensemble demonstrated that the most influential predictors of next-day oil prices are VIX, OVX, and MOVE (volatility indices for equities, oil, and bonds, respectively), and lagged oil returns. The results underscore the critical role of volatility spillovers and nonlinear dependencies in forecasting oil returns and suggest future directions for integrating macroeconomic signals and advanced volatility models. Moreover, we show that combining multiple machine learning procedures into a single meta-model yields superior predictive performance.

[1097] Rajat Dogra (Faculty of Economic Sciences, University of Warsaw) and Krzysztof Drachal (Faculty of Economic Sciences, University of Warsaw). ***Forecasting commodities prices with an enhanced Bayesian Dynamic Mixture Models.***

Abstract. Forecasting commodities prices remains a challenging topic, for example, because predictive relationships are unstable and the number of potential commodities prices drivers is often extremely large. To address these issues a hybrid forecasting framework – combining genetic algorithms (GA) with Bayesian Dynamic Mixture Models (BDMM) – can be applied (Nagy, I., Suzdaleva, E., 2013, Mixture estimation with state-space components and Markov model of switching, Applied Mathematical Modelling, 37, 9970-9984; Nagy, I., Suzdaleva, E., Karny, M., Mlynarova, T., 2011, Bayesian estimation of dynamic finite mixtures, International Journal of Adaptive Control and Signal Processing, 25, 765-787). BDMM models nicely deal with model and variable uncertainties, and intrinsically consider time-varying relationships between a response and explanatory variables. They are also based on an on-line dynamic estimation updating, which allows to include new information arriving from the market in a continuous manner, which mimics a real-market players perspectives. However, these features come with a price of computational issues, which can be huge, when the number of explanatory variables is large. To address this issue GA methods are incorporated into BDMM structure. In particular, the proposed approach first uses an evolutionary search procedure to identify important variables from the FRED-MD database, and afterwards inserts these variables into the BDMM environment (McCracken, M. W., Ng, S., 2016, FRED-MD: A monthly database for macroeconomic research, Journal of Business & Economic Statistics, 34, 574-589).

In particular, monthly prices returns of 42 commodities from energy, metals, and agricultural sectors, spanning the period from August 2013 to September 2023, are analyzed (World Bank, 2024, Commodity markets outlook). Forecast accuracy is compared against 23 alternative methods, including autoregressive models, historical mean, Dynamic Model Averaging, Dynamic Model Selection, and penalized regressions (such as, for example, LASSO, ridge, and elastic net regressions). The outcomes show that the proposed framework consistently selects relatively small predictor sets, typically containing only few variables, despite the very large initial candidate space. Monetary and liquidity related indicators are among most often chosen predictors, suggesting that these macro-financial conditions play the central role in commodities prices returns dynamics.

However, even very basic autoregressive models remain highly competitive in terms of mean squared forecast errors, comparing with more sophisticated methods. Nevertheless, the GA-BDMM model still outperforms the naïve method for all considered commodities, and historical mean for numerous ones. The analysis also reveals considerable time variation in models switching across episodes of major economic disruptions, such as the global financial crisis and the COVID-19 pandemic. These findings emphasize the importance of adaptive forecasting structures in commodity markets, characterized by ability to capture structural changes and dynamic linkages between response and explanatory variables. Overall, the proposed methodology and its application provide an interesting alternative to more conventional Bayesian model averaging methods in big data environments.

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[1101] Nora Grisáková (Faculty of Business Management, Bratislava University of Economics and Business, Bratislava, Slovakia) and Peter Štetka (Faculty of Business Management, Bratislava University of Economics and Business, Bratislava, Slovakia). ***A Dynamic Profit Maximization Model for the Expansion of AI Infrastructure under Monopoly Conditions.***

Abstract. This paper proposes a dynamic profit maximization model for a monopolistic provider of AI infrastructure under conditions of market saturation and technological depreciation of infrastructure. The model is formulated within an optimal control framework and links the firm's investment effort, the expansion of AI infrastructure in the relevant market, and discounted profit within a single analytical structure. The objective function is specified as the maximization of discounted profit subject to a dynamic constraint governing the expansion of AI infrastructure. The paper analyzes three scenarios—a baseline scenario, a high-barrier scenario, and a high-opportunity scenario—and complements the analytical results with numerical simulation analysis. The results show that the optimal investment trajectory depends on the effectiveness of investment effort, the cost intensity of investment, and the rate of infrastructure depreciation. A more favorable environment supports earlier and more intensive investment, whereas stronger barriers lead to a more cautious investment strategy and slower expansion of AI infrastructure. The contribution of the paper lies in linking dynamic optimization with the economic interpretation of investment in AI infrastructure under concentrated market conditions.

[1173] Ana Vendrell Blanco (UPM), Eduardo Caro (UPM), Javier Cara (UPM) and Jesús Juan (UPM). *The Impact of Photovoltaic Self-Consumption on Long-Term Electric Demand Forecasting Accuracy.*

Abstract. Accurate electric demand forecasting is essential for the operation and planning of power systems. In this work, we analyze the long-term evolution of forecasting accuracy using a demand prediction model developed and implemented in 2014, designed to generate hourly demand forecasts from one up to ten days ahead.

A key feature of this study is that the forecasting model is kept unchanged throughout the entire analysis period. The same model structure, parameters, and training strategy are applied year after year, allowing the isolation of changes in predictive performance that arise from structural modifications in the electric system rather than from model redesign or recalibration. For several consecutive years following its deployment, the hourly forecasting accuracy remained approximately constant, showing no significant interannual variations.

However, during the last three to four years, a pronounced deterioration in forecasting quality is observed. This degradation is particularly evident during the central hours of the day, where prediction errors increase substantially compared to previous years. To rigorously assess this effect, the study evaluates the evolution of forecast errors on an annual basis and investigates whether the observed differences are statistically significant.

The analysis is conducted using variance analysis techniques and formal statistical hypothesis testing to compare forecasting performance across years and time-of-day segments. The results provide clear evidence of a structural break in predictive accuracy, highlighting the limitations of traditional electric demand forecasting models when confronted with recent changes in demand profiles. The findings underline the need to reassess conventional forecasting approaches in modern power systems and motivate the incorporation of additional explanatory factors to address emerging sources of variability.

[1230] Dennis Shen (University of Southern California). *Obtaining personalized predictions from a randomized controlled trial on Alzheimer's disease.*

Abstract. The purpose of this article is to infer patient level outcomes from population level randomized control trials (RCTs). In this pursuit, we utilize the recently proposed synthetic nearest neighbors (SNN) estimator. At its core, SNN leverages information across patients to impute missing data associated with each patient of interest. We focus on two types of missing data: (i) unrecorded outcomes from discontinuing the assigned treatments and (ii) unobserved outcomes associated with unassigned treatments. Data imputation in the former powers and de-biases RCTs, while data imputation in the latter simulates "synthetic RCTs" to predict the outcomes for each patient under every treatment. The SNN estimator is interpretable, transparent, and causally justified under a broad class of missing data scenarios. Relative to several standard methods, we empirically find that SNN performs well for the above two applications using Phase 3 clinical trial data on patients with Alzheimer's Disease. Our findings directly suggest that SNN can tackle a current pain point within the clinical trial workflow on patient dropouts and serve as a new tool towards the development of precision medicine. Building on our insights, we discuss how SNN can further generalize to real-world applications.

[1237] Mónica Moreno Revelo (Universidad Nacional de Colombia, Universidad Mariana), Juan Bernardo Gómez Mendoza (Universidad Nacional de Colombia), Javier Revelo Fuelagán (Universidad de Nariño) and Diego H. Peluffo Ordoñez (Universidad Yachay Tech). *Deep Learning-Based Imputation of Irradiance Time Series Enhanced by Numerical Data.*

Abstract. Performing imputation of gaps in irradiance time series plays a fundamental role in applications related to environmental monitoring and photovoltaic (PV) systems. Consequently, numerous studies have explored the use of Machine Learning and Deep Learning techniques to complete missing segments in time series. However, only a few works have examined the integration of data obtained from different sources to exploit their complementary strengths. In this context, our research proposes a methodology that compares two Deep Learning architectures—BiLSTM and GAN—for imputing missing values in in-situ irradiance measurements using numerical data as an additional input feature. The methodology is applied to datasets from Viento Libre and Alice Spring, and the results demonstrate that incorporating numerical data significantly enhances imputation performance. Specifically, for the Viento Libre dataset for example, the proposed approach achieves an MAE of 70.98W/m², an RMSE of 105.60W/m², and a KL divergence of 0.3.

[1238] Milena Hoyos (Universidad Nacional de Colombia), Karoll Gómez-Portilla (Universidad Nacional de Colombia) and Daniela Cárdenas-Sánchez (Universidad Nacional de Colombia). *Random coefficient AR(2) in continuous time.*

Abstract. Time series whose persistence and dynamic behavior evolve over time are common in economics and finance. Classical fixed coefficient autoregressive models are often unable to accommodate the degree of heterogeneity, stochastic persistence, and local instability observed in macroeconomic aggregates, financial prices, and volatility measures. These limitations have motivated a large literature on random coefficient autoregressive models, in which autoregressive parameters evolve stochastically over time, allowing for endogenous variation in persistence and conditional second moments. Discrete time random autoregressive models have been shown to capture time varying dynamics and to generate non-Gaussian features such as volatility clustering and heavy tails (see the structured overview in Regis et al., 2022). More recently, a parallel literature has developed continuous time formulations with random coefficients, motivated by sampling-invariance, in-fill asymptotics, and the desire to model data observed at high frequencies. Prominent contributions in this direction include Tao et al. (2019) and Hoyos (2024), who develop continuous time AR(1) and VAR(1) models, respectively, with random coefficients driven by Brownian increments (see also Robinson, 2009).

This paper extends this line of research by studying a continuous time autoregressive process of order two with random coefficients. The choice of an AR(2) structure is not merely technical but is empirically and economically motivated. A continuous time AR(1) defines a first order stochastic differential equation with a single real characteristic root, implying monotonic mean reversion and a discrete time representation with a strictly geometric autocorrelation function. By contrast, a continuous time AR(2) corresponds to a second order stochastic differential equation whose characteristic equation admits either two real roots or a pair of complex conjugate roots, thereby allowing for non-monotonic autocorrelation patterns, and, in the complex root case, damped oscillatory dynamics. These features are frequently observed in practice. Business cycle indicators and output gaps often display cyclical adjustment following shocks; inflation exhibits overshooting and gradual reversal. Such stylized facts are difficult to reconcile with first order dynamics alone but arise naturally from second order equations. From a modeling perspective, the AR(2) specification therefore provides a parsimonious yet flexible framework capable of capturing dynamic patterns that an AR(1) cannot generate.

As in Tao et al. (2019), we introduce randomness in the autoregressive coefficients by allowing them to evolve via Brownian increments. However, moving from a first to a second order continuous time system fundamentally alters the structure of the discrete time representation and, consequently, the associated inference problem. We derive the exact discrete time representation of the continuous time AR(2) with random coefficients and show that it follows an ARMA(2,1) process. The moving average component arises endogenously from the second order differential equation and induces serial correlation in the discrete time errors, even when the underlying continuous time disturbances are serially uncorrelated. This feature is absent in first order continuous time random coefficient models and represents a key source of additional complexity in estimation and inference. Unlike the AR(1) case studied in Tao et al. (2019), where the discrete time errors remain serially uncorrelated, the AR(2) structure implies that ignoring the MA component leads to systematic misspecification.

Our estimation strategy exploits this exact ARMA(2,1) representation to recover the underlying continuous time parameters. The discrete time model serves as the likelihood-relevant object, but its parameters are explicitly linked to the continuous time coefficients through an analytically derived mapping. We study the finite sample properties of the proposed estimators using a Monte Carlo experiment. The simulation results show that the estimators exhibit finite sample bias, but that this bias declines with the span of the data when the serial correlation implied by the MA(1) component is correctly modeled. In contrast, estimation based on a misspecified discrete time model that ignores the induced serial correlation produces a persistent bias that does not vanish as the data span increases and leads to substantially inferior forecasting performance. These findings underscore the importance of accounting for the discrete time implications of higher order continuous time dynamics and complement existing evidence on misspecification bias in continuous time models.

By combining a second order continuous time specification with stochastic autoregressive coefficients, this paper contributes to the literature in three ways. First, it extends continuous time random coefficient autoregressive models beyond the first order, thereby allowing for richer and empirically relevant dynamics. Second, it derives the exact discrete time representation of this model and clarifies how second order continuous time dynamics induce moving average dependence in discretely sampled data. Third, it provides an estimation framework and a systematic finite sample and forecasting comparison that highlights the practical consequences of ignoring this induced serial correlation.

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[1274] Ebrahim Ghaderpour (Sapienza University of Rome), Hanieh Dadkhah (Sapienza University of Rome), Paolo Mazzanti (Sapienza University of Rome), Francesca Bozzano (Sapienza University of Rome) and Gabriele Scarascia Mugnozza (Sapienza University of Rome). ***Least-Squares Cross-Wavelet Analysis of Snow-Temperature Interactions and Spatial Trends in the Alps.***

Abstract. Understanding the interactions between snow cover and land surface temperature (LST) is essential for characterizing land-atmosphere processes in mountainous environments. Snow cover, through its high albedo and insulating properties, influences surface energy balance and affects both daytime and nighttime thermal dynamics. While the dominant annual cycle reflects seasonal radiative forcing, sub-annual variability provides additional insight into transitional processes, including snowmelt and soil moisture dynamics.

In this study, we investigate the interconnection between snow cover and LST in the Alps Conifer and Mixed Forests ecoregion using least-squares cross-wavelet analysis (LSCWA). LSCWA is a robust method for decomposing time series into the time-frequency domain without requiring interpolation or aggregation, allowing estimation of high-resolution cross-spectrograms and phase differences between cycles. We use MODIS monthly LST (MOD21C3) and snow cover (MOD10CM) data at 0.05° resolution from 2000 to 2025. Monthly time series for the 26-year period are obtained by averaging pixel values within the ecoregion. Some monthly images are missing due to factors such as frequent cloud cover and atmospheric noise.

The results show strong and statistically significant annual coherency between snow cover and LST (daytime and nighttime), with a phase difference of approximately five months, indicating a near anti-phase relationship. This reflects the expected seasonal opposition, where maximum snow cover coincides with minimum LST in winter and minimum snow cover aligns with peak LST in summer. Removing the annual cycle from the cross-spectrograms reveals statistically significant semi-annual (6-month) peaks. Although lower in amplitude, these semi-annual peaks exhibit a phase lag of approximately two months, suggesting a physically meaningful delayed response during spring and autumn, when energy is partitioned into snowmelt and evapotranspiration, thereby delaying surface warming.

These results highlight that while the annual cycle is dominated by radiative forcing, semi-annual variability provides insight into land surface processes governing the timing of temperature response to snow dynamics. In addition, we produce Pearson's correlation maps, as well as pixel-level coherency and phase delay maps, to reveal the spatial dynamics of snow–LST interactions. Furthermore, for each calendar month, trend maps are generated using the non-parametric Mann–Kendall test and Sen's slope estimator to investigate changes in snow cover and LST across the ecoregion since 2000.

Overall, these findings are relevant for climate and hydrological applications, providing improved understanding of snow–temperature interactions, constraining land surface processes in climate models, and informing predictions of snowmelt timing and ecosystem responses in alpine regions.

[1286] Tasi'U Musa (Department of Statistics, Ahmadu Bello University, Zaria, Nigeria), Musa Garba Abubakar (Department of Statistics, Nuhu Bamalli Polytechnic, Zaria, Nigeria), Hussaini Garba Dikko (Department of Statistics, Ahmadu Bello University, Zaria, Nigeria), Abubakar Usman (Department of Statistics, Ahmadu Bello University, Zaria, Nigeria), Sanusi Jibrin Alhaji (Department of Statistics, Aliko Dangote University of Science and Technology, Wudil, Nigeria) and Jamilu Garba (Department of Statistics, Ahmadu Bello University, Zaria, Nigeria). ***ON THE DEVELOPMENT OF VECTOR AUTOREGRESSIVE FRACTIONAL UNIT ROOT INTEGRATED MOVING AVERAGE (VARFURIMA) MODEL: A BIVARIATE CASE.***

Abstract. Long Memory is a statistical phenomenon describing a dynamic slow decay of autocorrelation function. The Autoregressive Fractionally Integrated Moving Average (ARFIMA) model is well-known for modeling time series data having such phenomenon, usually estimated in the interval $0 < d < 1$, d is a long memory parameter. The Autoregressive Fractional Unit Root Integrated Moving Average (ARFURIMA) is a univariate time series model designed to handle time series data with long memory in the interval of $1 < d < 2$ (called interminable long memory). This paper presents the multivariate version of the ARFURIMA to enable the simultaneous modeling of two or more time series data with interminable long memory. New multivariate fractional filter is proposed for filtering Multivariate Fractional Unit Root Integrated (MFURI) series and is used to obtain stationary series. The realized stationary series is used for the estimation of Vector Autoregressive Moving Average (VARMA) models. Therefore, incorporating the multivariate fractional filter and VARMA model will result in the formulation of the proposed Vector Autoregressive Fractional Unit Root Integrated Moving Average (VARFURIMA) model. Some well-established results/identities of stacking operators (vec and vech operators), duplication and elimination matrices as well as Moore-Penrose pseudoinverse are used in the process of developing the VARFURIMA. Preliminary results shows that the VARFURIMA outperformed the vector ARFIMA (VARFIMA) in terms of minimum RMSE and MAPE.

[1307] Gabriel David Pinto (Azrieli College of Engineering Jerusalem, Department of Industrial Engineering and Management). ***The Impact of AI on the Forecast Work of Planners.***

Abstract. This paper examines how artificial intelligence (AI) is transforming the daily work of supply chain planners, with particular emphasis on forecasting performance, planning discipline, and organizational adoption barriers. Using a mixed-methods approach that combines two industry surveys, qualitative interviews, and operational data from 14 companies, the study investigates the relationship between AI adoption, forecast accuracy, update frequency, and perceived adoption barriers across functional areas. The results show that AI-supported planning is associated with substantial and statistically significant improvements in forecast accuracy. Planners using AI-based tools outperform those relying on traditional methods, and more frequent updates of forecast parameters and safety stock levels are positively correlated with forecasting precision. Evidence from 14 companies further demonstrates an average forecast accuracy improvement of over 20% following AI implementation, highlighting the strong operational and financial implications of AI-driven planning. In parallel, the study finds that perceived barriers to AI adoption—such as system integration challenges, resource constraints, and human resistance—do not differ significantly across functional areas, indicating that AI adoption is an organization-wide challenge rather than a function-specific one. Overall, the findings suggest that AI's primary contribution lies not only in improving predictive performance, but also in reshaping planners' roles toward more proactive, data-driven, and cross-functional decision-making. Successful adoption therefore depends on aligning technological capabilities with disciplined planning processes and organizational readiness.

[1331] Francesco Lolli (Department of Sciences and Methods for Engineering (DISMI), University of Modena and Reggio Emilia), Antonio Maria Coruzzolo (Department of Sciences and Methods for Engineering (DISMI), University of Modena and Reggio Emilia), Enrico Mizzi (Department of Sciences and Methods for Engineering (DISMI), University of Modena and Reggio Emilia), Elia Balugani (Department of Sciences and Methods for Engineering (DISMI), University of Modena and Reggio Emilia) and Mohamed Zied Babai (Centre of Excellence for Supply Chain Innovation & Transportation (CESIT), Kedge Business School). ***Obsolescence Aware Intermittent Demand Forecasting with Enhanced mSBA Models.***

Abstract. Forecasting intermittent demand is a persistent challenge in spare parts management, particularly when demand declines due to obsolescence. Traditional intermittent demand methods typically assume stable demand patterns and may produce biased forecasts when obsolescence occurs. This study builds on the modified Syntetos–Boylan Approximation (mSBA) proposed by Babai et al. (2019) and introduces two new variants that update the demand size component alone or both demand size and inter-arrival time during zero-demand periods. Using real-world datasets with obsolescent and non-obsolescent items, results show that the proposed variants slightly improve forecast accuracy and reduce bias compared to classical methods, highlighting the value of adaptive updating mechanisms under obsolescence.

[1365] Nadeem Iqbal (National Skills University Islamabad) and Zeeshan Akmal (Global Banking School UK). ***Integrating Machine Learning and Econometric Techniques for Enhanced Forecasting Accuracy: Evidence from Macroeconomic Time Series.***

Abstract. Time series forecasting plays a central role in economic policy design, business planning, and financial decision-making. With the rapid growth of data-driven technologies, the fusion of traditional econometric models and modern machine learning techniques has become increasingly valuable for generating more precise forecasts. This study aims to investigate the comparative performance and integration potential of selected econometric models—such as ARIMA, SARIMA, and VAR—with advanced machine learning algorithms, including Random Forests, Long Short-Term Memory (LSTM) networks, and Gradient Boosting Machines (GBM). The empirical analysis is based on macroeconomic time series data from both developed and emerging economies, including GDP growth rates, inflation, and exchange rate volatility.

The research follows a hybrid modeling approach that combines the strengths of linear statistical models in capturing trend and seasonality with the nonlinear learning capacity of machine learning techniques. The methodology involves a three-stage process: (1) preprocessing and stationarity testing of data using Augmented Dickey–Fuller and KPSS tests; (2) development and estimation of econometric and machine learning models separately; and (3) integration of models through ensemble methods to improve forecast accuracy. Model performance is evaluated using key metrics such as Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and Diebold–Mariano tests for statistical comparison.

The findings reveal that hybrid models significantly outperform individual models, especially in capturing nonlinear dynamics and structural breaks often present in macroeconomic data. The LSTM-based hybrid approach demonstrates the lowest forecasting errors, showing notable improvements during periods of high volatility, such as post-pandemic recovery and global inflation shocks. Moreover, the study highlights that data frequency and the choice of lag length critically influence predictive accuracy. Ensemble models are particularly effective when dealing with noisy or irregular time series, providing more stable and interpretable results for policy and strategic applications.

This research contributes to the existing literature by offering a comprehensive framework for integrating econometric and machine learning models in time series forecasting. It emphasizes the importance of combining theoretical rigor with computational innovation to achieve robust and adaptive forecasting systems. The proposed hybrid methodology can be applied across domains such as finance, energy demand, climate prediction, and tourism forecasting. The study also provides guidelines for practitioners on selecting appropriate model combinations and parameter optimization strategies.

Ultimately, this work demonstrates that the convergence of statistical and computational paradigms can significantly enhance the accuracy, reliability, and interpretability of time series forecasts, thereby supporting better-informed economic and business decisions. The results and framework presented in this research align with the ITISE 2026 themes, focusing on methodological advances, empirical applications, and interdisciplinary insights into time series modeling and forecasting.

[1383] Mile Bošnjak (University of Zagreb, Faculty of economics and business), Ivan Novak (University of Zagreb, Faculty of economics and business) and Silvija Vlah Jerić (University of Zagreb, Faculty of economics and business). ***Time-Varying Functional Cointegration under Structural Instability.***

Abstract. We develop a time-varying functional cointegration framework for integrated Hilbertvalued time series in which the long-run equilibrium operator evolves smoothly over time and may also undergo abrupt structural breaks. We establish a representation result yielding a time-varying functional vector error-correction model (VECM) with a drifting and potentially discontinuous cointegrating space. Estimation is based on local covariance operators combined with B-spline regularization, while structural instability is detected using operator-valued CUSUM and MOSUM statistics. We show consistency of the local operator estimator under general nonstationarity and consistency of break-date estimators under fixed jump alternatives. Monte Carlo experiments calibrated to yield-curve dynamics confirm strong finite-sample performance. An application to euro-area AAA sovereign yield curves (2004–2024) documents pronounced smooth evolution in the equilibrium relation and a dominant structural break associated with the sovereign debt crisis. The results provide a unified econometric approach to long-run dependence in functional financial time series under structural instability.

[1451] Eleonora Cavallaro (Sapienza University of Rome, Department of Economics and Law, Faculty of Economics, Italy) and Bernardo Maggi (Sapienza University of Rome, Department of Statistical Sciences, Faculty of Engineering, Informatics and Statistics). ***The Fragility Behind the Peg: a Two Continuous-Time-Equation Framework for the Dynamics of the Currency Board.***

Abstract. In this research, we study a 2×2 continuous time dynamical model for a currency board, where the domestic liquidity depends on the dynamics of foreign reserves, i.e., the balance of payments. We want to show that a simplified version of our previous works, where all the economic agents involved in the currency board are modeled, is capable to describe if and when the system is not sustainable, and therefore may be spendable for forecasting analysis. We refer to Argentina's experience and employ a nonlinear continuous-time model to obtain more precise coefficients in terms of both efficiency of estimations and speed of convergence. This methodology is specifically suited to the macro-finance field. We show that with a nonlinear interaction in the expectations-debt dynamics, the economy is driven to a low-growth trap, which calls for repeated monetary policy interventions to preserve stability, de facto deviating from the currency regime. Our findings can help shape the discussion on the viability of a currency board regime, highlighting that it cannot substitute for structural competitiveness or external balance.

[1470] Dr. Jahanzaib Alvi (Institute of Business Management). ***Tail-Risk Herding and the Fragility of Diversification in Global Islamic Equity Markets.***

Abstract. This study examines whether herding behavior in global Islamic equity markets is an unconditional feature of Shariah-compliant investing or a conditional phenomenon that surfaces exclusively under severe market stress. Using a panel of 31–32 Islamic indices and exchange-traded fund (ETF) proxies spanning developed, emerging, Gulf Cooperation Council (GCC), South Asian, and Southeast Asian markets—comprising 86,615 daily observations from 2013 to 2026—we apply a layered identification strategy combining cross-sectional absolute deviation (CSAD) and cross-sectional standard deviation (CSSD) frameworks with a Hwang–Salmon beta-dispersion diagnostic. Unconditional herding is rare, detected in only 2 of 31 markets. Broad crisis classification yields only a marginal increase in convergence. Herding instead becomes strong and statistically reliable within the most extreme downside-return states: 45.16% of markets exhibit herding or weak herding during the worst 5% of trading days, rising to 67.74% under winsorized dispersion and remaining stable across stricter firm-coverage thresholds. Hwang–Salmon tests confirm that return-based convergence is accompanied by systematic-risk convergence in a meaningful subset of markets. The conditional nature of herding is explained through an integrated theoretical framework combining informational cascade theory, prospect-theoretic loss aversion, noise-trader risk, reputational institutional mimicry, and the structural architecture of Shariah screening. These findings establish that diversification benefits within Shariah-compliant portfolios are most fragile precisely when they are most needed, carrying direct implications for tail-risk hedging, regulatory surveillance, and the design of Islamic-finance research.

[1535] Filippo Petroni (Università d'Annunzio Chieti-Pescara). ***Forecasting Short-Horizon Energy Loss for Wind Farm Maintenance: A Mobility-Based Decision Framework.***

Abstract. The increasing integration of wind energy into power systems has intensified the need for predictive tools that support operational decision-making under uncertainty. In particular, wind farm operators face the challenge of anticipating short-term non-production events and allocating limited maintenance and monitoring resources efficiently. Traditional reliability metrics, such as availability or long-run failure rates, provide only aggregate information and are not designed to support short-horizon forecasting or real-time intervention planning.

This work proposes a forecasting-oriented framework for maintenance decision support based on stochastic modeling of wind dynamics and instantaneous mobility indicators. Wind speed is modeled as a continuous-time Markov chain (CTMC) over discretized regimes, estimated directly from observed time series. This representation captures the transition structure of wind conditions and enables the evaluation of short-horizon dynamics in a fully probabilistic setting.

A key element of the approach is the definition of a target variable representing short-horizon expected non-production. At each decision time, the expected energy loss over a fixed operational horizon (e.g., six hours) is computed conditionally on the current state of the system. This quantity serves as a ground truth for evaluating predictive signals and allows the problem to be framed as a forecasting task: identifying which time windows are most likely to incur high energy loss.

The predictive signals considered in this work are derived from instantaneous mobility indicators of the CTMC generator. In particular, the Rate of Occurrence of Failures (ROCOF) is interpreted as a short-term forecasting signal measuring the instantaneous transition intensity toward non-operational regimes. Unlike static hazard proxies, ROCOF captures the dynamic structure of regime switching and provides a first-order approximation of the probability of entering failure states over a short horizon. Additional signals, such as drift indicators combining failure and repair intensities, are also considered to capture directional effects in the evolution of the system.

Maintenance policies are implemented as ranking rules on a discrete decision grid, where signals are evaluated at each observation time. The forecasting performance of these signals is assessed using classification and ranking metrics. Specifically, the Area Under the ROC Curve (AUC) is used to measure the ability to discriminate high-risk periods, defined as time windows with the highest expected loss. Lift curves are used to quantify operational efficiency, measuring how much of the total expected loss can be captured when interventions are restricted to a limited fraction of time points.

The empirical analysis is conducted on a multi-site dataset of wind farms characterized by heterogeneous wind regimes. For each site, the CTMC generator is estimated from discretized wind-speed observations, and mobility-based indicators are computed consistently across locations. The results show that mobility-based signals significantly outperform benchmark approaches based on availability or marginal hazard rates. In particular, ROCOF-based signals provide strong predictive performance, achieving high AUC values and substantial lift gains. This implies that a large portion of expected energy loss can be anticipated and targeted using a relatively small number of interventions.

From a forecasting perspective, these findings highlight the importance of modeling transition dynamics rather than relying on static summaries of wind conditions. The proposed approach effectively transforms reliability indicators into predictive features, enabling a data-driven prioritization of intervention times. From an operational standpoint, this translates into more efficient maintenance planning, where resources are allocated to periods with the highest predicted impact on energy production.

Finally, the framework supports not only short-term intervention scheduling but also cross-site decision-making. Aggregated mobility measures, such as the integrated Total Mobility Rate, provide a structural indicator of regime variability and can be used to rank wind farms according to their exposure to non-production risk. This enables a hierarchical decision strategy combining forecasting at the time level with prioritization at the asset level.

Overall, the proposed methodology bridges stochastic reliability modeling and forecasting-based decision support, providing a scalable and interpretable approach for predictive maintenance in wind energy systems.

[1656] Frederik Hoffmann (FH Münster), Ann-Sophie Bülter (FH Münster), Jonas Homrighausen (FH Münster), Ludwig Horsthemke (FH Münster), Marina Peters (FH Münster), Markus Gregor (FH Münster), Ignacio Rojas Ruiz (University of Granada) and Peter Glösekötter (FH Münster). ***Conceptual Design and Preliminary Analysis of a Resource-Constrained Measurement Device Using Nitrogen Vacancy Centers.***

Abstract. This work presents a conceptual design and preliminary analysis of a resource-efficient measurement device using nitrogen vacancy centers to measure magnetic fields. The electric current is derived by using the Biot-Savart law. Laboratory instruments have broad measurement capabilities, like frequency bandwidth and accuracy, but are often oversized and expensive. Field-programmable gate arrays with dedicated fast analog-to-digital and digital-to-analog converters have limitations in terms of the frequency bandwidth of generated signals and the digitisation of analog signals.

We use a RedPitaya field-programmable gate array with an add-on board which includes an IQ Modulator. The high frequency signals have a typical frequency around 2.87 GHz and a limited bandwidth of 100 MHz. Due to the limited bandwidth, it is not possible to detect the whole optically detected magnetic resonance spectrum of the nitrogen vacancy center with its eight resonances. In this work, we show that it is possible to derive the electric current and the temperature from only four resonances, instead of the full optically detected magnetic resonance spectrum. The proposed approach significantly reduces hardware complexity while maintaining a root mean square error of 3.80 A, obtained over a temperature range of -25°C to 50°C.

[1675] Uwe Hassler (Goethe University Frankfurt), Marc-Oliver Pohle (Karlsruhe Institute of Technology) and Tanja Zahn (Goethe University Frankfurt). ***Simultaneous Inference Bands for Autocorrelations.***

Abstract. Sample autocorrelograms typically come with significance bands (non-rejection regions) for the null hypothesis of no temporal correlation. These bands have two shortcomings. First, they build on pointwise intervals and suffer from joint undercoverage (overrejection) under the null hypothesis. Second, if this null is clearly violated one would rather prefer to see confidence bands to quantify estimation uncertainty. We propose and discuss both simultaneous significance bands and simultaneous confidence bands for time series and series of regression residuals. They are as easy to construct as their pointwise counterparts and at the same time provide an intuitive and visual quantification of sampling uncertainty as well as valid statistical inference. For regression residuals, we show that for static regressions the asymptotic variances underlying the construction of the bands are the same as those for observed time series, and for dynamic regressions (with lagged endogenous regressors) we show how they need to be adjusted. We study theoretical properties of simultaneous significance bands and two types of simultaneous confidence bands (sup-t and Bonferroni) and analyse their finite-sample performance in a simulation study. Finally, we illustrate the use of the bands in an application to monthly US inflation and residuals from Phillips curve regressions.

[1682] Constantin Burgi (University College Dublin). ***How far ahead can the Federal Reserve forecast?.***

Abstract. Forward guidance has become an important tool for major central banks. We assess how far out this forward guidance has predictive content. We assess the Tealbook and FOMC projections for the main variables using existing and new approaches. We find that the projections for the Fed Funds Rate have predictive content up to nine quarters out while the other variables have virtually no predictive power beyond a quarter or two ahead. This suggests that the FOMC publishes projections well beyond their ability to predict and that the FOMC sticks to the Fed Funds projections beyond their ability to predict fundamentals. This could result in a delayed response of monetary policy to a new economic situation.

[1692] Challa Krishna Rao (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India), Tamminana Lokanadha Rao (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India), Sarat Kumar Sahoo (Department of Electrical Engineering Parala Maharaja Engineering College Berhampur,Odisha), Swetha Irugatla (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India), Pappu Baladhitya (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India), Kuchetti Krishna Rao (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India) and Vanjarapu Venkata Rao (Aditya Institute of Technology and Management Tekkali,Srikakulam,Andhra Pradesh,India). ***Dynamic Pricing-based Home Energy Management for Islanded Operation with Integrated Distributed Energy Resources.***

Abstract. An innovative technique for optimizing residential energy consumption using home energy management systems (HEMS) is introduced with a focus on reducing electricity bills and improving energy efficiency. The technique describes a dynamic pricing technique for load optimization in an islanded mode operation of HEMS, especially during situations when grid connection is not feasible. The proposed technique considers an integrated operation of major DER such as photovoltaic systems, electric vehicles, and battery energy storage systems, including situations when grid connection is not feasible. The technique demonstrates real-time control using dynamic pricing signals to maximize energy efficiency. Results have been obtained for two different outage situations: a short-term schedule and a continuous 24-hour islanding mode. The results obtained for different seasons, including spring, summer, and winter, indicate a reduction in grid dependency to 10% for spring months and a subsequent amplification to 50% in both summer and winter months for short-term outages. As per latest studies, a complete dependency on local resources can be achieved for full-day islanding situations. The latest research shows an impact of up to 60% in lessening grid dependency using such integrated HEMS systems under increasing demand due to escalating energy prices.

[1785] Nesrine Djebali (Faculty of Law, Economics and Management of Jendouba). ***Does income diversification matter for bank stability? A threshold analysis for MENA banks.***

Abstract. This paper investigates the relationship between income diversification and bank stability using a sample of 75 conventional banks from 11 Middle East and North Africa countries over the period 1999–2020. To capture the potential non-linear nature of this relationship, we employ the Panel Smooth Threshold Regression model. Using stability measure, our findings reveal the presence of a threshold effect in the diversification–stability nexus. Specifically, the results show that when net interest income diversification is below the threshold of 48.75%, it has a significant and positive impact on bank stability. In contrast, net non-interest income diversification significantly reduces bank stability when it is below the threshold of 51.15%.

[1788] Martial Ndeffo (Texas A&M University), Sina Mokhtar (Texas A&M University) and Dana Pittman (Texas A&M University). ***Global risk of dengue outbreaks and the impact of El Niño events.***

Abstract. Background

Dengue fever is an arboviral disease caused by the dengue virus (DENV). Its geographical distribution and health burden have been steadily increasing through tropical and subtropical climates in recent decades.

Methods

We developed a temperature- and precipitation-dependent mechanistic model for the global risk of dengue fever outbreaks using the basic reproduction number (R_0) as the metric of disease transmission risk. We used our model to evaluate the global risk of dengue outbreaks from 1950 to 2020 and to investigate the impact of annual seasons and El Niño events.

Results

We showed that the global annual risk of dengue outbreaks has steadily increased during the last four decades. Highest R_0 values were observed in South America, Southeast Asia, and the Equatorial region of Africa year-round with large seasonal variations occurring in other regions. El Niño was shown to be positively correlated with the global risk of dengue outbreaks with a correlation of 0.52. However, the impact of El Niño on dengue R_0 was shown to vary across geographical regions and between El Niño events.

Conclusions

Strong El Niño events may increase the risk of dengue outbreaks across the globe. The onset of these events may trigger a surge of control efforts to minimize risk of dengue outbreaks.

[1822] Jan-Ole Thranow (FH Münster), Felix Winters (FH Münster), Andre Loechte (University of Applied Sciences Muenster), Markus Gregor (Department of Engineering Physics, FH Münster—University of Applied Sciences), Peter Glösekötter (Muenster University of Applied Sciences) and Ignacio Rojas Ruiz (University of Granada). ***Data-Driven State-of-Charge Estimation for Rechargeable Zinc-Air Batteries Using LSTM with EIS-Based Feature Engineering.***

Abstract. This work presents a data-driven approach for state-of-charge (SoC) estimation of rechargeable zinc-air batteries (ZAB) based on electrochemical impedance spectroscopy (EIS). Due to the nonlinear electrochemical behavior and flat discharge voltage profile of zinc-air batteries, accurate SoC estimation remains challenging. The investigated cells employ a three-electrode configuration with a dedicated gas diffusion electrode (GDE) for discharge and a separate electrode for charging. This work focuses exclusively on discharge operation, as the two current paths involve physically distinct electrodes with fundamentally different impedance characteristics. High-dimensional impedance spectra are combined with physically interpretable features derived from a simplified equivalent circuit model (ECM) and compressed via principal component analysis (PCA). A long short-term memory (LSTM) network models the relationship between the resulting feature representation and SoC, with Bayesian hyperparameter tuning applied to optimize architecture and training configuration. Performance is compared against baseline models including multilayer perceptrons (MLP). The model is trained on multiple battery cells and evaluated on a completely held-out cell to assess cross-cell generalization. The results show that PCA compression of the combined EIS and ECM feature vector is the decisive optimization step, achieving a mean absolute error of 1.04% on an unseen test cell. In contrast, the choice of model architecture has a smaller impact on performance.

[1886] Adam Daouk (Lebanese American University), Ali Al Rifai (Lebanese American University), Pascale Bou Chahine (Lebanese American University) and Seifedine Kadry (Lebanese American University). ***Forecasting GDP Growth in the Arab World Using ARIMA and ETS Models: A Comparative Time-Series Analysis.***

Abstract. Accurate forecasting of gross domestic product (GDP) growth is essential for understanding macroeconomic trends and informing effective policy decisions, particularly in economically volatile regions such as the Arab World. This study presents a comparative time-series analysis using two widely applied and interpretable forecasting approaches: the AutoRegressive Integrated Moving Average (ARIMA) model and Holt's Exponential Smoothing (ETS) model. Annual GDP growth data for the Arab World were obtained from the World Development Indicators (WDI) database and cover the period from 1991 to 2023, following the exclusion of earlier years due to data inconsistencies. Both models were trained on historical observations and evaluated using a five-year holdout sample. Forecast accuracy was assessed using Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). The results indicate that ETS marginally outperforms ARIMA, achieving lower forecasting errors (MAE = 3.09, RMSE = 4.08) compared to ARIMA(0,1,1) (MAE = 3.25, RMSE = 4.10). While ETS produces smoother and more stable forecasts suitable for short- to medium-term planning, ARIMA demonstrates greater responsiveness to abrupt economic fluctuations. These findings suggest that ETS may be more appropriate for baseline policy forecasting, whereas ARIMA remains valuable for capturing short-term volatility in GDP growth.

[2003] Valeri Makarov (Universidad Complutense de Madrid), Ricardo Muñoz (Universidad Complutense de Madrid) and Julia Makarova (CNC, CSIC). ***Identification and Quantification of Complex Nonlinear Dynamics in Biological Recordings.***

Abstract. Modern biological recordings yield high-dimensional and high-definition time series. Their nonlinear analysis is a long-standing problem tangled by limited data stationarity and intrinsic neuronal noise. Here, we study the use of the correlation dimension (CD) to quantify the underlying nonlinear dynamics in local field potentials (LFP). We present a novel numerical method that combines linear preprocessing of time series with a nonlinear technique to estimate the CD and noise level in LFP generators. We show that the approach provides an accurate estimate of the CD and also reduces the required data sample size by orders of magnitude, thereby improving the time resolution.

[2098] Aayan Ali (Allen High School, Allen, TX 75002,) and Eugene Pinsky (Boston University Metropolitan Collega). ***Visualizing Time-Series Dynamics of GDP Growth and Gini Inequality Index Across Countries.***

Abstract. Income inequality is a central concern for living standards and social stability. Cross-country comparisons often ask whether rising output is associated with rising or falling inequality. This study examines how the changes in GDP per capita and the Gini index are associated across 50 countries and whether that relationship differs across two 10-year time periods: 2004–2013 and 2014–2023. Using country-year panel data, linear trends are estimated separately for GDP per capita (with a base-year-normalized index) and the Gini index within each time window. The resulting GDP and Gini slopes are then compared across countries using slope-slope scatterplots and quadrant-based classification using a standard Cartesian coordinate plane. Results indicate that the majority of countries had rising GDP and lessening inequality. Additionally, the most common shift across the time windows was from Quadrant IV to Quadrant I, as some countries continued to see economic growth while their inequality worsened. Overall, the findings support the interpretation that the growth-inequality relationship is heterogeneous across countries and can vary by time window. This can guide further research through extensions such as rolling-window estimations and creating a new index through slope standardization.

[2142] Ritwik Das (Plutous Research) and Auntara Nandi (Plutous Research). ***Predicting Stock Price Movements in High-Frequency Trading.***

Abstract. This research focuses on utilizing techniques to predict mid-price movements and bid-ask spread crossings in high-frequency trading. The study explores the use of support vector machines, random forests, and gradient boosting algorithms on limit order book (LOB) data, capturing stock price movements at the millisecond scale.

The dataset is split into two time periods: 9:30–11:00 and 11:00–12:00, with the former used for model fitting and assessment. Various performance measures, including recall, precision, and F1-measure, are employed to evaluate the machine learning models. Additionally, summary statistics are derived to fit a logistic regression model and compare its results with the machine learning approaches.

The findings indicate that while the models perform well during the 9:30–11:00 period, achieving precision levels of 70%–80%, they yield unsatisfactory results during the 11:00–12:00 strategy timeframe. The discussion highlights the challenges in achieving high backtesting accuracy and suggests potential avenues for improvement, such as incorporating additional time-sensitive features and considering time-series techniques. Furthermore, the study addresses the importance of factoring in transaction fees when evaluating real-life profitability, proposing an approach to reclassify spread cross labels to account for transaction costs.

[2231] Eric Grivel (IMS lab, Bordeaux INP, University of Bordeaux). ***Recursive Way to Get the Cross-Entropy Rate to Evaluate Data Model Dissimilarity in a State-Space Framework.***

Abstract. In many signal processing problems, such as GPS navigation, target tracking, and speech enhancement, the available data can be modeled a priori within a state-space framework. This framework describes how the state vector evolves over time and how it is related to the observations. Comparing or classifying state-space representations (SSRs) of a system can be of interest for estimation purposes, but not only. However, the number k of consecutive state vectors considered over time

may significantly impact the evaluation of similarity between the models. In this paper, we derive analytical expressions for the entropy associated with the equation updating the state vector under a given model, as well as for the Kullback–Leibler divergence and the cross-entropy between two different models, using a recursive approach. Under certain conditions, which are explicitly stated, we show that these measures, as functions of k , are either equal to or well approximated by affine

functions. The corresponding slopes define quantities known as rates in information theory. These rates do not depend on k and can therefore be used as meaningful criteria for comparing SSRs and, consequently, the a priori models used to describe the time series to be processed. Illustrations are provided for motion models.

[2292] Per B Solibakke (Norwegian University of Science and Technology). ***Decomposing Volatility in the microstructure turbulent Nordic/Baltic Power Market A Multifactor Stochastic Volatility Approach.***

Abstract. The paper examines the intricate mechanisms of the latent volatility in the turbulent Nordic/Baltic electricity market. Recently and from 2018, market microstructure, structural evaluation, and political turbulence need context, giving rise to a need of an analysis of several periods. In contrast to many future markets, the electricity contracts, Nord Pool one-day ahead, Nasdaq OMX future quarter contracts and Nasdaq OMX future year contracts have delivery periods (supply) and average price estimates of 24, 2208 and 8760 hours, respectively. Volatility modelling for these contracts, with differing delivery hours and fundamental to derivative pricing, risk management, and strategic portfolio allocation, presents a significant methodological challenge. Moreover, the market is mainly green (hydro) but for the last decade influenced by the green and turbulent wind and solar intermittency. Unlike conventional financial assets, electricity is a unique commodity characterized by non-storability, inelastic demand, and a critical reliance on physical transmission infrastructure and its balancing. The application of a Bayesian Markov Chain Monte Carlo (MCMC) methodology to estimate a Multifactor Stochastic Volatility (SV) model provides profound insights into the latent risk architecture of the Nordic/Baltic power market. The manuscript focuses on commodity market total volatility from one persistent component and one transitory component by using the MCMC based multifactor Stochastic Volatility (SV) model. The manuscript's core empirical finding—that the post-2018 green transition and market microstructure turmoil have dramatically elevated overall volatility while compressing volatility persistence (long memory), particularly for longer-dated contracts (2208 and 8760 hours)—signals a fundamental regime shift. The market is transitioning from a slow-moving, hydro-dominated fundamental risk pricing model (the persistent factors) to a fast-moving, weather-driven transient risk model (transitory factors). The empirical results demonstrate a structural break: the variance of the "fast-moving" short-term volatility factor is cannibalizing the predictable, "slow-moving" fundamental (hydro/nuclear) factor. By employing the Bayesian MCMC estimation (simulation) and the reprojection technique (a Kalman filter), we success in establish the mode and mean (with associated standard errors) from a two volatility factors SV-model for all period structures. Our results depict a higher volatility for the Nord Pool one-day ahead auction series (24 hours delivery) relative to the two longer delivery Nasdaq OMX contracts showing decreasing volatility (2208 hours delivery and 8760 hours delivery). The SV model persistence seems dependent on the length of contract delivery. From high persistence for the year contracts to low persistence for the Nord Pool one day ahead contracts. Furthermore, for the latest period from 2018 to 2026 reports both higher overall volatility for all contracts and an important change in persistence (lower). Shorter delivery contracts (one-day ahead and quarter) seem to show a relatively low but increasing persistence. Longer contracts (year) report a relative decreasing and varying persistence. The empirical results have distinct implications for the triad of market participants (producers/generators, consumers (industrial/utilities), and traders/investors. The 2018-2026 turbulence is the unavoidable byproduct of replacing dispatchable, predictable thermal and hydro baseload generation with intermittent, weather-dependent renewable resources.

[2325] Zeeshan Malik (Saudi Aramco), Reham Yousef (Saudi Aramco) and Ali Abusnina (Saudi Aramco).

CADE-GA: Context-Adaptive Deep Ensemble Meta-Learning via Genetic Algorithms for Time Series Forecasting.

Abstract. Ensemble methods have shown remarkable success in time series forecasting, yet existing approaches rely on gradient-based optimization for weight learning, limiting their ability to escape local minima and explore diverse weight configurations. We propose CADE-GA (Context-Adaptive Deep Ensemble via Genetic Algorithms), a novel framework that leverages evolutionary computation for ensemble meta-learning. CADE-GA employs a genetic algorithm to optimize instance adaptive ensemble weights conditioned on custom meta-features, enabling global search without gradient computation. We introduce four key innovations: (1) vectorized population evaluation for computational efficiency, (2) sigma decay for adaptive exploration-exploitation trade-off, (3) sparse mutation to maintain population diversity, and (4) domain-specific meta-features capturing time series characteristics. Theoretical analysis proves $O(1/\sqrt{T})$ convergence rate and $O(M \log M/\epsilon^2)$ sample complexity. Experiments on ETTh1 and ETTh2 datasets demonstrate consistent improvements of 2.5-2.7 % over gradient-based ensembles, validating the effectiveness of evolutionary approaches for ensemble meta-learning.

[2393] Rafael González-Val (Universidad de Zaragoza & IEB) and Miriam Marcén (Universidad de Zaragoza). ***The Impact of the Spanish Civil War on the Stationarity of Fertility Rates.***

Abstract. A civil war is among the most disruptive events in a nation's history, often shaping its development at multiple levels (Blattman and Miguel, 2010). Nevertheless, from an academic perspective, some of its consequences remain relatively underexplored. While there is extensive scholarly literature on the effects of wars on the hierarchy of cities and regions, their demographic impacts on population and birth rates have received much less attention.

The Spanish Civil War (hereafter SCW) began in 1936 following a failed military coup by an extreme right-wing faction of the army against the legally constituted Republican government, which had been formed in 1931. The war followed a period of heightened social and political polarization that, despite internal divisions, resulted in a clear-cut divide: Left (i.e., Republican/loyalist) versus Right (i.e., Nationalist/rebel). The coup quickly split both the army and the country into two camps. Initially, in 1936, Republican territory accounted for about 60 percent of the country's total population. The coup failed in four of the six largest cities (those with over 200,000 inhabitants)—Madrid, Barcelona, Valencia, and Málaga—but succeeded in two: Seville and Zaragoza. However, the rebellion soon secured control of 32 of the 49 provincial capitals, which were key centers of political, economic, and military power (Ortega and Silvestre, 2006). Over nearly three years, the frontlines gradually shifted in favor of the Nationalist army. The war ended in 1939, and General Francisco Franco, the leader of the rebel forces, established a right-wing dictatorship that lasted until 1975.

Excess mortality caused by the SCW is estimated at approximately 350,000 deaths, rising to around 500,000 when including the immediate postwar years up to 1942—roughly double the number caused by the Napoleonic Wars in Spain (Ortega and Silvestre, 2006). Of this latter total, around 200,000 deaths resulted from political repression: about 50,000 in areas controlled by the Republicans and nearly 150,000 in areas that progressively fell under Nationalist control (Preston, 2012).

At the city level, González-Val and Silvestre (2023) find that, for the full sample of provincial capitals, the SCW did not have a statistically significant effect on overall city growth. However, population growth in cities that had belonged to the losing side for most of the war experienced a significant negative impact compared with cities aligned with the winning side. According to their estimates, the effect of the war was temporary, lasting just over a decade (11–12 years), and tended to fade toward the end of that period. Nevertheless, despite being temporary, the shock left a lasting imprint on city size: twelve years after the war, the average population of losing-side cities was still about 6 percent smaller than it would have been in the absence of the conflict. A robustness check shows that the effect on regional population was similar.

We argue that much of this population loss corresponded to young men—married or of marrying age—whose absence created an imbalance in the marriage market: a “shortage” of men relative to an “abundance” of women, partly due to the increase in the number of widows. A key prediction of marriage-market models is that a decline in the ratio of men to women improves men's position while worsening women's position, yet very few papers directly study the impact of wartime sex-ratio shocks on fertility outcomes.

Ogasawara and Komura (2022) provide a valuable theoretical framework linking shocks to the sex ratio with fertility behavior. They develop a household bargaining model in which couples negotiate over the quantity and quality of children, with bargaining power determined by the sex ratio in the marriage market. Using panel data at the prefecture level in Japan and treating the exogenous impact of World War II as a natural experiment, they show that the wartime decline in the male-to-female ratio contributed to a smaller postwar decline in both fertility and child mortality. In particular, absent the decrease in the sex ratio, the fertility rate would have fallen by an additional 12 percent and the child mortality rate by an additional 13 percent between 1948 and 1970.

Bethmann and Kvasnicka (2013) use county-level census data for the German state of Bavaria in 1939 and 1946 and, treating World War II as a natural experiment, study the effects of changes in the adult sex ratio on out-of-wedlock fertility. They find that war-induced shortfalls of men significantly increased the non-marital fertility ratio in the mid-twentieth century. Similarly, Brainerd (2008) investigates the effects of exogenous (war-related) sex-ratio changes on the prevalence of non-marital fertility and finds evidence for post-WWII Russia of a negative correlation at the regional level between sex ratios and non-marital fertility.

In related work, Abramitzky et al. (2011) examine the effects of male scarcity caused by World War I mortality in France on marriage-market outcomes. They show that the reduction in the proportion of men increased men's likelihood of marrying and enabled them to marry women from higher social classes. In regions with higher postwar male mortality, women were less likely to marry, tended to marry at older ages, and the age gap between spouses narrowed. However, they do not explore the implications for fertility.

Building on this literature, we analyze whether there was a significant (transitory or permanent) change in the crude birth rate (defined as the number of live births per thousand inhabitants) following the SCW. To do so, we exploit a new long-term annual dataset (González-Val and Silvestre, 2020). We consider two spatial units: provinces (NUTS III regions) and provincial capitals (a subset of LAU II / NUTS V units). The total number of observations is 5,488 over the period 1900–2011 (49 provinces or capital cities $\times$ 112 years).

First, we use time-series methods to test whether each province's or capital's series is stationary or follows a unit-root process. Using Augmented Dickey–Fuller tests, we find strong support for the null hypothesis of a unit root in the crude birth rate: the null is not rejected in any case in the sample (0% rejections for both provinces and capital cities at the 5% level). We also allow for one structural break (Perron and Vogelsang, 1992) and two structural breaks (Clemente et al., 1998), and the evidence in favor of unit roots remains. Rejections increase only slightly, to 6% in the two-break specification. Interestingly, in this case the first break is often detected around the dates of the SCW, especially for provinces.

We conduct two robustness checks. First, we use the generalized supremum ADF (GSADF) test of Phillips et al. (2011, 2015), which does not impose exogenous breaks. The share of rejections rises but remains below 50%: the null is rejected for 10% of provinces and 41% of capital cities. Second, we apply panel unit-root tests (Levin–Lin–Chu, Im–Pesaran–Shin, and Pesaran). Results are mixed across tests and spatial units, but taken together they support the conclusion that crude birth rates behave as a unit-root process in panel data. This implies that after a major shock such as the SCW, changes in the crude birth rate are expected to be permanent rather than transitory.

Second, to better understand the impact of the SCW on crude birth rates, we estimate panel data models that exploit exogenous, province- (or city-) specific wartime male losses. The results indicate a positive and statistically significant effect of the SCW on crude birth rates, consistent with Ogasawara and Komura's (2022) model and previous empirical studies of similar war shocks. A more flexible specification shows that this effect emerges about ten years after the end of the war and persists until the end of the twentieth century. At the capital-city level, the positive effect weakens from the 1990s onward. In contrast, at the provincial level—which captures both total births and the overall population—the positive effect does not decline and lasts until the end of the sample period.

[2431] Anna Łyczkowska-Hanćkowiak (WSB MERITO University in Poznan) and Aleksandra Wójcicka-Wójtowicz (Poznań University of Economics and Business). *Timing Matters: Fuzzy Logic Optimization of Portfolios Using Weekly and Monthly Recommendations.*

Abstract. Investment decisions in equity markets typically combine individual knowledge, experience, and intuition, yet these subjective assessments are often complemented by analyst recommendations expressed via linguistic labels such as “buy,” “sell,” or “hold.” Such signals can also be generated algorithmically to provide consistent judgments.

This paper presents a case study that compares two horizons of fuzzy logic–based investment recommendations: short-term (weekly) and longer, month long sequences. In both settings, we employ a procedure built on trapezoidal oriented fuzzy numbers to derive natural language recommendations and benchmark them against expert assessments. The analysis spans companies of WIG20. The study's objective is to evaluate how the recommendation window length affects the alignment between TrOFN generated signals and analyst opinions, with implications for timing, uncertainty and practical usability of model driven guidance.

[2478] Sai Siddharth Nalamalpu (Sunset High School, Portland, OR 97229 USA), Kaining Yuan (Woodbridge High School, Irvine, CA 92604 USA), Aiden Zhou (Western Academy of Beijing, Bei Jing Shi, China) and Eugene Pinsky (Boston University Metropolitan College). *Forecasting MBTA Transit Dynamics: A Performance Benchmarking of Statistical and Machine Learning Models.*

Abstract. The Massachusetts Bay Transportation Authority (MBTA) is the main public transit provider in Boston, operating multiple means of transport, including trains, subways, and buses. However, the system often faces delays and fluctuations in ridership volume, which negatively affect efficiency and passenger satisfaction. To further understand this phenomenon, this paper compares the performance of existing and unique methods to determine the best approach in predicting gated station entries in the subway system (a proxy for subway usage) and the number of delays in the overall MBTA system. To do so, this research considers factors that tend to affect public transportation, such as day of week, season, pressure, wind speed, average temperature, and precipitation. This paper evaluates the performance of 10 statistical and machine learning models on predicting next-day subway usage. On predicting delay count, the number of models is extended to 11 per day by introducing a self-exciting point process model, representing a unique application of a point-process framework for MBTA delay modeling. This research involves experimenting with the selective inclusion of features to determine feature importance, testing model accuracy via Root Mean Squared Error (RMSE). Remarkably, it is found that providing either day of week or season data has a more substantial benefit to predictive accuracy compared to weather data; in fact, providing weather data generally worsens performance, suggesting a tendency of models to overfit.

[2527] Ignacio Rojas-Valenzuela (University of Granada), Victor Gonzalez Argudo (University of Granada), Olga Valenzuela (University of Granada) and Fernando Rojas (University of Granada). **A Multidimensional Framework for Regional Energy-Economic Transformation.**

Abstract. The transition toward sustainable energy systems requires a granular understanding of the feedback loops between electricity consumption, regional economic vitality, and social equity. This paper proposes an integrated framework that synthesizes the Regional Energy Economic Index (REEI) with advanced ensemble machine learning (ML), econometric causality analysis, and intersectional social theory. By bridging data from diverse contexts—the United States, Spain, and the Baltic region—we demonstrate how electricity patterns serve as proxies for structural economic change. Our methodology utilizes predictive models such as Gradient Boosting and LightGBM, alongside spectral analysis, to capture the complexities of both traditional demand and emerging prosumer production. Furthermore, we employ an intersectional justice lens to reveal how historical structural disadvantages compound energy burdens for marginalized communities. The framework categorizes regions into distinct transformation pathways, providing a diagnostic tool for equitable energy transition planning.

[2646] Wiranthe Herath (Drake University) and Yaser Samadi (Southern Illinois University Carbondale). **Partial Envelope and Reduced-Rank Partial Envelope Vector Autoregressive Models.**

Abstract. Traditional vector autoregressive (VAR) models have been extensively used in modeling multivariate time series data due to their flexibility and simplicity. However, they often suffer from overparameterization, particularly in high-dimensional datasets, limiting the inclusion of variables and lags. In many cases, specific lag effects may be of greater interest, particularly when significant cross-correlations occur at shorter lags. To address these challenges, we first propose the partial envelope VAR (PEVAR), which identifies and removes white noise and immaterial components of complex time series data by linking the mean function with covariance structures via a reduced subspace. The PEVAR model concentrates on a subset of important lag variables to improve estimation efficiency. We further extend this approach by integrating the partial envelope concept into the reduced-rank VAR framework and propose the reduced-rank partial envelope VAR (RPEVAR) model. RPEVAR simultaneously integrates the strengths of both the PEVAR and partial reduced-rank VAR models. These models offer a parsimonious technique by focusing on relevant lag variables during coefficient estimation, potentially leading to significant efficiency gains and enhanced accuracy relative to non-partial VAR models. Supplementary materials for this article are available online.

[2656] Marko Zoldoš (Addiko Bank AG). **How to create interpretable credit risk rules using data-driven segmentation (a pragmatic alternative to ML for credit risk management).**

Abstract. Motivation and problem

Banks must simultaneously reduce inflows of Non-Performing Exposures (NPE) and sustain growth in performing exposures — the classical Type I / Type II trade-off in underwriting. Conservative policies suppress losses but reject good clients, while Machine Learning (ML) models deliver strong discrimination at the cost of interpretability and difficult deployment as decision rules. Scorecards and logistic regression sit between the two but still struggle to translate continuous scores into the small, stable rule set required by credit policy, automated decisioning, and regulators. This work targets that gap directly: discovering high-risk patterns and converting them into auditable rules.

Data

The analysis covers the legal-entities (predominantly SME) portfolio of Addiko Bank AG, across working capital loans, overdrafts, other revolving facilities, investment and other term loans. Off-balance-sheet products are mostly excluded. Financial statements available at underwriting are updated to separate the "decision-time" view (information known to the underwriter) from the "outcome-time" view (realized portfolio risk).

Methodology

We propose a four-step transparent framework — a "poor man's ML model" — built on classical credit-scoring diagnostics but driven by combinatorial segmentation rather than global fitting. (1) Variable evaluation and smart binning using Weight of Evidence (WOE), Information Value (IV) and Kolmogorov–Smirnov (K-S) statistics on 10–12 bins per variable. (2) Ranking and business filtering to retain a shortlist of independent, economically meaningful predictors. (3) Systematic combination search across 2-, 3-, 4- and selectively 5-variable conjunctions of binned predictors, identifying the segments with highest empirical default rates above a minimum-volume threshold. (4) Consolidation of overlapping patterns into a short, stable catalogue of interpretable rule candidates.

Results

The procedure yields compact rules with clear economic narratives that isolate segments with increased default rates while remaining fully explainable. Operationally, this strengthens automated rejection rules, enables targeted risk exclusion, and improves alignment between risk and commercial functions.

Future work

Planned extensions include cross-country validation across the Addiko Group's SME portfolios and integration of PSD2 transactional time-series data.

[2803] Giulia Palma (Università di Siena) and Antonio Rizzo (università di siena). ***Context-Aware Neural Circuit Policies for Non-Stationary Industrial Energy Time Series via Error-Decorrelation Partitioning.***

Abstract. Industrial energy time series are highly non-stationary and affected by operational noise and regime shifts, challenging conventional forecasting models, including Transformers. We propose a neuro-symbolic framework that combines a Max Φ -cut-based sensor partitioning strategy with a Context-Aware Neural Circuit Policy (CA-NCP), a continuous-time model whose dynamics are modulated by contextual embeddings extracted from industrial metadata via a Large Language Model. Experiments on real-world tannery datasets show consistent improvements over LSTM, ODE-RNN, and zero-shot TimesFM baselines in accuracy, adaptation speed, and false-positive anomaly reduction, demonstrating the value of integrating discrete optimization, dynamical systems, and semantic context.

[2861] Daniele Bregoli (Polytechnic University of Marche), Marco Ciro Liscio (Polytechnic University of Marche) and Paolo Sospiro (ECampus University). ***Determinants of European Union Public Support for Development Aid: A Generalized Ordered Logistic Regression Analysis of Eurobarometer Data (1993–2019).***

Abstract. This study explored two key objective: (1) examining the relationship between European public support for development aid and individual (e.g., gender, age, and education) and country-related factors, as well as changes in the path of public support over time and (2) testing the application of pooled data analysis using a generalized ordered logistic regression (gologit) model on Eurobarometer surveys, which could potentially be extended to other topics. data from 16 independently pooled cross-sectional Eurobarometer surveys (1993–2019) have been used. This study focuses on the determinants of European citizens' support for aid actions toward developing countries throughout the years. A generalized ordered logistic regression model was used to simulate the likelihood of classifying aid.

The findings from the models demonstrate how variables including gender, age, education, occupation, political inclination, and place of residence influence support for developmental aid. This study demonstrates the potential of the gologit model for analyzing pooled cross-sectional data, suggesting its broader applicability to other research cases.

[2883] Alessandro Casella (Politecnico di Torino), Vincenzo Randazzo (Politecnico di Torino) and Eros Pasero (Politecnico di Torino). ***AI-Driven Smart Beta: Combining Crash Prediction Vetoes and Momentum for Retail Investors' Downside Protection.***

Abstract. Buy-and-hold (B&H) investing is simple and popular among retail investors but remains highly exposed to severe market drawdowns. This study proposes an AI-driven smart-beta framework focused on downside protection rather than pure return maximization. A computationally lightweight tree-based model (XGBoost) is compared with the deep learning time-series foundation model Chronos in a monthly rebalanced, equally weighted 10-ETF global portfolio. The strategy combines an AI crash-risk veto, momentum ranking among safer assets, and a daily 50% circuit-breaker, while incorporating realistic transaction costs of 0.15%. Against an S&P 500 B&H benchmark (94.70% cumulative return, 17.22% annual volatility, -24.50% maximum drawdown), the AI portfolios substantially reduced risk. XGBoost delivered a 31.01% return, 9.72% volatility, and -16.37% drawdown, with Chronos showing similar risk control (25.63% return, 9.74% volatility, -15.85% drawdown). SHAP explainability on XGBoost indicates that rolling volatility is the main driver of crash-veto activation. Overall, combining ML vetoes with momentum offers a practical, interpretable, and risk-managed alternative for retail investors, while optimized traditional algorithms can rival foundation models in financial risk classification.

[2884] Eugene Pinsky (Boston University Metropolitan College), Harini Saravaran (Boston University Metropolitan College) and Kunal Sivakumar (Boston University Metropolitan College). ***Analyzing Fishing Fleet Time-Series Dynamics in pre and post-Covid Periods.***

Abstract. Fisheries are central to global food security, marine conservation, and the livelihoods of millions worldwide, yet comprehensive understanding of fishing behavior and effort remains limited due to the scale of oceanic systems and constraints of traditional monitoring approaches. Recent advances in artificial intelligence and machine learning, combined with the growing availability of vessel tracking data, offer new opportunities to analyze large-scale fishing dynamics with unprecedented resolution. In this study, we leverage the Global Fishing Watch (GFW) apparent fishing effort dataset (version 3.0), derived from Automatic Identification System (AIS) data for over 190,000 unique vessels spanning 2012–2024, to characterize spatial, temporal, and behavioral patterns of global industrial fishing activity. Apparent fishing behavior is inferred at the individual AIS message level using neural-network-based classification models, enabling high-resolution estimation of fishing hours across fleets and regions. We present a reproducible data-processing and analysis pipeline for cleaning, aggregating, and analyzing fishing effort, while mitigating bias associated with unresolved vessel identifiers. To further explore the drivers of fishing behavior, we apply supervised machine learning models such as Linear Regression, Random Forest, and Gradient Boosting, to predict annual fishing effort using vessel- and fleet-level characteristics. The Random Forest model demonstrates superior performance, capturing nonlinear relationships in fishing activity. Additionally, time-series forecasting using the Prophet model is employed to project future fishing effort for major fishing nations, revealing heterogeneous national trajectories shaped by economic, policy, and operational factors. Collectively, these results demonstrate how AI-driven analytics can enhance understanding of large-scale fishing behavior, support ecosystem-based fisheries management, and inform strategies for sustainable marine resource use.

[2893] Jean-Michel Sahut (IDRAC Business School). ***Measuring and preventing ESG risks: integrating qualitative and quantitative data through artificial intelligence.***

Abstract. In recent years, there has been a growing recognition in the literature of the potential influence of environmental, social and governance (ESG) aspects on corporate risk forecasting. The objective of this investigation is to develop a comprehensive ESG assessment framework by integrating the soft and empirical data of publicly traded companies. It is anticipated that this amalgamation of numerical metrics and textual analysis will yield a more precise assessment of the organization's sustainability and social responsibility performance. The present study also explores the predictive power of this comprehensive ESG assessment for corporate misconduct. The empirical results demonstrate the robustness of this ESG performance evaluation method in terms of these three components E, S and G. Moreover, they show how incorporating ESG indicators improves the prediction accuracy of the model and significantly improves its ability to detect corporate misconduct at an early stage. This fills the current gaps in the rating agencies' assessment systems, which deliver divergent results, particularly in developing countries. The underlying rationale behind the influence of ESG performance on corporate governance, via the prediction of corporate misconduct in China, offers valuable insights for other developing countries with relatively weak institutional systems of governance.

[2967] Emilija Dzuverovic (Department of Economics, Ca' Foscari University of Venice), Andrew Harvey (Faculty of Economics, Cambridge University) and Dario Palumbo (Department of Economics, Ca' Foscari University of Venice). ***Score Autoregressive (ScAR) Models.***

Abstract. Score-driven time series models are now widely used in economics and statistics. The canonical model features a filter for a time-varying parameter that is a linear combination of its lagged value and the conditional score. It therefore depends on all the observations in the sample and invertibility must be established to ensure that reliable forecasts are made. Purely autoregressive score-driven models have not been considered in the literature and one of their attractions is that the question of invertibility does not arise. Score-driven autoregressions are proposed and their properties are investigated. An alternative approach, whereby restrictions are imposed on a standard score-driven model, is also considered. Both approaches can be modified using what we call a 'composite score'.

[3023] Yixin Li (The Hong Kong University of Science and Technology). ***Maximum Likelihood Estimation for Multivariate All-Pass Time Series Models.***

Abstract. All-pass models generate uncorrelated but dependent time series when the noise is non-Gaussian. In this work, we introduce a multivariate all-pass time series model, which has an explicit form that simplifies both theoretical analysis and computation. To estimate the model, we study the approximate maximum likelihood estimator and establish its asymptotic normality. For the order selection, the sequential likelihood ratio test is employed. Then, we present a procedure to identify the noninvertible structural VARMA model with the multivariate all-pass model. Simulations are carried out to investigate the finite-sample performance. Finally, empirical applications involving log returns and trading volumes are presented.

[3062] Youness Ablila (AgroBiotech Center, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco), Abdelhakim Amazirh (CRSA, Centre for Remote Sensing Applications, Mohammed VI Polytechnic University, Benguerir, Morocco), El Houssaine Bouras (CRSA, Centre for Remote Sensing Applications, Mohammed VI Polytechnic University, Benguerir, Morocco), Maria Jose' Escorihuela (isardSAT, Doctor Trueta 113 1er, 08005 Barcelona, Spain), Said Khabba (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco), Jose Antonio Martinez Casasnovas (Research Group in AgroICT and Precision Agriculture, Universitat) and Salah Er-Raki (AgroBiotech Center, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco). ***Time Series Analysis of Agricultural Drought Impacts on Rainfed Cereal Yields: Enhancing Drought Impact Assessment Through Yield Detrending in Morocco.***

Abstract. This study evaluates the impact of agricultural drought on rainfed cereal yields in Morocco from 2000 to 2022 using the recently developed Combined Drought Anomaly Index (CDAI). The analysis considers the effect of yield linear trends on drought–yield relationships. Results show that rainfed cereal yields are strongly affected by agricultural drought, especially during critical growth months from January to April, which correspond to key phenological stages. The 2015/2016 season was the most severely affected by drought, leading to significant yield reductions, while 2008/2009 was the most favorable season, with positive impacts on cereal production. The analysis also underscores the importance of removing long-term linear trends from yield data to better isolate the climatic signal. Using observed yields (tons-ha⁻¹), the correlation between cereal yield and seasonal CDAI reached $r = 0.78$ ($p < 0.01$). After detrending the yield time series, the correlation increased to $r = 0.87$ ($p < 0.01$), indicating a stronger and more accurate relationship between agricultural drought and yield variability. These findings demonstrate that yield detrending is a crucial step for robust assessment of drought impacts on cereal production and confirm the effectiveness of CDAI in capturing agricultural drought effects in semi-arid environments such as Morocco.

[3107] Challa Krishna Rao (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India), Bibhuti Bhusan Rath (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India), Dannana Sailaja (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India), Talabattula Lakshmi Durga Bhavani (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India), Potnuru Revathi (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India) and Gunta Mukkala Sri Ram Akash (Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India). ***Design of a Smart IoT based Diabetic Detection System Using Photoplethysmogram.***

Abstract. Diabetes is a common chronic lifestyle illness that affects a large population worldwide and is thus a very seriously managed condition. Also, the conventional techniques to check blood sugar include very inconvenient methods. Keeping in view the developments in the Internet of Things and cloud services with the advent of the Internet of Things (IoT) and the increasing impact of cloud services into the lives of people worldwide, the aim of the current study is to design a system based on the Internet of Things (IoT) with the aim of detecting diabetes with the help of Photoplethysmography. The effectiveness of our system relies upon the use of various effective machine learning models, XGBoost, Random Forest, Logistic Regression, and SVM. To ensure better accuracy using these models, a fivefold cross-validation method is used. The hardware technology employed is a portable and economical device with simple NIR sensor integration and ESP-32 with high-end capabilities for minimizing discomfort and convenience in device use. The developed system is implemented using Amazon Web Services (AWS) on a cloud platform and offers users a convenient and effective device for real-time diabetic status monitoring and ease of health data analysis through use of its developed web application. The effectiveness of our developed system is validated using two distinct datasets: PPG-BP and Mazandaran datasets. The proposed system reported an accuracy of 87.88 and 90 % with both datasets. Consequently, this developed system is able to transform and lead the way in the treatment of diabetic patients by developing a simple yet feasible method of disease diagnosis in the early stages.

[3167] Kumaraswamy Simhadri (Aditya Institute of Technology and Management, Tekkali), Banaja Mohanty (Veer Surendra Sai University of Technology, Burla, Sambalpur.), B.V.S Acharyulu (Lendi Institute of Engineering and Technology, Vizianagaram.) and Kanaka Raju Kalla (Aditya Institute of Technology and Management, Tekkali). ***Performance analysis of BKA-Optimized FONPID Controller for Frequency Regulation in Renewable-Integrated Airport Microgrids.***

Abstract. High-quality electrical power is vital for the reliable operation of critical infrastructures, such as airport microgrids, especially with increasing penetration of renewable energy. This study proposes a fractional-order nonlinear proportional–integral–derivative (NPID) controller to mitigate frequency deviations in an airport microgrid. The controller parameters are optimally tuned using the Black-Winged Kite Algorithm (BKA). The proposed method is evaluated against PI, PID, NPID, and FONPID controllers under varying operating conditions, including random load disturbances and parameter uncertainties. Simulation results indicate that the BKA-optimised FONPID controller achieves superior dynamic performance with significantly reduced frequency deviations and faster system stabilisation. Performance analysis reveals improvements in settling time, overshoot, and objective function for ITAE controllers compared to conventional controllers. The findings demonstrate that the proposed control strategy enhances system stability, efficiency, and robustness, providing an effective solution for renewable energy integration in microgrids. This work supports sustainable energy management in aviation infrastructure while addressing challenges related to energy reliability and environmental sustainability.

[3172] Marina Khismatullina (Erasmus University Rotterdam) and Bernhard van der Sluis (Erasmus University Rotterdam). *Multiscale Comparison of Nonparametric Trending Coefficients.*

Abstract. This paper proposes a novel framework to test for slope heterogeneity between time-varying coefficients in panel data models. Our test not only allows us to detect whether the coefficient functions are the same across all units or not, but if not, also determines which of them are different and where these differences are located. We establish the asymptotic validity of our multiscale test. As an extension of the proposed procedure, we show how to use the results to uncover latent group structures in the model. We apply our methods to test for heterogeneity in the effect of U.S. monetary shocks on 49 foreign economies and itself. We find evidence that such heterogeneity exists and discuss the clustering results for two groups.

[3177] Osama Abaza (University of Alaska Anchorage). *Crash Severity Prediction Using Temporal Weather and Roadway Data in Cold Regions.*

Abstract. Accurate prediction of crash severity remains a critical challenge for transportation safety, particularly in cold regions where rapidly changing environmental conditions introduce strong temporal variability and non-stationarity. This study presents a time-series–driven framework for predicting crash severity by integrating temporally resolved weather, lighting, and roadway surface condition data with historical crash records.

Hourly and daily environmental time series—including temperature, precipitation, visibility, surface state, and daylight conditions—are aligned with crash occurrence data to capture short-term dynamics and seasonal effects. Machine learning models are trained to exploit temporal dependencies in the data, allowing severity outcomes to be predicted as a function of evolving environmental states rather than static covariates. The framework is evaluated using multi-year datasets from cold-region road networks and validated across geographically distinct regions to assess temporal transferability and robustness.

Results demonstrate that incorporating explicit temporal structure significantly improves severity prediction accuracy compared to non-temporal baseline models. Seasonal patterns, freeze–thaw cycles, and abrupt weather transitions are shown to play a dominant role in severity escalation, highlighting the importance of time-aware modeling approaches. The proposed methodology supports short-term forecasting of elevated crash severity risk under adverse conditions and provides a scalable foundation for proactive safety interventions.

This work contributes to the time-series forecasting literature by demonstrating how non-stationary environmental signals can be effectively integrated into safety prediction models, with practical implications for real-time decision support and climate-adaptive transportation systems.

[3258] Khalil Mhadhbi (Department of Quantitative Methods, Faculty of Economic Sciences and Management of Nabeul, University of Carthage). *The Moderating effect of the shadow economy on the relationship between foreign trade and economic Growth: A Panel ARDL analysis in Developing Countries.*

Abstract. This study investigates the moderating role of the shadow economy in the relationship between foreign trade and economic growth in developing countries. Using a Panel Autoregressive Distributed Lag (ARDL) approach on a sample of 18 countries from Sub-Saharan Africa and Latin America over the period 2005–2020, the analysis distinguishes between short-term dynamics and long-term equilibrium effects. The results confirm a positive direct impact of trade on growth, consistent with standard theoretical predictions. However, the shadow economy significantly attenuates this positive relationship, reducing the long-term elasticity of trade by approximately 44% for an average level of informality. This moderating effect is further amplified in contexts of weak institutional quality. The findings also reveal a temporal duality: while informality acts as a structural brake on growth in the long run, it may serve as a short-term social buffer by absorbing adjustment costs linked to trade openness. The study underscores the necessity of complementing trade liberalization with formalization policies and institutional strengthening to fully harness the growth potential of international integration in highly informal economies.

[3292] Manuel Frondel (Frondel, RWI). *The Regional and Distributional Consequences of Tax Pass-Through: The Case of Germany's Fuel Tax Discount.*

Abstract. Exploiting exogenous variation in retail fuel prices from a temporary fuel tax discount in Germany, we explore the distributional consequences emerging from differential pass-through rates over space and time. We draw on daily gasoline prices of virtually all gas stations in Germany and neighboring France, with France serving as a control site, and estimate an event study model covering the full period of the discount from June to August 2022. We find average pass-through rates on the order of 96% for diesel and 82% for petrol, but with substantial variability by regional income and station density. Our results additionally reveal heterogeneity over time:

The magnitude of the pass-through rate dissipates sharply for both fuel types over the three months in which the discount was in effect, dropping to 46% for diesel and 74% for petrol by the final month, a pattern consistent with retailer responses to short-term changes in consumer attention. Taken together, our results indicate that average pass-through estimates may obscure spatial and temporal heterogeneity that bears upon the assessment of distributional effects: A back-of-the-envelope calculation indicates that 62% of the discount's financial relief accrues to households with above-median incomes.

[3294] F. Catarina Pereira (University of Minho, Department of Mathematics and Center of Mathematics, Portugal), A. Manuela Gonçalves (University of Minho, Department of Mathematics and Center of Mathematics, Portugal) and Marco Costa (University of Aveiro, Centre for Research and Development in Mathematics and Applications, Portugal). *Boost Fisher Scoring for Robust Parameter Estimation in Contaminated State-Space Models.*

Abstract. State-space models (SSM) provide a flexible framework for representing dynamic systems where the underlying states are unobserved, making them widely applicable in fields such as economics, engineering, and environmental sciences. These models are particularly useful for tracking latent processes in time series analysis, but their performance is often affected by outliers. Traditional Maximum Likelihood (ML) estimation may suffer from numerical instability and convergence failures in the presence of outliers.

This work proposes the Boost Fisher Scoring (BFout) algorithm, a robust estimation approach that integrates nonparametric bootstrap techniques into the Fisher Scoring iterative procedure. The method performs resampling on standardized innovations after a systematic outlier removal step, preserving the accuracy of the Fisher Information Matrix while improving numerical stability.

The performance of the proposed methods was evaluated through simulation studies under different conditions, including varying sample sizes, noise variances, and autocorrelation levels. The practical performance of the proposed algorithm is illustrated in a case study on short-term maximum temperature forecasting in Northern Portugal, where forecasts obtained from an online source are corrected using local weather station data. The results show a clear improvement in out-of-sample prediction accuracy, highlighting BFout as a robust alternative for real-time forecasting in contaminated time series settings.

[3834] Tapaswi Naga Sai Sree Kodali (SRM University AP), Jaya Sree Vyshnavi Royal Pallapothula (SRM University AP), Varshitha Tammareddy (SRM University AP), Aakash Kamishetti (SRM University AP) and Sarvani Anandaraao (SRM University AP). *Adaptive Multi-Sense Shark Optimization.*

Abstract. Nature-inspired metaheuristic optimization algorithms have been extensively used for complex, non-linear, and large-scale optimization problems; however, most of the existing methods have some drawbacks, such as fixed control parameters, poor sensory awareness, and early convergence. To overcome these issues, this paper presents a novel Adaptive Multi-Sense Shark Optimization (AMSSO) algorithm, which is an improved version of the traditional Shark Optimization (SO) algorithm. Unlike the traditional SO algorithm, which uses only one type of sensory system, the proposed AMSSO algorithm uses multi-sensory systems inspired by biological shark navigation, which combines vision, olfaction, and pressure sensation for better environmental awareness. Moreover, the proposed algorithm uses adaptive velocity control and multi-sensory fusion, which helps to maintain an efficient balance between exploration and exploitation during the search process.

The proposed AMSSO algorithm is comprehensively tested using various benchmark functions and real-world machine learning problems, such as feature selection and hyperparameter optimization. The experimental results show that the proposed AMSSO algorithm has faster convergence speed, higher accuracy, better stability, and lower variability compared to the traditional SO algorithm and some of the best existing metaheuristic optimization algorithms. The results also validate that the proposed approach successfully escapes local optima and maintains population diversity for complex

[3836] Inês Moreira (INESC ID), Lucas Pereira (ITI/LarSys), Pedro Carvalho (INESC ID) and Hugo Morais (INESC ID). ***Secondary Substation Power Demand Forecast to Support Distribution Network Operation.***

Abstract. Forecast methods are used in the power industry for several purposes and are the basis for multiple decision support tools, from the long-term planning phase to real-time operation. Predictive assessment of the power system security is one of the major advantages that an accurate forecast can bring. Extensive work can be found in the literature. However, forecast works are mainly focused on active power prediction, leaving reactive power with a gap in the literature, even with the value that can bring to utilities. Reactive power forecast can have a significant impact on the system operation and planning, mainly during the definition of new rules for distributed generation, aiming to avoid voltage constraints. Additionally, existing works addresses forecast at a system level where the uncertainties are lower or at the source level where high accuracy data are available. The main contribution of this report is the development of active and reactive power demand forecasting methodologies to be used at secondary substations. Methodologies based on regression, decision trees and neural networks were developed and compared. Post-processing algorithms were also applied to decrease forecast errors. In the end, an algorithm to automatically select the best forecast method in each secondary substation was also developed. All the algorithms have been included in a forecasting framework. The proposed framework has been tested considering real secondary substation raw data, and the results are compared with those obtained by a Portuguese utility. The results obtained by these algorithms allowed a reduction of 22% in the forecast error when compared to the reference methods of this utility.

[3856] Bevara Srikanth (Department of EEE, Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh), Konni Sivadatta (Department of EEE, Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh), Namballa Bhavani (Department of EEE, Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh), Palla Mahesh (Department of EEE, Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh) and Ashok Ganga (Department of EEE, Aditya Institute of Technology and Management, Tekkali, Andhra Pradesh). ***smart energy monitoring system for household applications using ESP32 micro controller.***

Abstract. Awareness of energy consumption to the consumers is fundamentally misaligned due to lack of information about energy billing development and energy usage on daily basis. Although domestic electricity bills are generated monthly, electricity is consumed continuously on a daily and hourly basis. Conventional energy meters installed in households are designed mainly for cumulative measurement of energy for billing purposes, not for consumer awareness or energy discipline. Therefore, the core problem is not the absence of energy meters, but the absence of daily, actionable, and consumer energy awareness at the household level. IoT-based energy monitoring systems provide cloud dashboards, analytics, and visualisation, but they rely heavily on continuous internet connectivity, increase hardware and maintenance costs, and require active user engagement with mobile applications. This paper proposes an approach to bridge the gap between daily electricity consumption and consumer awareness by developing a simple, cost-effective, and reliable smart energy monitoring system for household applications using ESP32 micro controller.

[3858] Xiaoran Wu (Hong kong university of science and technology) and Shiqing Ling (Hong kong university of science and technology). *Eigen-transform Tests for Mean Vectors in High-Dimensional Time Series Dependent Data.*

Abstract. Testing high-dimensional means has garnered significant interest in the era of big data. Conventional methods for this testing typically requires at least fourth moment of the data is bounded, and the data are independent over the time, which are not applicable to dependent or heavy-tailed data and thus may lose power and result in unrobustness. In this paper, we propose the eigen-transform test for high dimensional means, which are robust to dependent data and only require the variance of data is bounded, without condition on the fourth moment.

Our approach involves transforming the data onto several mutually independent directions by eigenvectors of the long-run covariance matrix, followed by conducting a sum-of-absolute-value type statistic. We provide theoretical results on the asymptotic properties of the statistic under both the null and local alternative hypotheses. Finite sample performances are illustrated via various simulations. We also apply the proposed test to analyze ADR premiums in stock markets and to provide early diagnosis of Alzheimer's disease, highlighting the robustness and efficiency of our approaches.

[3875] Victor Brasileiro (NEES - Center for Excellence in Social Technologies), Marcelo Falcão (NEES - Center for Excellence in Social Technologies), Breno Duarte (NEES - Center for Excellence in Social Technologies), Romildo Escarpini (NEES - Center for Excellence in Social Technologies), Luciano Cabral (NEES - Center for Excellence in Social Technologies), Dalgoberto Pinho (NEES - Center for Excellence in Social Technologies), Laisa Sousa (NEES - Center for Excellence in Social Technologies), Rafael Silva (NEES - Center for Excellence in Social Technologies), Nicholas Cruz (NEES - Center for Excellence in Social Technologies), Lenardo Silva (NEES - Center for Excellence in Social Technologies) and Bruno Pimentel (NEES - Center for Excellence in Social Technologies). *Impact of Data Quality on School Enrollment Forecasting for Brazil's National Textbook Program (PNLD).*

Abstract. Ensuring the availability of didactic materials within Brazil's National Textbook Program (PNLD) depends on reliable school enrollment forecasts. However, administrative time series often exhibit limited historical coverage and heterogeneous stability, which can constrain predictive accuracy. This study investigates how data quality affects forecasting performance using Brazilian School Census enrollment records from 2007 to 2023. We stratify school-stage series into three data-quality regimes defined from the available records, based on historical availability (number of observed years) and stability (Coefficient of Variation): Light (at least 4 years; CV up to 1.0), Medium (at least 5 years; CV up to 0.5), and Rigorous (at least 8 years; CV up to 0.3). We adopt a one-step-ahead protocol ($h = 1$) evaluated on two horizons: a pre-pandemic forecast targeting 2019 (training through 2018) and a post-onset forecast targeting 2020 (training through 2019), the latter potentially affected by the COVID-19 pandemic in Brazil. We evaluate 14 predictive models spanning classical statistical methods, machine learning algorithms, and fuzzy time series (FTS) architectures, using mean absolute error (MAE) as the primary metric. Results show that regime-driven effects are consistent across both horizons: moving from the Light to the Rigorous regime reduces MAE by approximately 30% for 2020 and 32% for 2019, while the best-to-worst model spread within a single regime is at most 4.6 points. This gain, however, comes at a substantial coverage cost—the eligible dataset shrinks from 77,315 to 8,677 series (11.2%). Under the highest-quality regime, FTS models show robust performance, with SeasonalFTS achieving the best MAE across both horizons (13.00 for 2019; 12.39 for 2020). To our knowledge, this is the first large-scale empirical quantification of the coverage-precision trade-off induced by data-quality stratification in administrative enrollment forecasting. The findings support quality-aware forecasting strategies for PNLD planning.

[3964] Bello Sani Yahaya (Cyprus International University). *Hybrid Deep Learning and Econometric Approaches for Forecasting Economic and Energy Demand Volatility in High-Dimensional Time Series.*

Abstract. Accurate forecasting of economic and energy demand indicators has become increasingly difficult due to nonlinear dependencies, structural breaks, volatility clustering, and the rapid growth of high-dimensional datasets. Traditional econometric approaches often fail to adequately model nonlinear temporal interactions, while purely deep learning-based methods may lack interpretability and statistical robustness. This study proposes a hybrid forecasting framework integrating Autoregressive Integrated Moving Average (ARIMA), Vector Autoregression (VAR), and Long Short-Term Memory (LSTM) neural networks for multivariate time series forecasting in volatile economic environments. The proposed framework incorporates Principal Component Analysis (PCA) for dimensionality reduction and an adaptive online learning mechanism to update forecasting parameters dynamically as new observations become available. Empirical analysis is conducted using monthly macroeconomic and energy market data from 2000–2024, including inflation, industrial production, electricity demand, oil prices, and renewable energy generation indicators. Forecasting performance is evaluated using RMSE, MAE, MAPE, and Diebold–Mariano statistical tests. Results demonstrate that the hybrid framework significantly outperforms standalone econometric and machine learning models across multiple forecasting horizons, particularly during periods of economic instability and demand shocks. The proposed methodology contributes to the literature on advanced forecasting systems by providing a scalable, interpretable, and adaptive framework suitable for real-world applications involving complex and high-dimensional time series data.

[3977] Lucas Mussoi (Federal University of Rio Grande do Sul), Fernanda Müller (Universidade Federal do Rio Grande do Sul) and Marcelo Scherer Perlin (Federal University of Rio Grande do Sul). ***Bitcoin's halving events and the fractal nature of mining energy consumption.***

Abstract. This study addresses a central critique of blockchain technology by examining the long-term energy consumption dynamics of Bitcoin's proof-of-work (PoW) consensus mechanism. While the energy intensity of Bitcoin mining is well documented, the influence of its programmed halving events on consumption patterns remains insufficiently understood. Utilizing data from the Cambridge Centre for Alternative Finance, this paper investigates whether these endogenous supply shocks induce measurable regime shifts in energy use, contextualized by exogenous regulatory interventions such as China's mining ban. Employing asymmetric multifractal detrended fluctuation analysis (MF-DFA), the findings reveal that Bitcoin's energy dynamics exhibit a complex, asymmetric multifractal structure that has evolved significantly across halving epochs. Early periods were characterized by strong multifractality and persistent heterogeneity during consumption declines, reflecting unconstrained operational expansion. A transition toward operational maturity emerged following the China ban, marked by converging scaling behaviors. A paradigm shift occurred after the fourth halving, wherein long-range correlations began to dominate fat-tailed distributions, suggesting that structural dependencies now suppress volatile expansions. The results further indicate that miner responsiveness is scale-dependent. Notably, Ethereum's transition to proof-of-stake (PoS) precipitated significant cross-chain effects, evidenced by a statistically significant reduction in the persistence of Bitcoin's energy consumption dynamics.

[4036] Jakub Smaga (AGH University) and Mateusz Zareba (AGH University). ***Assessing Climate Change Trends and Extremes in the Euro-Atlantic Sector: A Time Series Forecasting Framework Using Stratospheric Polar Vortex and Jet Stream Dynamics (1979–2024).***

Abstract. Regional climate variability in the Euro-Atlantic sector is governed by the interaction between thermodynamic warming and large-scale atmospheric dynamics, particularly stratosphere–troposphere coupling. While these processes are well studied in a physical climatology context, their role as sources of predictability in time series forecasting remains less explored. This study investigates whether dynamically relevant atmospheric variables can be exploited as exogenous predictors to improve subseasonal forecasts of surface temperature anomalies in Central Europe. Using ERA5 reanalysis data spanning 1979–2024, a supervised time series forecasting framework is developed to predict 14-day-ahead temperature anomalies. The model incorporates physically informed predictors, including stratospheric Polar Vortex Strength, Jet Stream Waviness Index, and Upstream Temperature Anomalies, alongside cyclical seasonal encodings. Forecasting performance is evaluated using rolling-origin cross-validation and an independent out-of-sample test period (2019–2024). The results confirm a heterogeneous warming signal across the Euro-Atlantic domain, with Central Europe exhibiting a pronounced trend ($+0.59^{\circ}\text{C}$ per decade) and increasing dynamical variability associated with enhanced jet stream instability. From a time series perspective, the inclusion of stratospheric and large-scale circulation predictors yields measurable forecast skill (Random forest model MAE $\approx 2.99^{\circ}\text{C}$, $R^2 \approx 0.25$) at a 14-day horizon, outperforming baseline persistence assumptions. Feature importance analysis indicates that stratospheric state and upstream temperature fields are among the dominant drivers of predictive performance, consistent with the physical mechanism of downward signal propagation. These results highlight that physically informed predictors, when embedded within statistical learning frameworks, enhance predictive skill and provide a principled basis for hybrid forecasting approaches in medium-range climate applications.

[4056] Qiang Xia (Department of Mathematics, South China Agricultural University). ***Robust Factor Analysis of Rank-Decomposition-Based Matrix Factor Model for High-Dimensional Time Series.***

Abstract. This study examines the robust factor analysis of the hybrid structure two-way factor model (Hs2wFM) for high-dimensional matrix-variate time series based on rank decomposition. For this novel model, a two-step algorithm is proposed to estimate the loading matrices through eigenanalysis of a non-negative definite matrix derived from the autocovariance matrices. To determine the number of factors, we introduce two innovative ratio-based methods that utilize maximum- and sum-type statistics to assess the serial uncorrelatedness of the time series projections onto specific spaces. Theoretical properties, including the convergence rates of estimated loading matrices and the consistency of ratio-based methods, are established under regularity conditions for the proposed model. The findings reveal that the convergence rates of the estimated loading matrices using the two-step approach are marginally superior. The effectiveness of the proposed method was validated through comprehensive simulations and analysis of real data.

[4099] Sreenubabu Dasari (Aditya Institute of Technology And Management), Vasanthi Ravada (Aditya Institute of Technology And Management), Sai Gowtham Vulli (Aditya Institute of Technology And Management), Tejeswar Nadiseti (Aditya Institute of Technology And Management), Rajesh Jada (Aditya Institute of Technology And Management) and Tarun Kumar Kondaka (Aditya Institute of Technology And Management). ***An IoT Framework For Peak Load Prediction Using Deep Learning Techniques.***

Abstract. The sudden change in electrical demand can result in a negative outcomes like transformer failures and short circuits. At present, the majority of systems in use exclusively focus on real-time monitoring over accurate peak load forecasting. A framework for peak load forecasting using smart meter data and deep learning models is presented in this paper. Long Short-Term Memory and Bidirectional LSTM methodologies are used to detect the non-linear temporal patterns in electrical load data. Accurate load forecasting helps in preventing transformer overloads and grid failures by predicting peak demand in advance. A comparative analysis is conducted to identify the most effective forecasting model for peak demand prediction.

[4131] Pankaj Kumar (National Institute of Technology Hamirpur, HP-177005, India), Disha Gupta (NIT Hamirpur) and Kavya Kumari (NIT Hamirpur). ***Incorporating Temporal Stock Price Patterns into Portfolio Optimization.***

Abstract. An innovative framework for portfolio optimization is proposed by integrating advanced time series forecasting with optimization techniques. Traditional models, which rely solely on historical data, often neglect the temporal dependencies of stock prices. To address this gap, ARIMA models are developed and validated on extensive datasets to capture volatility, seasonality, and trends in stock price movements. The forecasts generated are then incorporated into the portfolio optimization process, replacing conventional mean-variance analysis with a dynamic, forward-looking strategy. By utilizing predicted prices as inputs, the framework enables portfolios to adapt to evolving market conditions, thereby enhancing the accuracy and responsiveness of investment decisions.

[4160] Kalpdrum Passi (Laurentian University) and Jose Alonso Vasquez Pasco (Laurentian University). *Comparative Analysis of Machine Learning Models for Mo-torcycle Sales Forecasting in the Peruvian Market.*

Abstract. This study compares three forecasting models—SARIMAX, LSTM, and Prophet—for predicting motorcycle sales using real-world data from the Peruvian market (2017–2023). Feature selection was conducted using correlation analysis, Random Forest, and Gradient Boosting to identify the most relevant exogenous variables. Among the evaluated models, SARIMAX achieved the best performance with a Mean Absolute Percentage Error (MAPE) of 8.06%, outperforming Prophet (8.63%) and LSTM (9.24%). Results highlight the importance of incorporating external variables such as price and engine capacity in improving forecast accuracy. The findings provide practical in-sights for demand planning in markets characterized by long lead times and operational constraints.

[4235] Quang Phung Duy (Foreign Trade University), Huyen Nguyen Khanh (Foreign Trade University), Quyen Hoang Nam (Foreign Trade University), Thinh Nguyen Huu Thinh (Foreign Trade University), Thao Pham Thi Phuong (Foreign Trade University) and Dang Nguyen Hai (National Economics University). *Linear and non-linear ARDL estimation of Global Innovation and Economic Growth in Vietnam.*

Abstract. This study employs time-series econometric techniques, including ARDL and NARDL models, to examine the dynamic and asymmetric effects of the Global Innovation Index (GII) and Foreign Direct Investment (FDI) on Economic Growth (GDP) in Vietnam. The ARDL results indicate that innovation has a positive long-term effect on GDP, while FDI exhibits mixed short-term impacts. The NARDL model reveals significant asymmetry in the impact of innovation: increases in GII stimulate economic growth, whereas decreases do not produce a statistically significant negative effect. The estimated error correction term (ECT) is negative and significant, confirming the existence of a long-run equilibrium relationship, with an adjustment speed ranging from 15% to 28% annually. The results highlight both short-run dynamics and long-run adjustment mechanisms in the innovation–growth nexus. By jointly analyzing GII and FDI within a dynamic modelling framework and uncovering asymmetric effects, this study contributes to the existing literature on emerging economies. The findings provide useful insights for macroeconomic forecasting and policy design aimed at fostering innovation and sustainable economic growth in Vietnam.

[4239] Albert Antwi (Sol Plaatje University), Alexander Boateng (Modern College of Business and Science) and Daniel Maposa (University of Limpopo). *Seasonal phase modelling of heavy rainfall patterns in Semi-Arid regions Using the von Mises Distribution.*

Abstract. This paper applies the von Mises family of circular distributions to model the seasonal timing of heavy rainfall extremes in the semi-arid Kimberley, South Africa. Unlike conventional modelling approaches that emphasise mean rainfall, circular modelling captures phase-specific characteristics such as onset, peak clustering, and transitional shoulders. We evaluate three key variants the standard von Mises, generalised von Mises, and Sine skewed von Mises using maximum likelihood estimation with box constrained optimization. Model performance was assessed through predictive and probabilistic metrics, including Average Log Predictive Density, Akaike Information Criterion, and geodesic Continuous Ranked Probability Score. Results show that the standard von Mises distribution consistently outperforms more complex alternatives, providing the most parsimonious and reliable representation of Kimberley's unimodal summer rainfall regime. Analysis of the results reveals a sharp seasonal peak in January–February, a recurrent onset in November, and a deep trough in July, confirming the episodic and clustered nature of rainfall in semi-arid regions. Phase shift analysis further indicates approximately 19-day delay in the seasonal peak between baseline (2000–2016) and monitoring (2017–2026) periods, alongside stronger clustering of extremes. Although formal circular tests did not detect statistically significant differences, the phase analysis highlight emerging tendencies toward a later and more compressed rainfall season. These findings have practical implications for flood preparedness, reservoir operations, and agricultural scheduling, where timing rather than totals drives risk and resilience. The study demonstrates the methodological value of circular statistics in rainfall phase analysis, bridging a critical gap in semi-arid climatology.

[4253] Fabrice Nzepang (University of douala). *Alternating heads of state and structural transformation in sub-Saharan Africa: a panel VAR analysis.*

Abstract. The alternation of a head of state is an institutional tool that can foster the reallocation of labour, innovation and human capital and thus improve structural change and intra-industry productivity, which are the two components of structural transformation. Primary data collected by Limi Kouotou and Epo (2019), the Africa Sectoral Database (ASD) and the World Development Indicators (WDI) allow us to illustrate our points using the VAR method on a panel of 17 SSA countries. The results show that the alternation of heads of state is more important for structural change than for intra-industry productivity. The result also suggests that heads of state in SSA countries all tend to last 10 years in power (i.e. two 5-year terms on average) as these countries become richer and more productive. Furthermore, an important result is that 51.2% of the variance in the forecast error of the alternation of heads of state is due to that of FDI. This latter result indicates the role of large multinational firms, representing former colonial powers, changeovers in SSA. Our results suggest that alternation of heads of state is likely to promote structural transformation in SSA and recommend that sub-Saharan economy promote systematic alternations of their heads of state.

[4293] Alessandro Gorini (National Research Council, Water Research Institute (CNR-IRSA)), Maria Chiara Magnano (National Research Council, Water Research Institute (CNR-IRSA)), Andrea Fenocchi (University of Pavia), Helmi Saidi (National Research Council, Water Research Institute (CNR-IRSA)) and Marzia Ciampitiello (National Research Council, Water Research Institute (CNR-IRSA)). *Hydrological balance as a tool for a better water management strategy for assessing the hydrological dynamics of a large regulated lake in Northern Italy.*

Abstract. Lake Maggiore is a subalpine lake located in Northern Italy, between the Piedmont and Lombardy regions, and Switzerland. Its single outlet is represented by the Ticino River, whose flow is regulated by the Miorina dam. The river crosses a densely populated area west of Milan, rich in agricultural and industrial activities. Additionally, the Ticino River is the major tributary of River Po, the largest Italian river, contributing to 25% of its flow. These elements give Lake Maggiore a strategic role in shaping the regional economy, a factor further compounded by the lake notable touristic attraction.

The hydrological balance is fundamental in determining not only the real availability of water resource in a region, but also to investigate the critical elements of water resource ecosystems and of agricultural districts. The present research, part of the WINCA4TI Interreg project between Italy and Switzerland, examines for the first time the trends in the components of the hydrological balance of Lake Maggiore (i.e. inflow, outflow, lake volume, lake water evaporation and direct precipitation), during the last 40 years to evaluate the changes in the hydrological dynamics of this regulated lake, with the ultimate aim to develop efficient and sustainable water management strategies in a global warming context.

The hydrological balance of Lake Maggiore was assessed herein through processing pre-existing datasets, including both observations and hydrological model results between 1951 and 2024. Specifically, lake outflows were obtained from both observations and the CAMELS-CH (Catchment Attributes and MEteorology for Large-sample Studies – Switzerland) model, lake levels were obtained from observations, while lake water evaporation and direct precipitation were derived from the BigBang model datasets developed by the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Inflows to the lake were therefore determined as unknown by solving the balance equation for the lake. Compliance between the different model and observation datasets, needed to ensure the reliability of the balance, was verified through various independent tests. Trends in the hydrological balance components were assessed through Mann-Kendall and Sen's slope non-parametric methods. Data were analysed on annual, monthly and seasonal bases.

As a first example of the performed analyses, three years with peculiarly high lake inflow values have been observed between 1981 and 2020. Two of them, 1993 and 2000, correspond to years including particularly intense lake flood events, which had an estimated return period of maximum lake levels of 38 and 70 years, respectively. The year 2014 was characterised by even higher inflows than those of 1993 and 2000, yet the maximum lake level had an estimated return period of 14 years, smaller than the previous ones. Analyses show that the initial low lake level prior to the flood event determined the lower return period of the maximum lake elevation, highlighting how lake regulation can be crucial. As another example, the trend analyses of evaporation on lake surface revealed a significative increasing trend of 3.90 mm year⁻¹, as a result of air temperature warming, which in the European alpine area is larger than the global average.

The current work represents a starting point for further investigations into the hydrological balance evolution of the Lake Maggiore and Ticino River watersheds due to climate change and human use impacts. Furthermore, it highlights the potential of historic time series datasets to deepen our knowledge on hydrological dynamics of crucial areas for water storage. Further investigations will use statistical downscaling models to estimate the areal distribution of trends in hydrological balance components. Future predictions of the same components given by climate change models will also be evaluated, to gain a deeper understanding of the availability of water resources within the Ticino River and Lake Maggiore basins.

[4337] Kanaka Raju Kalla (Research Scholar, Department of EEE, School of Engineering, Godavari Global University, Rajamahendravaram), D.Ravi Kishore (Professor, HOD, Department of EEE, School of Engineering, Godavari Global University, Rajamahendravaram) and D.Vijaya Kumar (Professor, HOD, Department of EEE, Aditya Institute of Technology and Management, Tekkali). ***Reliable Prediction of Solar Global Tilted Irradiance Using TabNet with SHAP-Based Interpretability and Uncertainty Quantification.***

Abstract. Accurate prediction of Global Tilted Irradiance (GTI) is crucial for optimizing photovoltaic (PV) performance, especially in real-world conditions where solar panels are rarely mounted horizontally. This study compares four machine learning algorithms Decision Tree, Random Forest, XGBoost, and CatBoost with a deep learning based model, TabNet, for Global Tilted Irradiance (GTI) prediction using real-time meteorological data from the Visakhapatnam region in Andhra Pradesh, India, obtained from the Solcast platform. Comprehensive exploratory data analysis (EDA), feature engineering, and model evaluation were conducted using standard performance metrics (MAE, RMSE, R2) alongside rigorous uncertainty quantification and top error analysis. While all models achieved strong baseline performance ($R2 \geq 0.9978$), TabNet demonstrated superior reliability under high-variability conditions, yielding the lowest RMSE (6.5520W/m²) and minimum maximum error (41.99W/m²) among all models. Furthermore, SHAP-based interpretability confirmed TabNet's alignment with physical irradiance theory, identifying GHI, DNI, DHI, zenith, and atmospheric features as key contributors. The model's ability to maintain both high accuracy and explainability underpins its suitability for deployment in real-time PV control, grid balancing, and smart energy predicting systems. This research underscores the practical value of interpretable deep learning in solar energy prediction and positions TabNet as a robust alternative to conventional ensemblebased regressors for GTI estimation.

[4350] Modisane Seitshiro (North-West University) and Christian Fanevasoa (African Institute for Mathematical Sciences). ***Optimization Sensitivity in ARFIMA and FIGARCH Models for Precious Metals.***

Abstract. This study evaluates parameter estimation sensitivity in long-memory time series models, focusing on the ARFIMA and the FIGARCH models. The optimization techniques applied in the models utilized the daily logarithmic returns of four precious metals traded on the JSE, namely gold, rhodium, platinum and palladium. We compare four optimization algorithms given by BFGS, CG, L-BFGS and Adam against benchmark implementations in R packages given by arfima and rugarch. The results obtained indicate that ARFIMA estimates remain consistent across optimizers, while FIGARCH exhibits strong sensitivity to algorithm choice. BFGS provides stable and robust estimates, whereas CG often fails to converge, and L-BFGS and Adam yield inconsistent outcomes. These findings highlight the crucial role of optimization in ensuring reliable volatility forecasts, with practical implications for risk management and financial decision-making.

[4362] Kanayo Ogujiuba (School of Development Studies, University of Mpumalanga) and Lethabo Maponya (School of Development Studies, University of Mpumalanga). ***The Effect of Monetary and Macro variables on Capital adequacy Ratio: Evidence from South Africa.***

Abstract. The Capital Adequacy Ratio (CAR) is commonly seen as a key indicator of the banking sector's strength, providing an evaluation of a bank's capital adequacy relative to its risk-weighted assets. This study focuses on the impact of macroeconomic and monetary elements on the Capital Adequacy Ratio (CAR) in South Africa, acknowledging CAR's fundamental importance in ensuring financial sector stability within the Basel III regulatory framework. Although there is an increasing body of international literature on the determinants of CAR, there is still a deficit of empirical studies in South Africa that combine macroeconomic fundamentals with monetary policy factors. Employing quarterly time-series data from 2009Q1 to 2020Q4, the study utilises the Autoregressive Distributed Lag (ARDL) bounds testing method and Error Correction Model (ECM) to assess both short- and long-term connections between CAR and macroeconomic factors, such as the repo rate, inflation, exchange rate, credit expansion, and GDP. The empirical findings validate a consistent long-term relationship: the repo rate, exchange rate volatility, and credit growth have statistically significant negative impacts on CAR, whereas GDP growth shows a positive correlation. These results highlight the significance of integrating macroprudential factors into South Africa's monetary policy framework. Enhancing stress-testing capabilities and bolstering countercyclical capital buffers are crucial for boosting the banking sector's resilience to macroeconomic shocks. The findings offer critical insights for policymakers seeking to align monetary policy with financial stability goals in emerging economies.

[4409] José Luis Molina González (IGA Research Group. Salamanca University, High Polytechnic School of Engineering Avila), Santiago Zazo del Dedo (IGA Research Group - University of Salamanca), Fernando Espejo Almodovar (IGA Research Group. Salamanca University, High Polytechnic School of Engineering Avila), Carmen Patino Alonso (IGA Research Group. Salamanca University, Department of Statistics) and Juan Carlos García Prieto (CIDTA. Salamanca University, Faculty of Pharmacy). ***RainHealth©: A Machine-Learning Prototype for Early Hydro-Sanitary Risk Assessment in Reservoirs under Extreme Rainfall Events.***

Abstract. Extreme rainfall events may rapidly deteriorate reservoir water quality through increased runoff, sediment mobilisation, organic matter transport and microbiological contamination, generating hydro-sanitary risks for water supply systems and recreational water uses. Reservoirs are especially vulnerable because they integrate runoff contributions from large catchment areas and may accumulate pollutants transported during storm events. This study presents RainHealth©, a proof-of-concept machine-learning prototype designed to support early hydro-sanitary risk assessment in reservoirs after extreme rainfall events. The case study includes five reservoirs located in the Duero River Basin (Castilla y León, Spain). The dataset integrates meteorological, hydrological, physicochemical, microbiological and territorial predictors associated with rainfall-driven water-quality deterioration. A Random Forest model was trained and evaluated using an 80/20 stratified partition and repeated 5-fold cross-validation. The model achieved strong predictive performance, with RMSE = 0.0171, MAE = 0.0103 and $R^2 = 0.9901$, together with an overall classification accuracy of 96.69% for low-, medium- and high-risk categories. The most influential predictors were rainfall torrentiality, rainfall intensity, turbidity, organic matter and reservoir inflow. These findings support the potential of AI-based approaches for future early-warning systems in reservoir hydro-sanitary management under extreme rainfall scenarios.

[4410] Estevan Mendes (Pontifical Catholic University of Rio de Janeiro), Álvaro Veiga (Pontifical Catholic University of Rio de Janeiro) and Karla Figueiredo (Rio de Janeiro State University). ***Churn Prediction: A Hybrid Approach with Transactional Data and Topic Extraction via LLMs.***

Abstract. This study proposes a hybrid framework for customer churn prediction combining transactional data with textual topics extracted via Large Language Models (LLMs). Using real-world data from a top Brazilian acquirer, we compared traditional topic modeling (BERTopic) against an LLM-based approach (TopicGPT). The methodology involved mapping user conversations into a latent space and concatenating them using temporal grouping (long, medium, and short-term). Results indicate that the hybrid model achieves an AUC of 0.77, outperforming transactional-only models by 5 percentage points. Furthermore, TopicGPT demonstrated superior performance in topic extraction compared to BERTopic. The findings suggest that incorporating unstructured textual data significantly enhances predictive performance in the acquiring sector.

[4485] Laura Floroian (Transilvania University of Brasov) and Liviu Dogar (Transilvania University of Brasov). *Time-Series Modeling and Forecasting of Drug-Eluting Bioactive Glass/Polymer Coatings for Metallic Implants.*

Abstract. Predictive modeling of functional coating behavior represents an emerging intersection between biomaterials engineering and data science. This study proposes a time-series-driven framework for analyzing and forecasting the deposition dynamics and drug-release performance of multilayer PMMA/bioactive glass coatings loaded with ciprofloxacin and deposited on metallic implant substrates (316L stainless steel and Ti6Al4V). Experimental datasets were generated from controlled dip-coating processes involving repeated immersion-withdrawal cycles, followed by thermal stabilization. Measured variables included layer growth evolution, mass deposition, surface morphology descriptors, and antibiotic release profiles acquired over time.

To move beyond conventional descriptive characterization, temporal datasets were modeled using statistical and machine-learning forecasting approaches. Classical autoregressive integrated moving average (ARIMA) models were employed to capture linear temporal dependencies in deposition thickness and release kinetics, while multivariate regression models quantified relationships between process parameters (withdrawal speed, immersion duration, cycle number, and solution composition) and coating outcomes. Long Short-Term Memory (LSTM) neural networks were further implemented to learn nonlinear temporal correlations governing drug diffusion and coating stabilization phenomena.

Comparative evaluation demonstrates that hybrid modeling strategies significantly improve predictive accuracy relative to purely statistical analysis, particularly for long-horizon drug-release forecasting. The proposed framework enables estimation of coating performance from early-stage process signals, offering a pathway toward data-driven optimization and adaptive manufacturing of drug-eluting implant surfaces.

The results highlight how time-series forecasting methods can be integrated into biomaterials design workflows, transforming experimental coating development into a predictive, model-guided process aligned with smart manufacturing and digital biomaterials engineering paradigms.

[4525] Lucía Calderón-García (Universidad Francisco de Vitoria), Julio E. Sandubete (Universidad Francisco de Vitoria) and Ana Lazcano (Universidad Francisco de Vitoria). *Recursive HMM-Based Structural Monitoring for Adaptive Financial Time Series Forecasting.*

Abstract. Financial time series forecasting remains a particularly challenging task due to the non-stationary nature of financial markets. Financial series may exhibit changes in volatility patterns, transitions between regimes, abrupt disruptions, and gradual structural transformations that can deteriorate the accuracy of models trained under a fixed historical configuration. In this context, the challenge is not only to build accurate predictive models, but also to determine when they should be updated in order to remain aligned with the evolving underlying dynamics of the series.

To address this issue, this work proposes a recursive Hidden Markov Model (HMM)-based framework for one-step-ahead financial forecasting, in which the HMM acts as a structural monitoring mechanism and different neural models perform the predictive task. Unlike periodic or arbitrary updating strategies, the main contribution of the proposed approach lies in transforming the evolution of the latent structure inferred by the HMM into an operational and objective retraining signal. In this way, the system determines when the predictor should be updated according to changes detected in the internal dynamics of the series itself, reducing the dependence on fixed schedules or external criteria for model maintenance.

The proposed framework starts from an initial training window, on which both the predictive model and the HMM are estimated. The predictive component is designed as a modular element and is implemented using different neural architectures, including Multilayer Perceptron (MLP), Long Short-Term Memory networks (LSTM), Bidirectional LSTM (BiLSTM), and Transformer-based models. All these architectures are trained to perform one-step-ahead log-return forecasting using lagged values of the series. The HMM, in turn, is used to characterize the latent structure of the process. In this sense, the HMM is not used as a direct forecasting model, but as an interpretable mechanism for monitoring changes in the internal organization of the series.

As new observations become available, the HMM is recursively re-estimated over an expanding sample, and the number of hidden states is selected according to the Bayesian Information Criterion. This recursive procedure allows the system to track the evolution of latent regimes, the transition dynamics between them, and the structural stability of the series over time.

The retraining rule is based on the Switching Intensity statistic, computed from the transition matrix estimated by the HMM and the stationary distribution of the Markov chain. This measure summarizes the expected tendency of the system to switch between regimes. Rather than relying only on its absolute value, the proposed approach monitors its variation between consecutive recursive estimations. This variation is standardized through a Z-score computed over a recent window, allowing the system to identify changes in latent stability that are anomalous with respect to the recent behavior of the series itself.

When this standardized variation exceeds a predefined threshold, the system interprets that a relevant structural modification has occurred and activates the retraining of the corresponding neural predictor using the information accumulated up to that point. Otherwise, the current predictor is kept unchanged. Thus, the update is not performed arbitrarily or at a fixed frequency, but according to the structural evolution inferred by the HMM. This logic allows the HMM to operate as a structural monitoring layer applicable to different predictive architectures, so that the retraining decision is separated from the specific type of neural model employed.

The empirical evaluation is conducted on both synthetic and real financial series. First, three synthetic series with different numbers of hidden states —3, 5, and 8— are considered in order to analyze the behavior of the system under different levels of latent complexity. These synthetic configurations provide a controlled setting in which the internal regime structure is defined by design, making it possible to assess whether the proposed monitoring mechanism reacts coherently as the latent dynamics become more complex.

The approach is then applied to three daily financial series: NASDAQ, West Texas Intermediate, and gold, representing an equity market, an energy commodity, and an asset commonly associated with safe-haven behavior and financial uncertainty, respectively. The evaluation is mainly carried out in the log-return space, as log-returns constitute the target variable of the predictive models, and is complemented with the analysis of reconstructed prices as an additional interpretability layer.

In all cases, the proposed system is compared with non-adaptive models that share the same predictive architecture, initial training window, and out-of-sample evaluation period. The only difference between the two approaches lies in the updating policy: in the baseline version, each neural predictor is trained once and then kept fixed throughout the entire out-of-sample period; in the proposed recursive version, the same predictor can be selectively retrained when the structural signal derived from the HMM indicates a relevant change in the latent dynamics. This experimental design makes it possible to isolate the effect of the proposed retraining rule from the predictive capacity of the neural architecture itself.

The results obtained show that, in the synthetic configurations analyzed, the relative improvement increases as the number of hidden states grows, suggesting that the retraining mechanism is particularly useful when the internal dynamics of the series are more complex. In the real financial series, the updating policy guided by the latent structure improves, in general terms, the behavior of neural predictors compared with their corresponding non-adaptive versions. This improvement should not be interpreted only as an isolated reduction in forecasting error, but as evidence that the HMM-based signal provides useful information for deciding when to update neural models with different predictive architectures.

From this perspective, the contribution of this work is not limited to a specific predictive architecture, but rather lies in the model maintenance mechanism. The HMM functions as an interpretable structural monitoring mechanism, capable of transforming changes in latent dynamics into an objective retraining signal, while the predictive component preserves the forecasting role. In this way, the proposed framework connects regime inference with a practical retraining decision, providing a reproducible way to adapt neural predictors in non-stationary financial contexts.

[4558] Ashok Ganga (Godavari Global University Rajamahendravaram, Andhra Pradesh), D Ravi Kishore (Godavari Global University Rajamahendravaram, Andhra Pradesh) and D Vijaya Kumar (Aditya Institute of Technology and Management Tekkali, Andhra Pradesh.). ***An Intelligent Simulation-Based Fault Diagnosis Approach for Power Systems Using Attention-Enhanced Residual Learning with Bayesian Hyperparameter Optimization.***

Abstract. The accurate identification of power system faults and their classification are the keys to the safe and stable functioning of the contemporary electrical grids. The current research paper suggests a data-driven fault diagnosis method that utilizes the techniques of deep learning models on the simulated fault data in the simulated power system model created in MATLAB. Different types of faults in different operating conditions are taken into consideration to test the strength of the proposed method. One-dimensional Residual Network (ResNet) is used to acquire fault properties on the basis of the input signals, and its functionality is improved by the combination with an attention system to highlight informative features. Besides, Bayesian optimization is employed to optimize hyperparameters systematically and enhance classification. The original ResNet model has the accuracy of 94.07%, and it reaches 96.84% when it has attention. The ResNet-attention model is optimized to achieve the highest possible accuracy of 98.42%, which proves it to be very effective in dealing with multiclass fault classification. The efficiency of the proposed framework is ensured by performance evaluation based on precision, recall, F1-score, and confusion matrices. It was found that deep residual learning with attention and automated optimization presents a valid method to achieve fault detection and can aid real-time protection and surveillance of intelligent power systems.

[4582] Nazym Ainakul (Turan University), Aziza Zhuparova (Almaty Management University) and Saule Nurymova (Turan University). ***Human Capital and Regional Growth in Kazakhstan: The Role of Spatial Spillovers.***

Abstract. This paper examines the role of human capital in regional economic growth across Kazakhstan's twenty regions over the period 2000–2024. We construct a Human Capital Development Index (HCDI) from six indicators—higher education enrollment, R&D employment, labour productivity, life expectancy, TVET graduation rates, and doctoral output—and embed it in spatial panel models to estimate both direct effects and cross-regional spillovers. Fixed-effects and random-effects panel regressions reveal that a one-standard-deviation increase in HCDI is associated with a significant increase in gross regional product per capita (HCDI coefficient = 3.29, $p < 0.01$). Spatial Autoregressive (SAR) and Spatial Durbin Model (SDM) estimates show statistically significant positive spillovers ($p = 0.10$ – 0.58), indicating that human capital accumulation in one region raises output in neighbouring regions. The relationship is strongly asymmetric across region types: manufacturing-oriented regions exhibit human capital elasticities approximately twice as large as those of oil-producing regions, consistent with the hypothesis that extractive economies have lower absorptive capacity for educated labour. We identify a structural break around 2015 in the human capital–growth relationship, coinciding with the oil price collapse and subsequent labour market restructuring. Scenario analysis suggests that raising HCDI from its current national average of 0.21 to 0.40 by 2035 would add approximately 1.5 percentage points to annual GRP growth, contingent on simultaneous improvements in institutional quality and manufacturing absorption capacity. These findings underscore the insufficiency of education-focused policies alone and point to the need for integrated human capital–industrial policy frameworks.

[4621] Wen Chen (Sun Yat-sen University), Xiangliang Zhang (Tsinghua University) and Kunpeng Wu (Sun Yat-sen University). ***Estimating Intervention Impacts When Timing Is Unclear: An AR-LagDT Model with Distributed Lags.***

Abstract. Interrupted Time Series (ITS) analysis is widely used to evaluate intervention impacts, but conventional methods like the classical segmented regression (CSR) and "prediction" models (ARIMA, ETS, etc.) have limitations. CSR assumes an immediate effect, while "prediction" models rely on counterfactual estimates that become unreliable over time. To address this, we propose the Autoregressive with Lag Distributed Term (AR-LagDT) model, which explicitly accounts for intervention effect ambiguity using distributed lag functions. By incorporating varying fuzzy statuses (the onset and duration ambiguity of the intervention effect) and multiple distribution patterns, the AR-LagDT model provides more precise estimates of intervention dynamics. We validate the model through an empirical case study on Japan's COVID-19 State of Emergency and its impact on the Human Mobility Index in Tokyo. To enhance usability, we develop a user-friendly software application for AR-LagDT model. Our findings demonstrate the model's ability to capture the temporal progression of intervention effects, providing estimates of maximum impact, cumulative effect, and time-dependent changes. In the empirical analysis, AR-LagDT (e.g., MSE: 7.0139) demonstrate superior in-sample fit to CSR (e.g., MSE: 14.2741) while achieving a broadly similar performance level to the average of "prediction" models (e.g., MSE: 8.1845, ranging from 5.6944 to 14.1337). Moreover, the AR-LagDT model offers clearer interpretability of time-varying impacts. Despite challenges in selecting appropriate fuzzy statuses and distribution patterns, this model offers a robust and flexible framework for impact evaluations in various disciplines and enhances accessibility for researchers conducting intervention analyses in epidemiology, public health, and policy evaluation.

[4723] Kerem R Gür (METU), P. Cemre Yazıcı (METU), Pelin Erkaya (METU), Yağmur Türkmen (METU), Berke Baytak (METU), İsmail Güzel (METU - TÜBİTAK ULAKBİM), Pınar Karagöz (METU) and Ceylan Yozgatlıgil (METU). ***BeTiSe: A Comprehensive Benchmark Dataset for Time Series Stationarity and Structural Analysis.***

Abstract. Time series analysis faces fundamental challenges when series exhibit trends, structural breaks, volatility, or anomalies that violate stationarity assumptions. Existing statistical tests often produce inconsistent results, while emerging LLMs and deep learning approaches lack comprehensive benchmarks to evaluate their understanding of diverse time series properties.

We present BeTiSe, a large-scale synthetic benchmark dataset addressing these limitations through controlled generation of time series with well-documented characteristics. It contains thousands of univariate series across three length categories (short: 50–100, medium: 300–500, long: 1,000–10,000 observations), analytically generated to exhibit combinations of seven fundamental properties: (1) stationarity/non-stationarity, (2) deterministic trends, (3) stochastic trends, (4) seasonality patterns, (5) volatility dynamics (ARCH/GARCH/EGARCH/APARCH), (6) anomalies, and (7) structural breaks. Unlike real-world datasets where true underlying properties are unknown, each series is generated with explicit control over these characteristics.

BeTiSe provides comprehensive metadata, including binary flags and detailed transformation parameters, enabling evaluation across multiple tasks; stationarity testing, trend detection, anomaly detection, structural break localization, and time series classification. The controlled generation ensures balanced representation across property combinations, avoiding class imbalance common in real datasets.

We demonstrate its utility through three applications: (1) neural network classifiers that outperform traditional tests (ADF, KPSS, PP) in stationarity detection, (2) multi-task models for simultaneous detection and classification of trends, breaks, and anomalies, and (3) a training and evaluation resource for LLM-based time series foundation models. BeTiSe is publicly available with complete documentation, generation code, and baseline results, facilitating reproducible research across finance, economics, engineering, and natural sciences.

[4726] Cinzia Cirillo (University of Maryland), Asal Mehdi Tabrizi (University of Maryland) and Yan Liu (Microsoft). ***A Recursive Probit Model for Dynamic Discrete-Continuous Choices: The Case of Vehicle Ownership and Use Over Time.***

Abstract. The paper proposes a model formulation for discrete and continuous decision variables over time. The method relies on multinomial recursive probit for discrete choices and on linear regression for continuous variables. The two models and the relative correlation structure are estimated simultaneously using Maximum-Likelihood estimation. An approximation of the downstream utility with logsum allows the generalization of a more restrictive recursive binary probit model for which the expected utility can be calculated numerically. Numerical tests are conducted on simulated data for the vehicle ownership and miles driven problem. Estimation results demonstrate that model coefficients are correctly recovered, while an out-of-sample validation exercise attests that the variations in market shares and in the continuous outcome are well captured. The dynamic model structure formulated is general and applicable to a wide variety of problems not limited to the transportation field.

[4731] Neeti Singh (India meteorological department). ***A Data-Driven Framework for Short-Term Visibility Nowcasting at Indira Gandhi International Airport Using Multi-Horizon Gradient Boosting Models.***

Abstract. Accurate short-term visibility forecasting is critical for safe and efficient airport operations, particularly during the winter months when fog and mist frequently reduce runway visibility. This study presents a machine learning-based 12-hour visibility forecasting system for Indira Gandhi International Airport (VIDP), utilising historical METAR observations along with engineered temporal and meteorological features. A direct multi-step LightGBM regression approach was employed to predict visibility at 30-minute intervals over a 12-hour horizon, effectively capturing both persistence and dynamic atmospheric changes. The model was evaluated in a real-time operational environment from December 15, 2025, to January 31, 2026, and has proven to be highly useful for forecasters. Results indicate that the system reliably predicts short-term visibility trends, with particularly strong performance during persistent fog events and robust accuracy across the forecast horizon. The proposed framework offers a computationally efficient, interpretable, and operationally viable solution to support decision-making in aviation meteorology. Key features of the approach include:

- Use of 24 independent lead-time models to minimise error propagation and ensure stable 12-hour visibility forecasts.
- Incorporation of physics-informed features, such as lagged visibility, surface meteorological parameters, and temporal indicators, to capture atmospheric persistence. Demonstration of consistent winter-season performance, including prolonged fog events, providing reliable operational support for aviation decision-making.

[4741] Ibrahim Kachalla (Builders School of Engineering) and Joelle Al Fakhoury (Builders School of Engineering). ***THERMAL PERFORMANCE OPTIMIZATION OF BIO-BASED MASONRY BLOCKS USING NUMERICAL SIMULATION AND SURROGATE MODELING.***

Abstract. The thermal performance of masonry blocks plays a critical role in improving building energy efficiency and achieving regulatory compliance. In this context, the integration of machine learning techniques offers a promising approach to address thermal design challenges and optimize masonry block configurations. This study presents a computational framework for optimizing bio-based masonry block design by coupling numerical simulation with data-driven modelling. A parametric thermal model was developed in COMSOL Multiphysics to simulate steady-state heat transfer through masonry blocks with varying cavity geometries and material properties. A design-of-experiments approach was employed to generate a dataset of simulated configurations, from which key thermal performance indicators, including heat flux and thermal transmittance, were extracted. The simulation results were subsequently used to train a surrogate model using machine-learning techniques. The surrogate model enhanced prediction of thermal performance without requiring repeated finite element simulations. An optimization procedure was then applied to identify cavity configurations that minimize thermal transmittance while maintaining practical geometric constraints. The proposed workflow significantly reduces computational cost, forecasting and optimised the exploration of masonry block designs. Results demonstrate that the surrogate-assisted optimization approach can identify geometries with substantially suggest possible improvement to thermal insulation performance compared with conventional block configurations. This methodology provides a scalable digital design framework for developing next-generation bio-based masonry materials with enhanced energy performance evaluation. Future work could incorporate real-time sensor networks integrated with Internet of Things (IoT) systems to enable continuous monitoring and validation of the thermal performance of masonry wall assemblies.

[4793] Damir Jakus (Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture), Josip Vasilj (Fakultet elektrotehnike, strojarstva i brodogradnje), Joško Novaković (Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture) and Danijel Jolevski (Fakultet elektrotehnike, strojarstva i brodogradnje). ***Day-Ahead Electricity Price Forecasting Using Gradient Boosting Decision Tree Models: A Case Study of the Croatian Market.***

Abstract. Accurate day-ahead electricity price forecasting is essential for market participants to optimize bidding strategies and manage financial risks in increasingly volatile energy markets. This paper presents a comprehensive web-based system designed for day-ahead electricity price forecasting based on gradient boosting models, specifically applied to the Croatian market. The proposed approach integrates a multi-layered architecture that includes data ingestion from ENTSO-E and Open-Meteo, a robust backend for model selection, training and management, with an interactive frontend presentation layer. The performance of two state-of-the-art gradient boosting algorithms, XGBoost and LightGBM was evaluated using hourly DA market price data from 2022 to 2024 from Croatian electricity market. The results demonstrate that both models achieve similar accuracy for the year 2024. Monthly analysis reveals significant performance variations, with higher errors during periods of extreme volatility and price spikes, such as summer and late winter. The study highlights the importance of meteorological features and market fundamentals in capturing price dynamics.

[4799] Fatma Ezzahra Laadhari (MACMA Research Laboratory, Higher Institute of Management of Tunis (ISG Tunis)) and Adel Karaa (MACMA Research Laboratory, Higher Institute of Management of Tunis (ISG Tunis)). ***From Quarterly Labor Market Surveys to Official Statistics: Does the Method Matter in the Era of AI?***

Abstract. The rapid expansion of artificial intelligence methods in economic and social measurement has fundamentally reopened a central question in official statistics: do statistical indicators merely reflect underlying realities, or are they increasingly shaped by the methodological architectures used to construct them? This question has become particularly important in the context of labor market statistics, where growing behavioral complexity, compositional instability, and post-Covid structural disruptions challenge the ability of traditional econometric frameworks to fully capture rapidly evolving labor market dynamics. While machine learning and artificial intelligence methods now demonstrate remarkable predictive capacities at the individual level, their implications for the construction, interpretation, and reliability of official aggregate statistics remain insufficiently explored.

This paper addresses this issue by proposing a comprehensive framework linking probabilistic classification, compositional aggregation, latent dynamic modeling, and information geometry in order to investigate how different statistical learning paradigms shape the production of official labor market indicators under quarterly survey uncertainty. More specifically, the study asks whether the choice of classification methodology materially affects the informational structure, stability, and interpretability of quarterly labor market statistics in the era of artificial intelligence.

Using quarterly labor force surveys spanning the period 2009–2024, the paper compares several econometric and machine learning classifiers, including a traditional Multinomial Logit model, Multilayer Perceptron neural networks (MLP), and modern boosting algorithms such as XGBoost, LightGBM, and CatBoost. Rather than restricting the comparison to conventional predictive metrics alone, the analysis focuses on the complete probabilistic outputs generated by each classifier. This probabilistic perspective allows the study to move beyond hard classifications and to investigate how competing algorithms internally organize uncertainty, heterogeneity, and behavioral structures.

The proposed framework operates across three interconnected analytical levels: micro, meso, and macro.

At the micro level, each classifier produces individual probability vectors describing the likelihood of belonging to different labor market participation states. Standard predictive metrics — including accuracy, F1-score, cross-entropy, calibration quality, and probabilistic uncertainty measures — are used to evaluate individual-level predictive performance. However, the paper argues that these metrics alone remain insufficient for evaluating the broader statistical implications of classification algorithms when the ultimate objective is the production of reliable aggregate indicators.

At the meso level, the study introduces a Dirichlet aggregation framework that transforms individual probabilistic outputs into quarterly compositional labor market structures. This stage constitutes one of the central contributions of the paper. Instead of aggregating deterministic classifications into crude participation rates, the proposed approach models quarterly labor market compositions as probabilistic entities characterized simultaneously by directional structures and uncertainty intensity. Within this framework, the Dirichlet mean vector captures the quarterly participation composition associated with employment, unemployment, underemployment, and inactivity, while the concentration parameter measures the informational precision, coherence, and stability of these aggregate compositions.

This compositional perspective substantially enriches the literature on classifier evaluation. The paper demonstrates that different algorithms may generate similar predictive accuracy at the individual level while producing substantially different aggregate compositional structures once probabilities are aggregated over time. Consequently, the concentration parameters derived from the Dirichlet models are interpreted as new macro-statistical evaluation metrics reflecting the degree of informational confidence embedded within each classifier's probabilistic architecture. Higher concentration levels indicate stronger compositional coherence and greater structural consistency in the quarterly indicators generated by the corresponding algorithm.

At the macro level, the quarterly compositional outputs generated by the various classifiers are integrated within Bayesian latent factor models estimated through structural equation modeling techniques. These latent factors — represented as “Factors” in the perceptual maps — aim to recover the underlying structural dynamics governing labor market participation independently of classifier-specific noise. The factor structure provides a dynamic representation of the latent informational regime underlying official labor market indicators and allows the study to evaluate the extent to which different algorithms align with common macroeconomic participation dynamics.

To compare the informational behavior of the competing methodologies, pairwise Jensen–Shannon divergence matrices are computed between the quarterly compositional probability structures generated by each classifier. Unlike conventional performance metrics, the Jensen–Shannon divergence evaluates the informational distance between entire probabilistic systems. The resulting divergence matrices are then analyzed through multidimensional scaling (MDS) in order to construct a common perceptual space describing the informational geometry of the competing learning paradigms.

The empirical results reveal several major findings. First, the perceptual space shows that the traditional Multinomial Logit model remains remarkably close to official labor market statistics, suggesting that official indicators continue to rely implicitly on relatively stable and interpretable econometric probabilistic structures. In contrast, boosting algorithms occupy more distant regions of the informational space, indicating their ability to detect nonlinear interactions, local asymmetries, and hidden compositional heterogeneity that remain only partially reflected in official aggregate indicators.

Second, the perceptual map reveals a clear informational complexity gradient across methodologies. CatBoost emerges as the most informationally distinct algorithm, reflecting its strong capacity to capture fine-grained local structures and contextual nonlinearities. XGBoost and LightGBM occupy intermediate positions between classical econometric representations and highly adaptive nonlinear learning structures, while the MLP model behaves as a hybrid architecture situated between latent structural representation and adaptive learning. Meanwhile, the Bayesian latent factors occupy a separate position within the perceptual space, suggesting that latent structural dynamics operate at a deeper informational level than the classifiers themselves.

Third, the temporal evolution of MDS source weights reveals a major structural break associated with the Covid-19 crisis. Before 2020, the informational geometry of labor market statistics was primarily dominated by dimensions associated with probabilistic regularity, structural stability, and interpretable econometric representations. After the pandemic shock, however, dimensions associated with nonlinear adaptive learning progressively gained informational dominance. This shift suggests that the statistical nature of labor market dynamics itself has evolved toward greater fragmentation, contextual heterogeneity, and nonlinear complexity.

The paper argues that the rise of artificial intelligence in official statistics should therefore not be understood merely as a technological substitution of econometric methods by machine learning algorithms. Rather, the findings suggest that the increasing complexity of economic systems progressively transforms the informational requirements of statistical production itself. In this context, the methodological choice used to transform quarterly labor market surveys into official indicators increasingly matters because different learning paradigms generate distinct probabilistic structures, distinct uncertainty regimes, and distinct representations of economic reality.

Consequently, the study advocates for hybrid statistical architectures capable of combining the interpretability and institutional coherence of econometric models, the compositional consistency of Dirichlet aggregation, the macro-dynamic stability of Bayesian latent factors, and the adaptive learning capacity of modern artificial intelligence methods. Beyond labor market applications, the proposed framework contributes to applied econometrics, official statistics, compositional data analysis, explainable artificial intelligence, and information geometry by introducing a new perspective on how statistical methodologies themselves shape the informational construction of public indicators in the era of AI.

[4883] Regui Slimane (LEAM, FSJES Souissi Rabat, Rabat, Morocco). ***Detecting random coefficients in periodic regression models.***

Abstract. This presentation presents a pseudo-Gaussian test for detecting random coefficients in a periodic regression model applied to unbalanced panel data. The test is constructed based on uniform local asymptotic normality results. Simulation studies confirm the validity and effectiveness of the proposed test under both symmetric and asymmetric distributions. Furthermore, applications to real data demonstrate the practical advantages of the proposed model over the periodic regression model introduced by Regui et al. (2024).

[4922] Ann-Sophie Bülter (FH Münster), Ludwig Horsthemke (FH Münster), Glen Neiteler (FH Münster), Frederik Hoffmann (FH Münster), Sarah Kirschke (FH Münster), Tilman Sanders (FH Münster), Markus Gregor (FH Münster), Ignacio Rojas Ruiz (University of Granada) and Peter Glösekötter (FH Münster). ***Comparing FCNN and LSTM Architectures for Magnetic Field Prediction Using an All-Optical NV Diamond Setup.***

Abstract. This paper investigates the prediction of magnetic fields using an all-optical NV diamond sensing setup combined with neural network models. In contrast to previous work, the focus is placed on the generalization capability of the models across independent measurement data sets affected by drift. Three architectures are evaluated: two fully connected neural networks (FCNNs) and one long short-term memory (LSTM) network. The LSTM demonstrates improved prediction accuracy due to its ability to exploit temporal dependencies in the data. The inclusion of temperature as an additional input feature further enhances performance. However, significant discrepancies between measurement data sets, caused by drift, prevent reliable generalization across data sets for all models. These findings indicate that improving hardware stability is essential for achieving robust real-world performance of data-driven NV-based sensing systems.

[5036] Rui Alexandre Castanho (VALORIZA-IPP, Portalegre) and José Manuel Naranjo Gómez (University of Extremadura). ***Forecasting Territorial Accessibility and Sustainability Impacts of Transport Infrastructure: Evidence from Mainland Portugal.***

Abstract. This paper reassesses the role of transport logistics and infrastructure in shaping sustainable territorial development in mainland Portugal using an integrated quantitative and spatial approach. In this regard, the work is based on an Absolute Accessibility Index based on road network characteristics and municipal population distribution and combining it with multivariate socio-economic analysis and territorial cohesion indicators, the study identifies persistent spatial imbalances in accessibility and development. The results show that areas with the highest accessibility are strongly concentrated in central and coastal corridors, while inland, peripheral, and border regions continue to exhibit structural disadvantages. Moreover, the analysis suggests that successive funding and investment cycles have not substantially altered the underlying territorial inequality patterns. Such findings reinforce the importance of accessibility as a critical analytical variable for territorial assessment and provide a solid empirical foundation for future time-series modelling and forecasting of the long-term impacts of transport infrastructure policies on regional sustainability and cohesion.

[5101] Martin Wagner (Department of Economics, Analytics and Operations Research, University of Klagenfurt). *Forecasting Daily Tourism Demand 365 Days Ahead with Monthly Data: Disaggregation, Calendar and Mobile Phone Data.*

Abstract. The abstract is attached as PDF File.

[5161] El Houcine El Moussaoui (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco), Saïd Khabba (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco), Salah Er-Raki (AgroBiotech Center, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco) and Abderrahman Lahrouni (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco). *Analysis of Climate Trends in the Haouz Region Through Reference Evapotranspiration Time Series.*

Abstract. In this study, we assessed the reliability of daily ET_0 estimates derived from different Thornthwaite approaches (Th1, Th2, and Th3), Hargreaves–Samani variations (Harg-sam1, Harg-sam2, and Harg-sam3), and the Turc method, in comparison with the PM-FAO56 model. The evaluation was conducted using daily weather data from the Agdal site, located in central Morocco, covering the period from 2005 to 2019. Among the evaluated models, the Turc method exhibited the highest $R^2 = 0.95$ (RMSE = 1.27), indicating excellent alignment with the ET_0 _PM. The temporal analysis of the average ET_0 values and their variability over three periods (2005–2009, 2010–2014, and 2015–2019) shows that during the first two periods, the ET_0 averages were very similar, with low dispersion (approximately 1000 ± 30 mm/year). In contrast, during the third period (2015–2019), the average ET_0 value increased, with much higher variability (1139.96 ± 100 mm/year).

[5206] Wan Yun Hong (Universiti Brunei Darussalam). *Predictive Attribution of Urban Canopy Air Quality Drivers in an Equatorial Background Atmosphere.*

Abstract. Characterizing the urban background atmosphere in equatorial regions is challenging due to the complex monsoonal, diurnal and human dynamics. This study evaluates the atmospheric steady-state of a university campus in Brunei Darussalam by monitoring the canopy layer at high resolution over 6 months. Non-parametric variance testing and random forest regression modeled the Pollutant Standard Index (PSI) alongside meteorological and operational variables. Kruskal-Wallis testing revealed that while PSI remains consistently “Good”, it shows significant sensitivity to diurnal ($H = 99.03$) and academic operational ($H = 15.46$) factors, isolating NO₂ as a distinct anthropogenic tracer ($H = 30.73$ across academic terms). Optimizing the random forest regressor with the previous day’s autoregressive lag term enhanced predictive performance ($R^2 = 0.961$, RMSE = 1.46 and MAPE = 10.42%). Feature importance analysis demonstrates that atmospheric persistence governs the baseline physics, whereas air temperature and relative humidity regulate immediate contemporary variations. This predictive framework provides a robust environmental management benchmark for stable, low-pollution tropical canopy environments.

[5341] Aitor Diez Mateo (University of Deusto), Roberto Garay-Martinez (University of Deusto), Cruz Enrique Borges Hernandez (University of Deusto) and Ana García Garre (Votiva Energy). *Hybrid Machine Learning Approach for Short-Term Load Forecasting in Small Commercial Buildings.*

Abstract. The building sector accounts for 34% of global energy demand, making accurate short-term load forecasting essential. Small commercial buildings remain challenging due to high-frequency noise and data sparsity. This study proposes a hybrid machine learning framework that decouples behavioral load shapes from climate-driven magnitude variations. K-Means clustering identifies operational archetypes, while a dual-stage supervised pipeline predicts daily shapes via a non-linear SVM classifier and peak magnitude via regression. Validated on real-world 15-minute office building data from Murcia, Spain, the framework consistently outperforms ARIMAX, Prophet, persistence, and zero-shot foundation models (TimesFM, Chronos-t5). The best configuration achieved $R^2=0.83$ and MAE=0.37 kW, confirming that domain-specific behavioral decoupling surpasses general-purpose pretraining in small-scale commercial datasets.

[5374] José Juan Hernández-Gálvez (Universidad de Las Palmas de Gran Canaria), Stefano Sanfilippo (Universidad de Las Palmas de Gran Canaria), José Juan Hernández Cabrera (Universidad de Las Palmas de Gran Canaria), Jose Évora-Gómez (Universidad de Las Palmas de Gran Canaria), Octavio Roncal-Andrés (Universidad de Las Palmas de Gran Canaria) and Mario Caballero-Ramírez (Universidad de Las Palmas de Gran Canaria). ***A Pipeline for Electricity Forecasting under Data Scarcity, Fragmentation, and Nonstationarity.***

Abstract. This paper presents ANGEL, a structured forecasting pipeline designed for electricity demand prediction in microgrids under conditions of data scarcity, fragmentation, and nonstationarity. Rather than focusing solely on model choice, the framework integrates three key components: (1) Observation, incorporating mechanism-informed drivers such as environmental and temporal variables to stabilize learning; (2) Representation, using data-efficient models like Kolmogorov–Arnold Networks (KAN) to capture nonlinear relationships; and (3) Evolution, modeling demand changes over time through a Degree of Adoption (DoA) variable and continual learning strategies. Evaluated on real microgrid data, the approach shows significant improvements over baseline models, reducing forecasting error substantially. The results highlight that effective forecasting in constrained settings depends on aligning the learning pipeline with the structural properties of the data, emphasizing the importance of feature design, flexible representations, and adaptation to evolving demand patterns.

[5380] Yuvraj Sunecher (University of Technology, Mauritius), Naushad Mamode Khan (University of Mauritius) and Vandna Jowaheer (University of Mauritius). ***Discrete Multivariate Copula based Model fitting to Longitudinal Count Data.***

Abstract. In this paper, we develop the Poisson INAR and Negative Binomial (NB) INAR models for longitudinal count data. As for the estimation of model parameters, we use the generalised estimating equation (GEE), generalised quasi-likelihood (GQL) and maximum likelihood (ML) estimation methods. The correlation parameters are estimated using the multivariate copula method. Through simulation studies, we compare the performance of GQL, GEE and ML. An application on number of seizures is also presented.

[5393] Ignacio Rojas (University of Granada). ***Test.***

Abstract. Test

[5441] Stefano Rinaldi (University of Brescia), Chiara Franzoni (University of Brescia), Salvatore Dello Iacono (University of Brescia), Lavinia Chiara Tagliabue (University of Turin), Robert Birke (University of Turin) and Silvia Meschini (University of Turin). ***Hybrid Model for Long-Term and Short-Term Power Demand Forecasting in HPC Data Centers.***

Abstract. The power demand of High Performance Computing (HPC) infrastructures exhibits both stable weekly regularities and rapid workload-driven fluctuations, which are difficult to capture reliably with a single modeling paradigm. Achieving more sustainable HPC operation requires accurate forecasts at multiple horizons: short-term predictions support operational control (e.g., proactive power capping and energy-aware scheduling), whereas long-term forecasts are essential for planning activities (e.g., capacity provisioning and energy procurement). Together, these capabilities reduce operational cost and risk while enabling more efficient and sustainable datacenter management.

This paper investigates multi-horizon forecasting of aggregated active power consumption in an operational HPC datacenter utilizing a four-month dataset (five-minute time intervals) from the University of Turin. We propose a hybrid residual-learning framework that integrates a long-term structural forecaster with a short-term residual corrector utilizing a Temporal Convolutional Network (TCN) to address the simultaneous presence of weekly regularities and short-term workload-induced fluctuations. Assessment utilizing a rolling-origin protocol covers a timeframe of 15 minutes to 6 hours and extends 1 to 3 weeks into the future. Performance of the proposed approach have been compared against a SARIMA baseline.

[5462] Anastasiia Kazovskaia (Hong Kong University of Science and Technology). *Estimation and Inference In Multiple-Regime Threshold CCC-GARCH(1, 1) Model.*

Abstract. This paper introduces the first-order multiple-regime threshold constant conditional correlation GARCH model (MT-CCC-GARCH). We establish sufficient conditions for its stationarity and geometric ergodicity under a fractional moment framework that accommodates the heavy-tailed phenomenon of log-returns without finite variances in financial markets. We then study the quasi-maximum likelihood estimates (QMLE) of its parameters and show that the estimated thresholds are super-consistent with rate being the sample size n , converging to minimizers of independent compound Poisson processes. In contrast, the remaining estimated parameters are $\sqrt{n}$ -consistent and asymptotically normal, and are asymptotically independent of the estimated thresholds. Finally, we give a non-standard inference procedure of thresholds via a small-threshold-effect reparameterization. Our theory and procedure are supported by numerical evidence from Monte Carlo simulations.

Remark: Dear Committee, I would like to submit this to the session chaired by Prof. Ling Shiqing, but I am not sure which specific session is the appropriate one. Thank you!

[5470] Alessandro Cardinali (Universita' di Firenze). *Confidence bands for local non-stationarity detection.*

Abstract. This article develops asymptotic theory for the sample (time-averaged) variance of the locally stationary wavelet packet (LSWP) processes. Our focus is the periodogram and the sample variance, and in particular its average. Under a near-epoch dependence (NED) condition on the periodogram, and mild moment and summability assumptions, we establish a central limit theorem and a consistent estimator for the average process variance. These results yield asymptotic stationarity bands for the average variance, providing a simple, theoretically grounded benchmark for second-order stationarity in packet-domain models.

[5526] Ciro Rodriguez-Leon (CITIC-UGR), Maria Dolores Aviles-Perez (University Hospital Clínico San Cecilio), Oresti Banos (CITIC-UGR), Miguel Damas (CITIC-UGR), Javier Medina (CITIC-UGR), Manuel Munoz-Torres (University of Granada), Hector Pomares (CITIC-UGR), Miguel Quesada-Charneco (University Hospital Clínico San Cecilio) and Claudia Villalonga (CITIC-UGR). *Group-Based Blood Glucose Forecasting in Type 1 Diabetes: Bridging the Gap Between General and Personalized Models.*

Abstract. Continuous Glucose monitoring enables Blood Glucose Level (BGL) forecasting, yet current deep learning models face a critical trade-off: general models lack individual accuracy, while personalized models suffer from a severe "cold-start" problem requiring extensive historical data. This study proposes an intermediate group-based forecasting paradigm utilizing time series clustering. We trained Long Short-Term Memory networks under a general, group-based, and personalized approach to forecast BGL at 60- and 120-minute prediction horizons. Based on our previous research, patients were partitioned into six groups using K-means clustering applied to time series data. Results indicate that group-based models outperformed general baselines for patient groups with controlled BGL, enhancing clinical safety and reducing forecasting errors. Crucially, the group-based approach proved more robust than pure personalization, matching or exceeding personalized performance in 75% of overall cases. Most notably, personalized models failed to predict severe hypoglycemia in controlled patients due to a lack of these events in individual historical data, a vulnerability successfully bypassed by group-based models leveraging collective cluster histories. Ultimately, group-based forecasting emerges as a practical solution for Type 1 Diabetes management, providing the accuracy needed for critical event prediction while drastically reducing the data accumulation period required for rapid clinical deployment.

[5530] Ties van der Heijden (Delft University of Technology), Pascal Sado (justervesenet), Gertjan Kok (VSL), Bart Pleiter (Alliander) and Pedro Vergara Barrios (TU Delft). *Practice-Oriented Quantile Forecast Validation for Distribution Grid Load Exceedance Prevention.*

Abstract. Probabilistic load forecasting plays a key role in congestion management for distribution system operators (DSOs), yet a gap remains between how forecasts are evaluated and how they are used in practice. Standard metrics such as CRPS and prediction interval coverage assess overall statistical quality but do not explicitly capture the ability of models to predict load exceedance events, which are central to operational decision-making.

This work proposes a practice-oriented validation framework for quantile forecasts, designed to assess performance in the context of load exceedance prevention. The framework evaluates models along four dimensions: statistical accuracy, calibration, quantile coherence, and tail risk. In particular, we introduce Conditional Value at Risk (CVaR)-based metrics to quantify the severity and calibration of exceedance events relative to grid capacity thresholds.

The framework is applied to compare three model families, like gradient-boosted trees (OpenSTEF), LASSO quantile regression, and a non-crossing quantile regression neural network, using a Dutch distribution grid dataset. This extended abstract focuses on the proposed methodology; empirical results will be presented at the conference. The approach aims to better align probabilistic forecast evaluation with the operational needs of DSOs.

[5560] Ronan Timon (University of Galway, Ireland) and James McDermott (University of Galway, Ireland). ***Offline Changepoint Annotation to Online Changepoint Detection: A Framework for Wastewater Treatment Sensor Data.***

Abstract. Wastewater treatment plants (WWTPs) are crucial infrastructure. Continuous monitoring of plant conditions using sensor technology has enabled real-time monitoring, forecasting and control. WWTP processes, namely the biological reactor, exhibit highly non-linear relationships, multiscale seasonality, and dependency on hydrodynamics and sensor status. WWTP operators may benefit from automated detection of changepoints, i.e. points in time such that WWTP parameters clearly differ before and after. A challenge is the high cost of manual annotation of changepoints for training and evaluation of models. In this study we contribute an “offline-to-online” framework for annotation and detection of changepoints. We first detect changepoints in WWTP data a posteriori (offline) using a dynamic programming method with several cost functions, filtering for high-consensus points. These are reviewed by the authors, and verified independently by WWTP experts. This algorithm-assisted annotation reduces the expert annotation burden. The verified labels are then used to test a suite of real-time (online) changepoint detection methods.

[5671] Eric Grivel (Université de Bordeaux - Bordeaux INP - IMS lab) and Pierrick Legrand (Université de Bordeaux - Bordeaux INP - IMS lab). ***Introducing Robust Least-Squares Methods in the Detrended Fluctuation Analysis.***

Abstract. Detrended fluctuation analysis (DFA) is a widely used method for estimating the Hurst exponent of time series exhibiting nonstationary trends. In its standard formulation, DFA relies on the least-squares (LS) criterion at several stages of the procedure, including trend removal and Hurst exponent estimation. In practice, the estimation is often sensitive to the practitioner’s choice of local trend sizes, which can significantly affect the estimated Hurst exponent. Moreover, the LS criterion may be poorly suited in the presence of outliers or limited sample sizes. To address these limitations, we propose robust extensions of the DFA. They are based either on a least trimmed squares method or on an iterative weighted LS approach. In the latter case, the weights are defined using Cook distance. This allows all scales to be considered without requiring any a priori selection of local trend sizes. This strategy also improves the stability of the regression step without introducing too many tuning parameters. Illustrations are provided to demonstrate the relevance of the proposed approaches, especially in the presence of outliers.

[5693] Lawrence Madziwa (Namibia University of Science and Technology) Prosper Chimunhu (Department of Mining and Metallurgical Engineering, WASM, Curtin University, Bentley, Australia) and Thabo Falayi (Department of Chemical Engineering, University of Johannesburg, Johannesburg, South Africa). ***Machine Learning-Based Forecasting of Monthly Gold Prices for Strategic and Investment Decision-Making.***

Abstract. Metal prices, particularly gold, are central to investment decision-making and significantly affect the financial performance of companies within the mineral industry. Forecasting gold prices accurately is challenging due to their non-stationary nature, volatility, and the impact of numerous macroeconomic, geopolitical, and supply-demand factors. While various machine learning and statistical techniques have been applied to forecast gold prices, comparative analyses of their effectiveness remain scarce. This study employs seven univariate methodologies: Autoregressive Integrated Moving Average (ARIMA), Support Vector Regression (SVR), Gated Recurrent Unit (GRU), and three gradient boosting techniques (CatBoost, LightGBM, and XGBoost) to forecast monthly gold prices from 1988 to 2024. The results highlight that gradient boosting models, particularly CatBoost and XGBoost, display strong predictive capabilities with accuracies exceeding 98%. Notably, the GRU-XGBoost hybrid model achieved the lowest RMSE of 4.5139, surpassing standalone models. This research indicates that hybrid modeling approaches can effectively enhance prediction accuracy, facilitating strategic investment decisions.

[5705] Jiří Tomčala (IT4Innovations, VSB – Technical University of Ostrava). ***Quantum Machine Learning for Time Series Forecasting of Energy Price Trends for Community Networks.***

Abstract. Quantum Machine Learning (QML) methods can be applied wherever classical Machine Learning (ML) techniques are used, including the field of time series forecasting. From an external observer's perspective, QML maintains similar attributes to classical ML, such as training sets, test sets, and accuracy calculations; however, the internal processes and structures differ significantly. QML takes advantage of the exponential growth in complexity of the quantum state of a parameterized quantum circuit with respect to its number of qubits. This allows for the creation of a billion-dimensional space of quantum states using only a few dozen qubits. Consequently, QML is better suited for complex predictions about the distant future rather than for simpler tasks that involve forecasting just a few time steps.

This contribution will elucidate the principles behind two primary QML methods for time series forecasting: the Variational Quantum Circuit (VQC) and the Quantum Recurrent Neural Network (QRNN). Additionally, an example of their application will be presented, along with the measured results.

[5755] Ahmad Amin (PhD Candidate, Istanbul Sabahattin Zaim University), Syed Mgafur Ahmad (PhD Candidate, Istanbul University) and Mahadi Hasan Miraz (Associate professor, Industrial Engineering Department, Istanbul Atlas University). ***Digital Transformation in Islamic Finance: Enhancing Business Performance Through FinTech Innovation.***

Abstract. FinTech and digital transformation have changed the global financial sector, forcing financial institutions to change their operations, platforms, and strategy. Sharia values such as ethical investment, transparency, risk-sharing, and the prohibition of interest make Islamic banking distinctive in its response to digital innovation. This study explores how FinTech innovation influences the efficiency and performance of Islamic finance businesses. We study how FinTech, digital transformation, and Sharia compliance affect Islamic financial institutions' business performance directly and indirectly. A quantitative study recommends PLS-SEM for evaluating construct links. This study suggests conducting polling among employees, managers, and clients of Islamic banking and financial institutions in developing and emerging countries. How blockchain, AI, digital payment systems, mobile banking, cloud computing, and big data analytics increase operational efficiency, customer service, transparency, decision-making, financial inclusion, and corporate sustainability is examined. Efficient digital capabilities boost organisational performance and competitiveness. FinTech innovation and digital transformation lower transaction costs, automate processes, improve service delivery, and engage customers, enhancing company performance. Sharia compliance should increase consumer trust, legitimacy, and credibility, enabling sustainable economic growth. Operational efficiency may mediate the relationship between digital transformation and firm performance since digital technologies improve corporate outcomes largely via internal processes and resource optimisation. An integrated technological, organisational, and ethical research paradigm enriches Islamic banking and digital transformation literature. FinTech innovation, Sharia compliance, and operational excellence are strategic priorities in this research, unlike previous studies on technology adoption. Studies suggest FinTech innovation and Sharia-driven digital transformation may improve Islamic finance business performance, competitiveness, resilience, and sustainability.

[5796] Bachir Kaddar (University Of Sciences and technology of Oran, University of ibn khaldoun of Tiaret) and Hadria Fizazi (University Of Sciences and technology of Oran). ***An Adaptive Online Framework for Non-Stationary Time Series Forecasting via Multi-Scale Gated Transformers.***

Abstract. The proliferation of high-frequency streaming data in econometrics, environmental monitoring, and smart infrastructure has created an urgent demand for forecasting models that can autonomously adapt to non-stationarity, concept drift, and multi-scale temporal dependencies. Traditional batch-learning methods lack the flexibility to evolve with shifting data distributions, while conventional deep learning approaches often suffer from catastrophic forgetting and prohibitive retraining costs in continuous learning scenarios.

This paper presents a novel online learning framework that integrates hierarchical multi-scale representation learning with an adaptive, incremental update mechanism. Our methodology employs a transformer-based architecture enhanced with gated attention mechanisms to simultaneously capture short-term fluctuations and long-range dependencies in streaming time series. To address structural breaks, the framework incorporates a lightweight drift detection module utilizing adaptive feature recalibration and frequency-domain regularization. This enables the automatic identification and utilization of latent periodic and quasi-periodic patterns in real-time. Furthermore, we introduce a hybrid learning objective that merges deep temporal representations with statistical regularization, enhancing both generalization capability and model interpretability.

Comprehensive experiments conducted on diverse benchmark datasets—spanning financial markets, climate analytics, and IoT sensor streams—demonstrate that our framework consistently outperforms state-of-the-art statistical models and contemporary deep learning baselines. Results show significant improvements in key metrics, specifically sMAPE and MASE, while maintaining superior adaptation speed and computational efficiency. This work bridges the gap between modern representation learning and established time-series theory, offering a scalable solution for real-time forecasting in dynamic, non-stationary environments.

[5811] Maria Chiara Magnano (National Research Council, Water Research Institute (CNR-IRSA)), Alessandro Gorini (National Research Council, Water Research Institute (CNR-IRSA)), Andrea Fenocchi (University of Pavia), Helmi Saidi (National Research Council, Water Research Institute (CNR-IRSA)) and Marzia Ciampittiello (National Research Council, Water Research Institute (CNR-IRSA)). ***Assessing climate variability and extreme events for water resource management in the Lake Maggiore basin .***

Abstract. The Lake Maggiore basin, shared between Italy and Switzerland, is a large and complex Alpine catchment characterised by strong climatic gradients and high ecological value. Understanding its meteorological and climatic characteristics is crucial to support water resource management and climate adaptation strategies in the context of climate change. Within the framework of the Interreg WINCA4TI project, meteorological data collected within the Lake Maggiore basin since the early 1970s were summarised and analysed in depth to define its climatic evolution, both in terms of long-term trends and of the frequency of extreme events.

Precipitation and air temperature datasets were compiled from multiple sources, including the International Commission for the Protection of Italian-Swiss Waters (CIPAI) as well as national and regional datasets. These data, although heterogeneous in temporal coverage and measured variables, provide a comprehensive overview of the climatic variability and evolution of the basin over the last five decades (1971-2024).

Data and methods. The analysis is based on data of precipitation and temperature at monthly scale, obtained from meteorological stations distributed across both the Italian and Swiss sectors of the basin. Several complementary approaches were applied: 1. spatial analysis of precipitation using isohyet maps and comparison of representative years (e.g., 2022 drought vs. 2024 wet conditions); 2. temporal analysis of seasonal cumulative deviations from the means of the 1991–2020 reference period; 3. trend detection in annual and seasonal series using the Mann–Kendall test and Sen’s slope estimator; 4. assessment of drought and temperature anomalies using indices such as the Standardized Precipitation Index (SPI) and the Standardized Anomaly Index (SAI); 5. hierarchical cluster analysis to identify recurring annual climate regimes; 6. assessment of extreme temperature, precipitation and wind events using the European Extreme Events Climate Index (E3CI).

Results. Annual and seasonal precipitation trends are not statistically significant, reflecting a high variability. Conversely, the temperature analyses (over 1981-2020) indicate a statistically significant warming, with annual increases of approximately +0.07 °C for maximum and +0.06 °C for minimum temperatures. Spatial precipitation analyses confirm that the basin is not uniformly exposed to rainfall: the highest values generally occur in the upper Valle Maggia, Val Grande and Val Strona valleys, while the Ossola valleys and the southern sector of the basin receive substantially lower amounts.

A hierarchical cluster analysis based on annual precipitation and temperature (Ward's method) identified five climatic regimes for the period 1981–2024: cool-humid, very humid cool, warm-humid, and two variants of warm-dry. Notably, warm years, both humid and dry, have become more frequent in recent decades, indicating increasing pressure on water resources and ecosystems. A second model integrating extended features (seasonal components and extremes) identified three major recurring regimes: warm-humid, cool-humid (typical of early decades), and warm-dry (which has become increasingly recurrent in recent years). These regimes distinguish years characterised by effective hydrological recharge from years with marked water deficit, providing a critical information for water management planning. The temporal evolution of the clusters highlights a shift in baseline climatic conditions, as regimes once considered exceptional –such as warm-dry years – are becoming increasingly frequent.

SPI and SAI analyses reveal episodes of drought and heat anomalies, while the E3CI index highlights increasing occurrences of extreme temperatures and, locally, wind intensity. The SPI index confirms strong interannual rainfall variability. For minimum temperatures, the SAI index shows an overall positive trend, with a growing number of years exhibiting positive anomalies during 1991-2024. For maximum temperatures, the SAI displays a stronger shift, with negative anomalies concentrated in the first half of the period and predominantly positive values in the second half (SAI in 2024 is near zero, aligned with the 1991-2020 mean). These emerging trends are consistent with larger-scale observations across the Alpine region, where ongoing warming and altered seasonal precipitation patterns are reshaping both natural and managed water systems.

Overall, the results indicate a basin undergoing marked warming, increasing temperature extremes, and persistent rainfall variability in the absence of significant long-term rainfall trends. However, seasonal signals, particularly the declining autumn precipitation and reduced summer rainfall, pose challenges for water storage, ecological resilience, and allocation planning. The recent alternation between extreme drought conditions (2022–2023) and very wet conditions (2024) further highlight the need for dynamic and adaptive management strategies. The growing dominance of warm-humid and warm-dry regimes highlights increasing climatic instability, with likely consequences for snow accumulation, meltwater contributions, river discharge seasonality, lake levels and their management and water quality.

These findings provide a comprehensive picture of the basin evolving climate dynamics and the growing dominance of warm and dry conditions. Future analyses will focus on refining seasonal and extreme event indices and applying predictive models to explore possible future scenarios. Such insights will be crucial to guide water resource governance, ecosystem protection, and climate adaptation strategies across this transboundary Alpine basin.

[5837] Theodor R. van Caspel (Federal University of Santa Catarina), Gabriel Thaler (Federal University of Santa Catarina) and Rodolfo C. C. Flesch (Federal University of Santa Catarina). ***Extracting running-in dynamics from operational time series using long short-term memory networks.***

Abstract. The running-in phase of hermetic reciprocating compressors is characterized by slow, non-stationary changes in operational signals and is commonly assessed using empirically defined test durations or manually defined indicators. From a data-analysis perspective, this constitutes a feature extraction problem, as informative temporal patterns might be identifiable from long and noisy time series acquired during operation. This paper investigates the use of Long Short-Term Memory (LSTM) networks as a data-driven feature extraction mechanism for running-in analysis based on electrical current and vibration measurements. LSTM-based sequence encoding is used to transform raw time-series segments into compact representations that summarize their temporal structure and enable discrimination between running-in and steady-state regimes, as well as characterization of intermediate conditions in the learned feature space using a multilayer perceptron (MLP). Model structure, input configuration, and segmentation parameters are selected through an optimization procedure under weak supervision. Experimental results show that the extracted LSTM features capture consistent temporal signatures of running-in across different compressor units, with one unit exhibiting outlier behavior in latent space analysis. The results support the use of recurrent neural networks for non-invasive running-in assessment in rotating machinery and related condition monitoring tasks.

[5877] Jose Gomez (Mines Paris PSL), Yves-Marie Saint-Drenan (Mines Paris PSL), Yehia Eissa (Mines Paris PSL) and Philippe Blanc (Mines Paris PSL). ***Spectral Fidelity of Diffusion Models for Surface Solar Irradiance Downscaling: Why Regime-Conditioned Evaluation Matters?***

Abstract. Generating realistic 1-min solar irradiance from coarse satellite inputs requires models that reproduce variability across timescales—yet how to evaluate this fidelity remains an open question. We show that standard spectral metrics can be misleading: averaging over sky regimes (clear vs. cloudy) cancels regime-specific artifacts, hiding where models fail. We propose regime-conditioned spectral evaluation that separates smooth and variable weather conditions, and apply it to diffusion, Markov chain, and cGAN generators across 15 European BSRN stations (5756 test days). The diffusion model closely reproduces cloud-driven variability (generated-to-real noise ratio ≈ 1.0), but regime-conditioned analysis reveals 3.6-fold excess noise in smooth (clear-sky) regions—an artifact invisible to global metrics. A conditional spectral loss reduces this artifact (days exceeding 5-fold excess: 25.9% $\rightarrow$ 2.3%) but at the cost of variable-sky fidelity (noise ratio 1.01 $\rightarrow$ 0.77), illustrating tradeoffs that regime-conditioned evaluation helps identify.

[5899] Phemelo Seaketso (North-West University), Martin Chanza (NORTH-WEST UNIVERSITY) and Modisane Seitshiro (North-West University). ***Developing a Hybrid Modelling Framework Integrating Linear Statistical Models and Non-Linear Machine Learning to Capture Temporal Structures and Complex Dynamics.***

Abstract. Accurately modelling time-dependent phenomena remains a key challenge in data science, especially when data exhibit both linear temporal structures and complex non-linear dynamics. Traditional statistical models, such as ARIMA and state-space models, effectively capture linear dependencies and offer interpretability but often fail to represent non-linear patterns. In contrast, machine learning methods can learn complex relationships but typically overlook explicit temporal structures and lack interpretability. This paper proposes a hybrid modelling framework that integrates linear statistical models with non-linear machine learning techniques. The approach decomposes a time series into linear and non-linear components, models each separately, and combines the results. Empirical results using platinum stock prices show improved forecasting accuracy compared to individual models.

[5944] Nina Golyandina (St.Petersburg State University), Nikita Fedorov (St.Petersburg State University), Ikbal Khasas (St.Petersburg State University) and Alexander Khramov (St.Petersburg State University). ***SSA or MSSA? On the Supportiveness of a Similar Auxiliary Series for Forecasting.***

Abstract. This paper introduces the concept of a supportive time series within the "signal + noise" model, framed by the family of Singular Spectrum Analysis (SSA) methods. A supportive series is an auxiliary series that enables more accurate estimation and forecasting of the main series' signal. We compare the standard SSA method for single series analysis with its multivariate extension (MSSA) for analyzing two series. To choose between SSA and MSSA for optimal forecast accuracy when the underlying series model is unknown, we propose the CHOICE algorithm. This algorithm leverages theoretical and empirical findings on the signal estimation accuracy of SSA and MSSA for sums of sinusoids with identical frequency sets. The performance of the CHOICE algorithm is validated on model examples and applied to meteorological data. In this real-world application, it significantly reduces forecast error compared to using either SSA or MSSA exclusively.

[6093] Martín Solís (Technological Institute of Costa Rica) and Luis-Alexander Calvo-Valverde (Technological Institute of Costa Rica). ***Improving the Prediction of Homicides with a Lumpy and Erratic Pattern, through Deep Learning and Data Augmentation.***

Abstract. It is relevant to implement strategies that can contribute to the reduction of crime. Crime forecasting is one of these strategies. This study proposes different models to forecast homicides from time series that have intermittent and erratic patterns. Intermittent and erratic patterns appear when the forecasting focuses on specific crimes that are priority to combat but don't occur with high intensity as it is the homicide, or in the forecasting of crimes in regions with low population density. Traditional forecast methods tends to fail with intermittent and erratic patterns, therefore it is relevant to find new alternatives to forecast homicides. We generated a dataset of homicides that occurred between January 1, 2015, and February 28, 2024, in 82 areas. New methods for modeling erratic and lumpy time series were implemented based on Deep Learning. These methods were compared with traditional methods. Our proposal llamaug got the best performance. However, the best option to develop a tool for forecasting homicides in multiple regions of the country is the implementation of the best model for each region

[6104] Juan R. Trapero (Departament of Business Administration, University of Castilla-La Mancha), Diego J Pedregal (Departament of Business Administration, University of Castilla-La Mancha), Pablo García (Departament of Business Administration, University of Castilla-La Mancha) and Caroline Biron (VITAM – Centre de recherche en santé durable, Université Laval). ***Absenteeism Forecasting using State Space models.***

Abstract. Workforce planning is one of the key elements that companies must optimize to achieve a competitive advantage. Challenges associated with work-force planning are ubiquitous, as they affect the majority of organizations, ranging from healthcare systems to military units (Peck, 2025). The work-force planning process relies on three pillars: (i) predicting future workforce demand; (ii) predicting future workforce supply; and (iii) evaluating policies to optimize the gap between (i) and (ii) (Edwards, 1983).

One of the current challenges that hinders accurate predictions of workforce supply is absenteeism, understood as the voluntary or involuntary absence of employees from work. Absenteeism is of paramount importance for most organizations due to its direct negative impact on workforce productivity.

Research on absenteeism forecasting has been primarily driven by machine learning approaches within the field of occupational health (Montano et al., 2020; Skorikov et al., 2020). In this context, identifying the key factors behind employee absenteeism is essential for developing forecasting models that estimate the probability of sickness absence. Once these key factors are identified, targeted interventions can be designed to reduce absenteeism.

However, beyond the occupational health perspective, absenteeism forecasting is also crucial from a production-planning standpoint. Absent employees can severely disrupt a company's production capacity. Human Resources departments must decide whether to outsource part of the workforce, rely on overtime, increase staffing levels, and so on, where each option involves significant costs. Therefore, accurate absenteeism forecasts are essential for optimizing workforce strategies. Despite its relevance, the literature on absenteeism forecasting for production planning remains scarce.

This work proposes a forecasting model based on dynamic linear regression to predict TI absenteeism hours for the upcoming week, using daily observations of past absenteeism and planned working hours for the following week. Other well-known forecasting models, as well as the company's current operational procedure, are used as benchmarks.

The data of this work has been obtained from a logistics leader managing fluctuating demand driven by seasonality and market trends. This variability is addressed through contracts that allow for a percentage of deviation with the main contractor. However, the labor supply has become increasingly unstable due to talent retention challenges, more flexible collective bargaining agreements, and a recent spike in spontaneous absenteeism. Historically, the company relied on demand forecasting and advanced shift planning to meet these requirements. However, this is no longer sufficient; they must now also accurately estimate absenteeism.

The objective is to forecast the daily absenteeism hours due to sickness leave. To achieve this, we use past information on TI absenteeism and, as an exogenous variable, the planned working hours, which are known not only for the past but also for the following week. Planned hours can therefore be used as a leading indicator. The dataset covers the full year of 2025 and is divided into a hold-in sample (the first 150 observations) and a hold-out sample comprising the remaining data. A rolling-origin evaluation experiment is conducted with a forecasting horizon of 7 days.

The forecast of absenteeism can be approached using either a time-series methodology or a causal framework. The former relies solely on past information about daily absenteeism to identify patterns that can be projected into the future. The time series models employed are Exponential Smoothing and Naïve approaches. The causal models incorporate an exogenous variable—namely, the planned working hours which are known one week in advance and can therefore be used to estimate future absenteeism levels. Linear Regression, Decision Trees and Dynamic Linear Regression models are considered in this study.

The results show that the Dynamic Linear Regression is the most accurate forecasting model.

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[6124] Beatriz Royo (Fundación Zaragoza Logistics Center) and Maria Teresa De la Cruz (Fundación Zaragoza Logistics Center). *Forecasting Raw Material Price Volatility in SMEs: A Lightweight Hybrid Approach Using Open Data and Explainable Models.*

Abstract. Small and medium-sized enterprises (SMEs) frequently operate under severe data limitations when attempting to anticipate supplier-specific price fluctuations. Supplier Material Price series (SMPP) are often short, irregular and strongly shaped by contractual timing, whereas upstream Raw Material Market Prices (RMPP), such as crude oil or industrial metals, are long, continuous and openly available. This structural asymmetry is evident in industrial pilot settings, such as a plastics-processing use case developed within a recent EU Project (R3Group, GA No. 101091869), where manufacturers working with crude-oil-derived polymers operate with only a few years of SMPP data while relying on highly volatile global commodity markets to price their components relying on crude-oil-derived polymers. Such constraints leave SMEs exposed to sudden cost shocks, reinforcing the vulnerability of downstream actors in concentrated upstream supply networks (Sheffi, 2015). In practice, many SMEs rely on manual monitoring of commodity dashboards, a reactive and labour-intensive practice that offers limited predictive capability.

Recent advances in procurement forecasting highlight the potential of machine learning for anticipatory cost management. Deep learning approaches, such as multivariate LSTM architectures, have shown strong performance in predicting procurement-relevant price movements but typically require large, high-frequency datasets that SMEs rarely possess (Lee et al., 2022). Similarly, complex energy and commodity forecasting models, such as the deep-learning frameworks tested for Bloomberg energy indices, deliver competitive accuracy but depend on proprietary data infrastructures and computational resources beyond most SME contexts (Ben Ameer et al., 2024). Research on procurement analytics further confirms that SMEs face adoption barriers due to limited digital maturity, lack of data governance, and the need for explainable tools that support negotiation and sourcing decisions (Mandl, 2023).

This paper addresses these challenges by proposing a minimum dataset, two stage forecasting framework explicitly tailored to SMEs operating under data scarcity. The approach leverages the length and stability of open RMPP series to overcome the short and irregular nature of SMPP and generate forward looking cost signals that support tactical procurement decisions.

In Stage 1, upstream RMPP series are forecast using a hybrid set of models: SES, ARIMA, Random Forest, XGBoost, and LightGBM, all trained exclusively on lagged values to prevent leakage. A recursive strategy is used to produce multi-horizon forecasts (1, 3, 6, 10 months), evaluated through a rolling origin expanding-window procedure that replicates operational forecasting conditions. This design captures the temporal dependencies of commodity markets while remaining computationally lightweight, enabling SMEs to implement the pipeline on standard hardware without specialised infrastructure.

In Stage 2, predicted RMPP values are mapped to SMPP through low complexity and explainable regression models, reflecting the need for interpretability in procurement settings. Because SMPP histories are typically sparse and contain few aligned observations for $h > 1$, only the one step ahead horizon ($h=1$) provides sufficient data for reliable estimation—a structural constraint confirmed in multiple SME cases. Two modelling approaches are tested: linear regression, offering transparency for contract justification, and XGBoost, capturing mild nonlinear pass-through behaviour without sacrificing interpretability.

To contextualise performance under ideal information conditions, two direct baselines: SARIMAX with exogenous RMPP and XGBoost Exogenous, forecast SMPP directly from observed upstream prices. These models serve as methodological upper bounds by eliminating forecast propagation errors. Their role is conceptual: they illustrate the ceiling attainable when high quality exogenous data are fully available, a scenario rarely met in SME environments but critical for benchmarking architecture-driven trade-offs.

The evaluation uses MAPE as the primary business-aligned metric, complemented by MAE. Errors are aggregated by horizon and across rolling-origin folds, ensuring fair comparison between models operating under different information sets. Results show that the two-stage framework provides stable and actionable cost forecasts despite limited SMPP data, demonstrating that simple, transparent models, when combined with long open-data series, offer a robust path for SMEs to anticipate upstream volatility.

In summary, this work contributes a lightweight, interpretable, and reproducible forecasting architecture designed for SMEs that lack extensive historical datasets and advanced analytics capabilities. By bridging freely accessible commodity indices with minimal supplier data, the proposed framework enables proactive risk management, supports procurement planning, and offers a scalable foundation for future adoption of more advanced analytics tools as data maturity increases.

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[6129] Nailia Gabdrakhmanova (RUDN). ***Neural network models and Lotka-Volterra models in the assessment and forecasting of industry growth sustainability.***

Abstract. The work is dedicated to the development of mathematical models for assessing the sustainability of economic development based on time series data of financial indicators within a specific sector of the economy. Sustainable development in this context refers to the transition to "green technologies," meaning the development of the sector without exacerbating environmental issues. The models have been developed using a combination of neural network models and the Lotka-Volterra model. In the constructed models, the neural network time series models enable the forecasting of future values of the financial indicators and the estimation of the parameters of the Lotka-Volterra model. The developed Lotka-Volterra models and Hamiltonian formalism allow for an assessment of the stability of growth within the economic sector. Verification of the developed models has been conducted using multivariate time series data from a specific industry, incorporating expert assessments.

[6168] Challa Krishna Rao (Engineering Aditya Institute of Technology and Management Tekkali, Srikakulam, Andhra Pradesh, India.), Sarat Kumar Sahoo (Parala Maharaja Engineering College Berhampur, Odisha.), Gandam Deepika (Engineering Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India.), Ilupothi Jahnvi (Engineering Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India.), Konchada Lahari (Engineering Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India) and Bora Manikantha (Engineering Aditya Institute of Technology and Management, Tekkali, Srikakulam, Andhra Pradesh, India). ***A Comprehensive Review of Wireless Communication Protocols for Battery Management Systems in Electric Vehicles.***

Abstract. Recent studies identify BLE and Zigbee as promising candidates for low power, short range multi node architectures, while Wi-Fi and UWB can deliver higher through put and lower latency with careful electromagnetic and reliability optimization. NFC based and hybrid approaches are also gaining interest for secure data readout, second life battery applications, and maintenance without continuous wireless connectivity. Beyond telemetry, next generation WBMS platforms are integrating cloud connectivity, digital twins, and machine learning algorithms to enable predictive diagnostics, remaining useful life estimation, and over the air (OTA) parameter optimization. These capabilities improve state of charge (SOC) and state of health (SOH) estimation accuracy while enabling fleet level monitoring and continuous, software defined performance enhancement throughout the battery lifecycle. However, the deployment of wireless BMS introduces new design challenges concerning cyber security, functional safety, synchronization, and coexistence with other in vehicle wireless systems, along with the need for standardized, automotive qualified communication protocols and certification frameworks. This paper surveys the state-of-the-art developments in wireless communication for EV BMS, encompassing industrial implementations, experimental demonstrators, and research proposals up to 2025. It provides a comparative analysis of BLE, Zigbee, Wi-Fi, UWB, LoRa, and NFC technologies in terms of performance, scalability, cost, and safety implications. On this basis, the study identifies application-oriented technology choices and highlights promising hybrid and cloud integrated architectures that are shaping the future evolution of BMS in electric vehicles

[6300] Songqing Zhao (Capital Group). *Market Regime Transitions and Investor Behavioral Dynamics: A Hidden Markov Model Approach to Regime-Conditional Asset Allocation.*

Abstract. This paper investigates the interplay between macroeconomic market regimes and investor behavioral patterns in driving asset allocation decisions. Using a Hidden Markov Model (HMM) framework with rolling retraining, we identify latent market states—including risk-on, risk-off, and transitional regimes—from U.S. fixed income and equity data. We demonstrate that regime transitions are not merely statistical phenomena but reflect systematic shifts in investor risk appetite and behavioral biases, including herding, loss aversion, and overreaction to monetary policy signals. Under each identified regime, we construct regime-conditional allocation strategies employing multiple weighting schemes (equal-weight, risk-parity, mean-variance optimization) and transition-probability-driven rebalancing, informed by state persistence metrics. Empirical backtests spanning 2010–2024 show that the proposed framework significantly outperforms the Bloomberg U.S. Aggregate Bond Index (AGG) benchmark, achieving a Sharpe ratio of 2.61 versus 0.75 and reducing maximum drawdown from 18% to 3.5%. Our findings suggest that aligning portfolio rebalancing rules with quantitatively detected behavioral regime shifts can yield substantial improvements in risk-adjusted performance, offering actionable implications for institutional asset managers and behavioral finance practitioners.

[6415] Ali Hadi (International Hellenic University), Muhammad Munim Shafi (International Hellenic University), Asadullah Safi (International Hellenic University), Aristeidis Mystakidis (International Hellenic University) and Christos Tjortjis (International Hellenic University, School of Science & Technology). *Short-Term Traffic Speed Prediction and Pattern Discovery Using Sensor Data.*

Abstract. The sustained growth of urban populations has worsened chronic traffic congestion, with detrimental impacts on multiple dimensions of urban livability, including increased commute times, reduced road safety, and the degradation of local air quality. Thus, traffic speed prediction (TSP) is an important component of intelligent transportation systems (ITS) because urban traffic behavior is dynamic, nonlinear, and time dependent. This study addresses the challenge of short-term TSP using time-series regression techniques applied to the METR-LA dataset utilizing a multi-sensor subset containing one week of data. After a reconstruction into a tabular format, the data were preprocessed using interpolation via forward/backward filling, and transformed using temporal and lag-based features. On the modeling side, a comparative analysis with Linear Regression (LR), K-Nearest Neighbors (KNN), Decision Tree (DT), and Random Forest (RF) models was conducted, while clustering provided additional insights into traffic-state patterns. Results indicated that KNN achieved the best performance after tuning (MAE = 2.22, RMSE = 4.38, $R^2 = 0.899$). The findings illustrated that simple interpretable models can support TSP and traffic-state understanding.

[6457] Rodrigo Schons Arenhart (Universidade Federal de Santa Maria), Adriano Mendonça Souza (Universidade Federal de Santa Maria) and Daniel Arruda Coronel (Universidade Federal de Santa Maria). *The impact of minimum wage on industrial employment in Brazil: a time series analysis using the Kaitz index.*

Abstract. This study investigates the effect of the minimum wage (MW) on industrial employment (IndEmp) in Brazil, using the Kaitz Index (minimum wage/median wage). Analyzing monthly data from 2002 to 2016 with an ARDL model, the findings show that MW decreases employment. In contrast, an increase in the Kaitz Index raises employment. This indicates that the positive impact of the Kaitz Index can counterbalance the negative effects of the minimum wage. Additionally, GDP (GDPBr) positively influences employment, while the interest rate (Selic) has a negative effect. The study suggests that Brazilian wage policy should consider the distributive effects of the minimum wage to support industrial employment.

[6570] Tom Vanwalleghe (Departamento de Agronomía, Universidad de Córdoba). *Can AI Foundation Models Predict Aquifer Decline? Benchmarking TimeGPT Against Traditional Forecasting in Southern Spain's Endangered Wetlands".*

Abstract. Groundwater resources in southern Spain face mounting pressure from illegal irrigation extraction, threatening ecologically sensitive wetland systems such as Doñana National Park. Accurate short-to-medium-range forecasting of aquifer water levels is critical for monitoring compliance, triggering early warnings, and informing biodiversity conservation decisions. Yet the limited length and irregular nature of hydrological monitoring records in these systems make reliable forecasting a persistent challenge. Traditional process-based numerical models (e.g. VISUAL BALAN) or statistical approaches remain dominant in practice but are constrained by their parametric assumptions and limited capacity to generalise across regimes.

Inspired by the recent success of foundation models in natural language processing and computer vision, we investigate the applicability of TimeGPT, a state-of-the-art time-series foundation model, to groundwater level forecasting in a hydrological context where such models remain largely unexplored. Using continuous water table depth records from a piezometric well located in a dehesa grassland ecosystem in Andalusia, we evaluate the model across three forecast horizons (7, 14, and 21 days ahead) in both zero-shot and fine-tuned configurations, benchmarking against ARIMA, ETS, and Prophet.

Our results demonstrate that the fine-tuned foundation model consistently outperforms all statistical baselines at longer horizons, while the zero-shot configuration already achieves competitive performance with minimal data requirements — a particularly attractive property in data-scarce monitoring networks. These findings suggest that time-series foundation models offer a promising, low-overhead pathway to improved hydrological early-warning systems in ecologically critical and legally contested groundwater catchments.

[6573] Pieter de Kok (Vrije Universiteit Amsterdam), Francisco Blasques (Vrije Universiteit Amsterdam, Tinbergen Institute) and Siem Jan Koopman (Vrije Universiteit Amsterdam, Tinbergen Institute). *In-sample dynamic selection of models and parameters for optimal forecast combination.*

Abstract. A new information criterion, based on Kullback-Leibler divergence, for in-sample selection of optimal forecast combinations is derived and performance is demonstrated by means of a simulation study. It balances fit and complexity for aggregation of predictions in a data-efficient way with respect to cross validation and existing information criteria. This ensures the optimal selection of expert models to be used in a forecast combination and therefore increasing forecast accuracy. A dynamic extension is given by a score-driven setup to select the optimal time-varying model combination without re-estimation and re-evaluation every new time-window.

[6614] Yves R. Sagaert (VIVES University of Applied Sciences), Joost van der Haar (KU Leuven) and Robert Boute (Katholieke Universiteit Leuven). *Integrating forecasting and inventory decisions for multi-store food service operations.*

Abstract. We present a novel decision-making approach that integrates demand forecasting and inventory management for multi-store food service operations. The focus is on determining thawing quantities for frozen ingredients by transferring them from freezer storage to cold rooms for use in prepared dishes. This replenishment decision is particularly challenging due to ingredient commonality across multiple dishes, which amplifies complexity when combined with the uncertain and non-stationary demand for dishes. To address this, we propose a bound-and-shave approach that first estimates lower and upper bounds for each ingredient's optimal thawing quantity using cost-sensitive regression. A greedy cost-sensitive classification algorithm then iteratively reduces the initial upper bound in increments of thawing batch sizes until further reductions are predicted to yield no additional cost savings or the lower bound is reached.

Applied to eight food restaurants, the bound-and-shave model reduces food waste up to 74.7% and total operational costs by 50% under high service-level requirements. Independent ingredient-level forecasts proved inadequate when component commonality is high, underscoring the relevance of this methodology for assemble-to-order systems in food service, retail, and manufacturing.

[6679] Oumaima Hamou (ENCG Béni Mellal, LAREMO, Sultan Moulay Slimane University, Béni Mellal 9MCP+M4, Morocco), Mohamed Oudgou (ENCG Béni Mellal, LAREMO, Sultan Moulay Slimane University, Béni Mellal 9MCP+M4, Morocco) and Abdeslam Boudhar (ENCG Béni Mellal, LAREMO, Sultan Moulay Slimane University, Béni Mellal 9MCP+M4, Morocco). ***Forecasting MASI and MASI ESG Indices: Evaluation and Limitations of the BiLSTM Model.***

Abstract. The increasing integration of ESG (Environmental, Social, and Governance) criteria, combined with recent advances in artificial intelligence, is transforming financial forecasting methods. This study assesses the relevance of the Bidirectional Long Short-Term Memory (BiLSTM) model for forecasting the MASI and MASI ESG indices, highlighting the contribution of bidirectionality in capturing the complex dynamics of financial markets. The analysis is based on daily data covering the period from September 2018 to June 2025, with a forecasting horizon extending from July 2025 to June 2026. Thanks to its bidirectional architecture, the BiLSTM model simultaneously leverages past and future information in the time series, enabling more accurate modeling of nonlinearities, long-term temporal dependencies, and the complex interactions characteristic of stock market indices.

The results indicate that the BiLSTM model outperforms traditional forecasting approaches, with particularly strong performance for the MASI ESG index, underscoring the critical role of ESG criteria in market stability and the anticipation of price movements. However, certain limitations remain, particularly regarding the interpretability of deep learning models and the integration of macroeconomic or alternative variables. These findings suggest that hybrid approaches combining deep learning and econometric models could further enhance forecasting accuracy and robustness. Overall, this study demonstrates that the adoption of BiLSTM models tailored to the Moroccan context represents a promising tool for supporting sustainable and resilient finance, while strengthening governance and decision-making in financial markets.

[6759] Yves R. Sagaert (Predictive AI and Digital Shift, Department of Computer Science, VIVES University of Applied Sciences), Kandrika Pritularga (Centre for Forecasting and Marketing Analytics, Lancaster University Management School) and Nikolaos Kourentzes (Independent). ***Trustworthy Explanations for an Uncertain World: Relative Forecast Interpretability.***

Abstract. Explainability is often treated as an absolute property of a model or method, for both statistics and machine learning. Explainability of a model is key to both examining its validity, and gaining insights for the application on hand. We argue that explainability, inference, and validity should be framed together, as the usual approach of treating these separately or sequentially, leads to a circular logic. Inference and explanations provided by a model are meaningful when a model has been shown to be valid. Likewise, for a model to be shown valid, we need to be able to query its inference, and validate it against some prior theoretical framing, where explainability becomes essential. The issue arises from inference being meaningful when a model is valid, but validity requiring inference itself. So far we rely on a strict definition of validity, where the model is shown to provide a correct abstraction of the system under investigation. We can also use a weaker threshold of validity, where the predictive power of the model becomes the metric of relevance. In forecasting discipline, this is the implicit assumption at the core of the majority of the research corpus. However, this brings the tension that we can have a forecast that performs very well predictively, but is not explainable, which can harm its trustworthiness, especially when it errs. This is a common occurrence with machine learning methods.

There are various tools to establish explainability, for linear or nonlinear models. These have various limitations, the most common of which is often requiring independence of the covariates. When this is not satisfied, model inference weakens, whether we have access to model coefficients or proxy evaluations, such as those provided by the SHAP values. We argue that the issue in this logic is that it focuses on a single model, assuming that it is possible to obtain a trustworthy assessment of the model on its own. However, for most cases, key assumptions will be violated, as for example the aforementioned independence. Moreover, practically, an analyst is tasked to support decision makers and stakeholders, who need to understand what are the main drivers of a forecast, irrespective of how this information is obtained.

In this work, we argue that one can sidestep these complications by examining validity and explainability as relative quantities against a pool of models. Our assumption is that all forecasts represent approximations of the unknown underlying demand generating process, for instance in the context of business applications, and as such it is highly unlikely that any of the investigated forecasts will be appropriate. Likewise, this approximation is not consistent over time, providing us an additional dimension of evaluation. Therefore, we cast explainability and trustworthiness of forecasts as relative quantities between alternative forecasts, and temporally as new data become available. The model that provides the most consistent narrative about the data across these dimensions, is more likely to be a plausible model for a time series, and the inference we obtain from it, more reliable.

Our work does not claim to resolve the quest for causality, which we argue is a philosophical question for the case of business applications, where there is no strong theoretical framing. The contribution is to be able to indicate which forecasts provide a more consistent understanding of the data, with the relevant covariates. The objective is to be able to support high performing forecasts with the ability to extract relevant insights for decision makers with high confidence. This research is a first step towards providing a new class of tools to address the questions of model interpretability and validity, casting them as relative quantities.

[6779] Lamia Jallal (Agrobiotech Center, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco), Saïd Khabba (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco), Salah Er-Raki (Agrobiotech Center, Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco), Jamal Ezzahar (LMFE, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco), Oumaima Kaissi (Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Ben Guerir Morocco), Zoubair Rafi (Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Ben Guerir Morocco) and Abdelghani Chehbouni (Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Ben Guerir Morocco). ***Calibration of the AquaCrop Model by Using Micrometeorological Times Series to Optimize Pea Irrigation in Semi-Arid Region.***

Abstract. This study calibrated and validated AquaCrop for pea cultivation under semi-arid condition (Chichaoua, Morocco) by using the measured micrometeorological time series. The model demonstrated good overall performance with average $R = 0.82$ across calibration and validation phases. Average RMSE values were 3.7% for canopy cover, 0.69 mm/day for evapotranspiration, and 15.5 mm for soil water content. Key calibrated parameters included canopy growth coefficient (CGC) = 0.923% per growing degree days (GDD), canopy decline coefficient (CDC) = 0.299% per GDD, and maximum transpiration coefficient ($K_{cTr,x}$) = 0.95. Phenological stages were expressed in growing degree days (base 5°C): 1251 GDD (maximum canopy), 1592 GDD (senescence), and 1833 GDD (maturity). Irrigation optimization at 40% threshold depletion achieved 843 kg/ha yield with 32% water savings compared to farmer practices.

[6801] Aurora Polo-Rodríguez (University of Granada), Jafari Fereshteh (Institute of Computer Science, University of Bern, Switzerland), Joseph Moerschel (University of Applied Sciences and Arts Western Switzerland, Sion, Switzerland), Limei Zhang (Computer Science and Technology Shandong Jianzhu University Jinan, China), Ignacio Rojas (University of Granada) and Javier Medina Quero (University of Granada). ***Towards Explainable Vision-Based Photovoltaic Nowcasting: Performance Analysis and Visual Incident Interpretation.***

Abstract. Photovoltaic (PV) power nowcasting is commonly performed using physical meteorological sensors, with solar irradiance being one of the most informative variables. Recent advances in computer vision have motivated the use of sky cameras as low-cost alternatives capable of capturing cloud dynamics and atmospheric conditions. However, the extent to which image-based observations can replace dedicated irradiance measurements remains an open question. This paper presents an experimental comparison between two approaches for real-time PV power nowcasting: (i) a sensor-based model using irradiance measurements and (ii) a vision-based model relying exclusively on hemispherical sky images. Both approaches were evaluated using a temporal cross-validation protocol over a real PV installation dataset collected in Sion, Switzerland, between June and August 2025. The task corresponds to a photovoltaic nowcasting problem, where the objective is to estimate the current PV power production from the latest available observations. Using the irradiance-based model as a gold standard, the sensor-driven approach achieved an average MAE of 1,692~W and RMSE of 2,846~W, while the vision-based model obtained an MAE of 5,360~W and RMSE of 6,620~W. Nevertheless, the image-based approach was able to capture relevant atmospheric information and provide meaningful nowcasting capability while offering complementary advantages such as visual interpretability and environmental awareness. To exploit these capabilities, we introduce an explainability layer based on the Qwen multimodal vision-language model that generates human-readable descriptions of sky conditions and operational incidents directly from camera images. This enables the nowcasting framework not only to estimate current PV power production but also to provide visual explanations of cloud coverage, atmospheric phenomena, and potential anomalies affecting power generation.

[6820] Christoph Hametner (Institute of Mechanics and Mechatronics, TU Wien), Genario Oliveira (Institute of Mechanics and Mechatronics, TU Wien) and Stefan Jakubek (Institute of Mechanics and Mechatronics, TU Wien). ***Battery Ageing Prediction: Information-Driven Data Analysis and Model Parametrisation.***

Abstract. Reliable battery ageing prediction is a key enabler for the safe, efficient, and economical operation of electrified vehicles and battery-powered systems. Accurate prediction of capacity fade and related ageing phenomena supports improved system design, operation, and maintenance planning, while also contributing to longer battery lifetime and reduced total cost of ownership. At the same time, the development and parametrisation of ageing prediction models are strongly limited by the high cost and long duration of experimental testing. This motivates the need for methodologies that not only improve prediction accuracy, but also provide a better understanding of how much experimental effort is actually required for model development.

This work addresses battery ageing prediction from two complementary perspectives: information-driven data analysis and data-based modelling. On the one hand, the contribution investigates existing ageing data retrospectively in order to assess how much relevant information for prediction is actually contained in the available measurements. Based on information analysis and optimality criteria, the study explores to what extent the underlying experimental effort could, in principle, be reduced while still preserving the essential information content required for ageing prediction model parametrisation. The aim is therefore to systematically evaluate how efficiently the available data support ageing prediction and to identify how much redundancy may be present in extensive experimental studies. In this way, the work provides valuable insights for the design of future test campaigns and for estimating the measurement effort truly needed for reliable model development.

On the other hand, the work considers data-driven ageing prediction models that map operational and environmental conditions to future degradation trajectories. Beyond single-model approaches, the study outlines the potential of ensemble modelling concepts to improve robustness and generalization across varying usage scenarios. By combining complementary model structures or training perspectives, ensemble-based approaches may help capture different degradation characteristics more reliably and reduce sensitivity to limited or heterogeneous training data.

The overall idea is a systematic analysis for battery ageing prediction based on a large-scale battery ageing dataset, linking the information content of experimental data with scalable prediction models. Such an approach can support the faster development of ageing-aware battery management strategies and provide practical guidance for the interpretation of existing ageing datasets as well as for the design of future experimental efforts. The presented concepts are particularly relevant for applications in which reliable lifetime prediction must be achieved under limited testing budgets and diverse operating conditions.

[6894] 雅雯 贲 (15636189009). *Development of a Multi-Model Ensemble Simulator with Bayesian Optimization for Robust Prediction of Multivariable Water Quality in Drinking Water Treatment Processes.*

Abstract. Traditional mathematical modeling of water treatment processes often struggles to accurately represent the dynamic nature. To address these problems, a novel data-driven water treatment process simulator has been developed. The simulator leverages time series data from various water treatment stages, including influent/effluent monitoring, coagulation, sedimentation, filtration, and disinfection. A Bayesian hyperparameter optimization approach is utilized to integrate six diverse time series models, including both conventional machine learning (XGBoost, LightGBM, CatBoost) and deep learning models (TFT, TiDE, TSMixer). The simulator's efficacy is demonstrated through a case study of a full-scale drinking water treatment plant in Jiangsu Province, China. Scenario analysis shows that the simulator, utilizing historical water quality data, reagent dosing records, and future influent water quality and reagent dose projections, achieves high accuracy in predicting effluent parameters such as pH, turbidity, CODMn, and residual chlorine. Notably, the TimeSeries Deep Encoder (TiDE) model performed best, attaining a mean absolute percentage error (MAPE) of 1.09% on the test set. Furthermore, feature importance analysis identified the influent CODMn, temperature, and post-ozone dosage as key influencing factors of the effluent CODMn. These findings provide valuable guidance for optimizing water quality monitoring and control strategies in practical applications. This developed data-driven simulator presents a robust and comprehensive tool for enhancing water treatment plant operation. Its ability to provide reliable effluent water quality predictions, coupled with insights into key influencing factors of various effluent parameters, holds significant potential for optimizing reagent dosing, improving treatment efficiency, and ensuring the delivery of safe drinking water.

[6925] Hinaunye Eita (School of Economics, University of Johannesburg,) and Kesaobaka Mmelesi (School of Economics, University of Johannesburg, VAT Registration No. 4900127681). *The impact of innovation on carbon dioxide emissions in developing countries .*

Abstract. This study investigated the impact of innovation on carbon dioxide (CO₂) emissions in developing countries, using a dynamic panel system Generalized Method of Moments (GMM) model for the period 2008–2022. Analysis covers a panel of selected developing countries and contrasts the findings between high-income and low-income groups. The findings reveal that innovation, significantly, reduces CO₂ emissions across developing countries, confirming its role in promoting environmental sustainability. However, the magnitude of this impact differs by income level. Innovation has a stronger mitigation effect in low-income countries, while its influence is statistically insignificant among high-income developing economies, possibly due to saturation in technological capacity. The need for policy recommendations emerge. This is so because innovation alone may not immediately offset emissions from rapid industrialization, making policy coherence critical. Governments should align innovation policies with environmental regulation, carbon pricing and education systems that equip workers with green skills. Doing so ensures that innovation becomes a driver of inclusive and sustainable growth, fostering long-term resilience against climate change.

[6934] Pierdomenico Duttalo (University of Tuscia) and Francesco Lisi (University of Padova). *Short-term sea level forecasting using data-driven models and lunar phase information.*

Abstract. Framework Sea level forecasting is of primary importance for coastal management, navigation safety, and the protection of infrastructure and marine ecosystems (Khan et al., 2023; Pineau-Guillou and Lazure, 2025). The sea level observed at a given coastal location results from the superposition of processes acting on different temporal scales. In particular, it includes an astronomical component, driven by the gravitational interaction between the earth, the moon, and the sun, and a meteorological component influenced by atmospheric factors such as pressure, wind, wave motion, and precipitation.

In the Venice Lagoon, historical observations indicate a marked increase in both the frequency and magnitude of flooding events over the last century. Exceptional floods, such as those of November 1966 and November 2019, highlighted the strong sensitivity of total sea level to small-scale meteorological features and exposed the limitations of operational forecasting systems when atmospheric predictions are affected by high uncertainty (Massalin et al., 2007; Di Nunno et al., 2021; Umgiesser et al., 2021).

Most forecasting approaches available in the literature rely on complex physical or hydrodynamic models and require the explicit prediction of meteorological variables. While these methods provide a detailed description of surge dynamics, they are often computationally expensive and operationally demanding. In this work, we investigate an alternative strategy based on statistical modelling for short-term sea level forecasting that does not require the direct prediction of meteorological variables. As a novel contribution, lunar phase information is introduced as an exogenous variable to implicitly capture part of the astronomical tidal dynamics in a parsimonious and physically meaningful way.

Objectives and contribution This study explores a set of statistical and data-driven methods for short-term sea level forecasting, with the dual objective of comparing the predictive performance of parametric and non-parametric models and assessing the effectiveness of lunar phase information as an exogenous variable. In particular, the proposed framework evaluates whether lunar phases can implicitly represent the timing and modulation of the astronomical tide and improve short-term forecasts without relying on explicit meteorological predictors.

Methods Four classes of forecasting models are considered. (1) Seasonal AutoRegressive Integrated Moving Average with eXogenous variables (SARIMAX), employed as a linear and interpretable baseline capable of representing seasonal patterns and autoregressive dependencies. (2) Seasonal Functional AutoRegressive models with eXogenous variables (SFARX), which extend classical autoregressive formulations in the functional approach. (3) Generalized Additive Models (GAM), allowing for flexible nonlinear and smooth relationships between predictors and sea level. (4) K-Nearest Neighbors (KNN), a non-parametric analogue-based approach exploiting similarity among historical sea level states. All models are trained using historical sea level observations combined with lunar phase information and are evaluated through a rolling forecasting experiment with a 24-hour prediction horizon. In addition, the methodology is applied to three locations presenting markedly different environmental and tidal characteristics: Venice (Italy), Vardø (Norway), and Hiroshima (Japan). Model performance is assessed using standard accuracy and comparative metrics, including the mean squared error (MSE), the root mean squared error (RMSE), the Diebold–Mariano test, and the Model Confidence Set (MCS) procedure.

[7046] Igor Nesteruk (Institute of Hydromechanics, National Academy of Sciences of Ukraine, Kyiv, Ukraine). ***Real Infection Spreading Rates for the COVID-19 pandemic in Ukraine estimated with the Use of the Novel Reproduction Number.***

Abstract. Two subvariants of the Omicron strains NB.1.8.1 and XFG caused the rapid increase in the number of COVID-19 cases registered in Ukraine in the summer of 2025. In this regard, there is a need for objective estimates of the recent infection spreading rate and its comparison with previous periods of the COVID-19 pandemic. Recently proposed new reproduction numbers enable the estimation of the ratio of the actual number of infected individuals (registered and hidden) at different periods without the need for integration of differential equations and identification of the model parameters. The simple method of calculation was applied without smoothing the weekly datasets. The results for the period 2020-2023 and the summer of 2025 are presented and compared with calculations of the effective reproduction number available in the literature. The new reproduction number and the method for estimating it can be recommended as a simple tool for controlling real epidemic dynamics.

[7076] Mihai Mutascu (West University of Timisoara, and ZHAW Zurich University of Applied Sciences) and Scott W. Hegerty (Northeastern Illinois University). ***Does Trade Competition with the United States Influence CO2 Emissions in China?***

Abstract. When two large economies vie for market share, especially through lowering pollution standards, global emissions might be significantly affected. This paper investigates the relationship between U.S. - China trade competition and Chinese CO₂ emissions from February 2004 to December 2022 using wavelet methodology. The analysis reveals that while short-term interactions between trade competition and emissions are idiosyncratic and often fluctuate, the long-term findings indicate a significant coupling effect. As China expands its industrial and manufacturing sectors to meet global demand - particularly from the U.S. - there is a corresponding rise in energy-intensive production reliant on coal and fossil fuels, leading to increased CO₂ emissions. The study highlights that the effectiveness of Chinese environmental policies may appear neutral in the short-term but is contingent upon broader geopolitical dynamics and U.S. economic growth patterns. Moreover, overlooking geopolitical risks and the global economic context can undermine the significance of these environmental policies, potentially exacerbating trade competition through relaxed Chinese environmental regulations. These insights underscore the critical influence of the U.S. economy on Chinese environmental policy and the need for a comprehensive approach to understanding trade and environmental interactions.

[7117] Raphael Schilling (Fraunhofer EMFT), Ferdinand Heinrich (Fraunhofer EMFT), Florens Fraidling (Fraunhofer EMFT) and Franz Wenninger (Fraunhofer EMFT). ***Attribution Consistency in Time-Series Foundation Models.***

Abstract. # Background

Several good working time series foundation models (TSFMs) have recently emerged. Despite their strong empirical performance, the internal decision mechanisms of these models remain difficult to interpret. To understand and further improve such models, it's important to comprehend how they process input. Gradient-based attribution offers a direct way to quantify sensitivity at the timestamp level.

This work investigates the cross-model similarity of SmoothGrad attributions for three TSFMs—Chronos 2, Moirai 2, and FlowState. In addition to examining similarity, we investigate whether attribution profiles reflect the temporal structure expected in the underlying data.

Research question

Are SmoothGrad attributions produced by Chronos 2, Moirai 2, and FlowState similar, and do these attributions expose meaningful temporal structure?

Data

We evaluate 3 datasets, each represented by a fixed context window of $T=512$ timesteps and approximately 100 series per dataset: ETTh1 (Zhou et al., 2021), Electricity (Lai et al., 2017), and three DigiSeal. For ETTh1 and Electricity, a 24-hour periodicity is expected.

The DigiSeal dataset was produced within a project called DigiSeal, funded by the Bavarian Collaborative Research Programme (BayVFP) of the Free State of Bavaria — Funding Line “Digitalization” (Grant No. DIK0559/04). The DigiSeal consortium consists of Fraunhofer EMFT, EagleBurgmann Germany GmbH & Co. KG, Molkerei Alois Müller GmbH & Co. KG, and Hochschule München

Models

Chronos 2 (Ansari et al., 2025) and Moirai 2 (Liu et al., 2025) are patch-based Transformer forecasters, while FlowState (Graf et al., 2025) is a state-space-model-based forecaster. To ensure valid gradient-based attributions, implementation-level adjustments were applied in Chronos-2 and Moirai-2 to avoid autograd-breaking operations, without altering the predictions.

Attribution method

For calculating the attribution, the method SmoothGrad is applied. This method creates $N (=50)$ copies of the time series and adds to each gaussian noise ($\text{std}=5\%$ of the input range). Each of the N copies is passed to the TSFM to predict the next value. Since all TSFM in this study are implemented in PyTorch, the gradient vector of the predicted output can be calculated using the `predicted_value.backward()` function. The mean of these gradients over all N passes is the SmoothGrad attribution. This attribution can be interpreted as an importance score for each of the 512 context timestamps.

Similarity and summary metrics

Cross-model similarity is assessed using Pearson correlation between attribution vectors, computed per series for each model pair and then averaged per dataset.

We quantify the recency bias via a recency ratio R_{32} , defined as the fraction of attribution mass contained in the last 32 timesteps. A uniform attribution distribution would yield $R_{32} = 32/512 = 0.0625$.

To assess periodic structure per dataset and model, we compute the autocorrelation of attribution vectors and average autocorrelation curves across the series of each dataset.

Results

This section shows the results of the recency bias analysis, the cross-model agreement, and the periodicity of the attributions.

##Recency bias

Across all datasets and models, attribution mass is concentrated disproportionately near the end of the context window. The observed R_{32} values are substantially above the uniform baseline and span from 0.16 to 0.42. Moirai 2 exhibits the strongest recency concentration, Chronos 2 the most conservative, with FlowState showing clear recency emphasis as well. This consistent pattern indicates that, for the first forecast step, all models rely strongly on the most recent context.

Cross-model agreement

Pairwise Pearson correlations between SmoothGrad attribution vectors are consistently high, in the range of 0.88 to 0.99 across datasets. This provides evidence that these heterogeneous TSFMs focus on similar patterns of the input data.

Periodicity

For ETTh1 and Electricity, a 24-hour periodic component is expected. In accordance with this expectation, the attribution autocorrelation curves exhibit periodic structure compatible with a daily rhythm for all three models (Chronos 2, Moirai 2, and FlowState).

The DigiSeal datasets do not present a comparably clear periodicity. Correspondingly, Chronos 2 and Moirai 2 do not show pronounced periodic peaks in attribution autocorrelation on DigiSeal. FlowState, in contrast, exhibits a slight periodic component in its attribution autocorrelation on DigiSeal.

Conclusion

The high cross-model Pearson score of SmoothGrad attributions shows that under identical attribution settings (context length 512; SmoothGrad with $N=50$), Chronos 2, Moirai 2, and FlowState focus on similar parts of the provided input data. Since the expected 24-hour periodicity is visible in the attribution structure on ETTh1 and Electricity for all three models, one can assume that the models can leverage periodicities in the input data. At the same time, however, it seems that FlowState is biased toward discovering these periodicities, even if it is questionable whether periodicity actually exists.

It is not surprising that all models have a strong bias toward the most recent values, as these are closest to the value to be predicted.

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[7295] Eduardo Caro (Universidad Politécnica de Madrid), Jesus Juan (Universidad Politécnica de Madrid), Javier Cara (Universidad Politécnica de Madrid) and Ana Vendrell (Universidad Politécnica de Madrid). *Performance Analysis of Electric Load Forecasting Models under Extreme Weather Conditions.*

Abstract. Accurate short-term electric load forecasting is essential for power system operation, market efficiency, and the integration of renewable resources. Nevertheless, model performance is often reported as an average over long evaluation horizons, which can mask significant accuracy degradation under atypical meteorological conditions. In particular, extreme temperature events may push electricity demand into out-of-distribution (OOD) regimes, where models trained on historical patterns may fail to generalize reliably.

In this study, we analyze the quality of short-term electricity demand forecasts during days affected by extreme meteorological conditions. Specifically, we focus on extreme temperature episodes as well as disruptive winter weather events, including heavy snowfall periods such as the Filomena storm. The empirical analysis is conducted using hourly electricity demand data from the Spanish peninsular power system, enabling a detailed evaluation of forecasting performance under both normal and extreme operating regimes.

The study uses real-world data from the Spanish power system, including both observed electricity demand and the corresponding official demand forecasts, together with meteorological variables obtained from ECMWF reanalysis and forecasting products, which are publicly available online. By combining power system and weather information from open-access sources, the proposed analysis supports a transparent and reproducible evaluation of forecasting robustness under extreme conditions.

[7400] Gyorgy Terdik (University of Debrecen). *Graphical Lasso for Measuring Associations in Elliptically Symmetric Distributions: An EM Approach.*

Abstract. We extend sparse graphical modelling beyond the Gaussian framework by developing emGLasso, an EM-type generalization of the Graphical Lasso suitable for elliptically symmetric distributions (ESD). We show that zeros in the concentration matrix correspond to zero conditional correlations for ESDs, preserving the interpretability of conditional associations. Two important ESD families — the multivariate symmetric generalized hyperbolic (MSGH) and multivariate power exponential (MPE) distributions — admit variance-mixture representations that enable closed-form E-step updates. The resulting weighted GLasso estimator, iterated within the EM algorithm, effectively handles heavy-tailed and peaked data. Simulation studies demonstrate substantial improvements in graph recovery under non-Gaussian conditions, while Gaussian performance is recovered as the shape parameter approaches 1. A brief real-data example on body-dimension measurements illustrates practical applicability.

[7523] Octavio Roncal Andrés (SIANI, Universidad de Las Palmas de Gran Canaria), Jose Juan Hernandez Cabrera (SIANI, Universidad de Las Palmas de Gran Canaria), Mario Caballero (SIANI, Universidad de Las Palmas de Gran Canaria), José Juan Hernández Gálvez (ULPGC), Ana María Placido Castro (SIANI, Universidad de Las Palmas de Gran Canaria) and José Évora (SIANI, Universidad de Las Palmas de Gran Canaria). *Constraint-Aware Multivariate Time Series Forecasting for Day-Ahead Photovoltaic Generation: a Case Study.*

Abstract. Accurate day-ahead forecasting of photovoltaic generation is essential for monitoring, operational planning, and energy management in public infrastructures. This paper presents a technical study of the Energigran case, a real-world forecasting scenario centered on the photovoltaic plant at Infecar (Gran Canaria, Spain), where hourly power generation is predicted 24 hours ahead from multivariate time series combining environmental and operational signals. The input space includes cyclical temporal features, solar radiation, ambient temperature, cell temperature, local consumption, and grid exchange, while the target variable is hourly generated energy.

The work focuses on two complementary objectives: predictive performance and physical consistency. Beyond conventional error minimization, the forecasting models are evaluated under a set of domain-driven constraints derived from photovoltaic behavior and energy balance. In particular, the study considers monotonicity with respect to solar radiation, efficiency degradation under increasing cell temperature, and consistency with the site-level balance between generation, consumption, and grid exchange. These constraints are incorporated as executable metamorphic relations and used both for model regularization and for post-training technical assessment.

We compare four configurations: supervised TabNet, TabNet with constraint-guided training, supervised Kolmogorov-Arnold Networks (KAN), and KAN with constraint-guided training. Results show that the best predictive performance is obtained by the constraint-aware KAN, reaching an MAE of 428.10 and an R^2 of 0.8760, while the supervised KAN achieves very similar results (MAE 428.72, R^2 0.8758). In addition, the constraint-aware KAN reduces physically inconsistent behaviors from 32.18% to 29.59%, showing that the integration of domain constraints can improve behavioral reliability without sacrificing forecast accuracy.

These results suggest that, in energy forecasting scenarios where operational interpretability matters, constraint-aware evaluation provides a useful complement to standard error metrics and helps bridge the gap between accurate forecasts and behaviorally reliable predictions.

[7659] Nellie Chen (QSI International School of Shenzhen), Guohua Lu (BASIS International School of Shenzhen) and Eugene Pinsky (Boston University Metropolitan College). ***Forecasting State-Level Unemployment with Hybrid Statistical and Neural Time Series Models under Normal and Shock Conditions.***

Abstract. Forecasting unemployment rates is critical for informing policy decisions, resource allocation, and social safety net planning. This study constructs state-level time series models using monthly socioeconomic data from the U.S. (1987–2024). The datasets comprise five variables, including median household income, population, labor force participation rate (LFP), and initial jobless claims, as independent variables, and unemployment rate as a dual variable (both independent and dependent). The data exhibit non-stationary behavior, shown by abrupt spikes amid seasonal patterns. To address this, robust statistical models such as ARIMAX and neural architectures (LSTM and TCN) were applied, leveraging gating mechanisms to manage temporal dependencies and dilated convolutions for capturing long-term trends, thereby being resilient to disruptions from sudden spikes. The study has two directional aims: to test model performance under normal seasonal patterns and to evaluate performance under abnormal situations driven by the COVID-19 pandemic. Five models were evaluated, grouped into two categories: regression-based (Ridge Regression and ARIMAX) and neural network-based (Recurrent Neural Network and Temporal Convolutional Network). Each model predicts monthly unemployment rates either for all 50 U.S. states (as with LSTM and TCN) or for a subset of representative states—Wyoming, Louisiana, Arkansas, and North Dakota (as with ARIMAX and Ridge Regression)—due to computational constraints, with performance verified on test datasets. Performance is assessed using Root Mean Squared Error (RMSE) and R-squared (R^2). Results show that Ridge Regression yields the best performance among time-series regressors, while LSTM performs best among neural networks both before and after the pandemic. Filtering different features within neural networks further indicates that initial claims have the greatest impact on model performance. This study addresses the challenge of forecasting unemployment spikes for welfare monitoring and offers guidance on optimal model choice during unexpected disruptions in labor trends.

[7665] Fereshteh Jafari (Inst. of Computer Science, University of Bern, Switzerland.), Joseph Moerschell (Inst. of Systems Engineering, University of Appl. Sciences and Arts Western Switzerland.) and Kaspar Riesen (Inst. of Computer Science, University of Bern, Switzerland.). ***Sequential LSTM Modeling for Short-Term PV Power Forecasting.***

Abstract. Accurate photovoltaic (PV) power forecasting is critical for grid operation, yet long-horizon prediction remains challenging due to meteorological variability and error accumulation. In particular, jointly modelling two structurally distinct sources of uncertainty — meteorology-driven irradiance dynamics and autoregressive temporal power propagation — within a single model often degrades performance at extended horizons. To address this, we propose a two-step sequential LSTM framework for 60-minute-ahead PV power forecasting that explicitly decomposes these uncertainty sources into dedicated stages. The first LSTM integrates meteorological variables (solar irradiance and temperature) with historical PV power to generate a 30-minute-ahead prediction, while the second LSTM extends the forecast to 60 minutes by modelling autoregressive PV dynamics conditioned on first-step predictions and temporal features.

The framework is evaluated on one year of high-resolution data from a real-world PV installation and benchmarked against a persistence reference and a direct single-step LSTM. Results show that the proposed decomposition improves robustness for extended horizons, particularly under meteorologically challenging conditions, while maintaining comparable performance in stable regimes. These findings underscore the benefits of task-specific sequential modeling for adaptive PV forecasting systems.

[7756] Rafael Rodrigo-Guillen (University of Alicante), Higinio Mora-Mora (University of Alicante), Jorge Azorin-Lopez (University of Alicante) and David Gil (University of Alicante). ***Early Detection of Crowd-Flow Anomalies in Urban Time Series Using Conv1D-LSTM and Dynamic Thresholding.***

Abstract. The early detection of abnormal crowd-flow patterns is a relevant challenge in smart-city monitoring, especially in urban areas where sudden concentrations of people may require preventive intervention. This paper presents a hybrid framework for anomaly detection in pedestrian-flow time series derived from urban video streams. The proposed approach combines a Conv1D-LSTM multistep predictor with a dynamic thresholding mechanism based on local statistics of the prediction error. Instead of detecting anomalies directly on the observed signal, the method learns the expected temporal behaviour of pedestrian flow and activates alarms when the discrepancy between observed and predicted values becomes statistically significant.

The framework is evaluated on a real-world urban scenario in Dublin, where pedestrian counts are extracted from a public livecam using YOLOv8 and transformed into a univariate time series. Controlled anomalous episodes are introduced into the real signal to evaluate the detection capability under realistic noise and non-ideal acquisition conditions. Results show that the proposed model detects the anomalous event in the test region with full event-level recall, although false positives remain a limitation in short and highly variable test intervals. These findings suggest that prediction-residual based detection is a promising and interpretable strategy for early warning systems in urban crowd-flow monitoring.

[7806] Alexander Tyrsin (Leibniz Universität Hannover), Michail Gerasimov (Leibniz Universität Hannover) and Michael Beer (Leibniz Universität Hannover). ***Vector Entropy Modeling as a Tool for Monitoring and Forecasting the State of Economic Systems.***

Abstract. Systems in economics are often described in the form of a set of indicators characterizing their functioning. Their features include adaptability, stochasticity, and unsteadiness of behavior, the complexity of relationships between elements, and small data samples. Monitoring and forecasting the state of economic systems in the context of such limited information is a well-known problem.

During monitoring, the state of the system is analyzed using a set (vector) $X=(X^{(1)},...,X^{(m)})$ of mutually correlated time series, where $X^{(j)}=(x_1^{(j)},x_2^{(j)},...,x_n^{(j)})$ is a set of values at equidistant time points of the j th indicator of the system. Monitoring is carried out at certain points in time $t_1, t_2, ..., t_n$. At each moment t_i , we consider data samples in the form of implementations of observed indicators characterizing the functioning of the analyzed system elements.

To enhance the possibilities of monitoring and enhance the analyses possibilities, we introduce a new approach and test it on real data a systematic approach for monitoring and forecasting the state of economic systems that meets the main features of economic processes. It is based on the decomposition of the entropy $H(X)$ of a continuous random vector introduced by Claude Shannon in [1], then called differential entropy. This decomposition has the form [2] $H(X)=H_V(X)-G_R(X)$, where $H_V(X)$ is entropy "measure of randomness", $G_R(X)$ is an entropic "dependence measure".

The decomposition of the entropy $H(X)$ into entropic measures of randomness and dependence allows us to identify the main systemic patterns. The value $H_V(X)$ is equal to the marginal entropy corresponding to the complete independence of socio-economic indicators, it characterizes the consideration of the system as consisting of parts (additivity) and allows us to estimate the random component of time series and their trends.

The value $G_R(X)$ reflects the degree of relationship between the indicators, characterizing the properties of the system as a whole (integrity): with complete mutual independence between the elements of the $G_R(X)=0$; with strict functional dependence between at least two elements of the system $G_R(X) \rightarrow +\infty$. The larger $G_R(X)$, the closer the connections between the elements of the system and the more organized the system is, and the lower the entropy of the system $H(X)$.

Since $H_V(X)$ and $G_R(Y)$ characterize different aspects of the behavior of the system, we will consider the entropy of $H(X)$ in the vector form $[(H)_V(X); G_R(X)]$. By tracking the behavior of the vector $h(X)$, it is possible to draw conclusions about the state of the system under study, detect emerging trends in its state, and identify the components $X^{(j)}$ that had the greatest impact on the change in the state of the system. For example, we can interpret the components of the vector as dynamic development and stability (safety).

An example of entropy monitoring of socio-economic indicators of Germany and its regions from 1993 to 2024 will be considered. The analysis included 12 key macroeconomic indicators.

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[7842] Konstantina Papaioannou (National and Kapodistrian University of Athens), Anna-Maria Kanzola (National and Kapodistrian University of Athens) and Panagiotis E. Petrakis (National and Kapodistrian University of Athens). ***Forces of Change & Wild Cards in Medium-Term Projections.***

Abstract. “Λέγει που Ἡράκλειτος ὅτι πάντα χωρεῖ καὶ οὐδὲν μένει, καὶ ποταμοῦ ροὴ ἀπεικάζων τὰ ὄντα, ὥς δις εἰς τὸν αὐτὸν ποταμὸν οὐκ ἂν εμβαίης

Heraclitus claims that there is constant movement, as though it be a river's afflux to describe events, and none may enter the river twice.” – Plato, Cratylus, 402a

In recent years, and particularly following the unexpected shock of the COVID-19 crisis, forecasts about global economic dynamics have shifted substantially. Whereas the international economy had previously adapted to disturbances largely limited to cyclical financial crises, it is now entering a polycrisis phase, characterized by the interaction of environmental degradation, geopolitical instability, and increased systemic uncertainty and major catastrophic risk. In this context, it becomes especially important to reassess how medium-term forecasts toward 2030 differ from earlier expectations formulated around 2017. To address this, the analysis draws on a series of global economic outlook reports and applies an integrated methodological framework that combines forecasting, early warning detection, and risk assessment.

The methodology consists of three complementary modeling approaches that operate jointly. The first is an econometric model that produces baseline forecasts using structured macroeconomic indicators such as GDP growth, inflation, energy prices, interest rates, trade volumes, environmental factor, and exchange rates, allowing both prediction and estimation of the relative influence of each variable. The second is a machine learning model designed to detect forces of change of economic change by incorporating both quantitative indicators and text-based variables extracted from reports, including supply chain pressures, inflation trends, credit conditions, and policy uncertainty, in order to estimate the probability of slowdown or recession. The third component introduces exogenous shocks into the analytical framework, enabling the simulation of system responses under conditions of heightened uncertainty and the assessment of potential economic impacts. Together, these approaches form a unified framework that integrates standard forecasting, anticipatory signal detection, and forward-looking risk analysis.

[7852] Anthony Faustine (Eaton Corporation, ITI/LARyS) and Lucas Pereira (ITI, LARSyS, Técnico, Universidade de Lisboa). ***Model Predictive Control for Battery Storage in Net-Load Levelling: A Comparison of MILP and Heuristic Strategies under Perfect and Learned Forecasts.***

Abstract. The increasing integration of decentralised Photovoltaic (PV) systems and electric vehicles into Low Voltage (LV) distribution networks introduces significant variability in net-load patterns, exemplified by the "duck curve" (daytime overgeneration) and sharp peak demands. Addressing these challenges is critical to maintaining network reliability and minimising infrastructure costs. This study presents a comparative analysis of Mixed Integer Linear Programming (MILP) and heuristic control strategies within a Model Predictive Control (MPC) framework for load levelling using a Battery Energy Storage System (BESS), evaluated under perfect and LightGBM-based net-load forecast scenarios. These forecasts serve as input to the MPC framework, which optimally schedules MPC charging and discharging actions of MPC over a 24-hour horizon to minimise the net-load deviations from predefined thresholds. Under perfect forecasts, MILP achieves superior load levelling performance through predictive optimisation, while the heuristic provides a robust, low-complexity baseline. With LightGBM forecasts, the performance gap between MILP and heuristic approaches widens due to forecast uncertainties, underscoring the critical role of robust control strategies in handling imperfect net-load predictions for BESS operation

[7854] Leonardo Moreno (Univerisdad de la República). ***A Finsler-Based Extension of the Gini Index for $[0,1]$ Concentration Analysis on Riemannian Spaces.***

Abstract. This work aims to develop a modification and extension of a classical concentration measure: the Gini index. This indicator is widely used because it provides a synthetic, comparable, and easily interpretable measure of inequality, which explains its central role in many areas of the social sciences, including development economics, poverty and social exclusion studies, educational inequality, and the assessment of the inclusiveness of tourism development.

However, some of its limitations are also well known. In particular, markedly different distributions may share the same Gini value, thereby concealing important features of the underlying inequality structure.

The main objective of this work is to propose a new family of concentration measures based on a geometric reformulation of the Gini index, incorporating tools from Finsler geometry in order to overcome these limitations and capture the structure of inequality more faithfully. The resulting measure will naturally extend to the multivariate case and, more generally, to settings in which the data lie on a Riemannian manifold, thus broadening its applicability to contemporary econometric analysis

[7865] Wassim Mannai (Faculty of Economics and Management of Sfax, University of Sfax), Malek Abaab (Faculty of Economics and Management of Sfax, University of Sfax), Layth Sliman (Efrei Research Lab., Paris Pantheon-Assas University, Villejuif, France) and Kamel Helali (Faculty of Economics and Management of Sfax, University of Sfax). ***Nonlinear Energy and Security Effects in Cryptocurrency Markets: Evidence from Traditional and Green Cryptocurrencies.***

Abstract. The rapid expansion of cryptocurrency markets has raised growing concerns about their long-term sustainability, particularly regarding energy dependence, environmental externalities, and systemic security risks. Traditional cryptocurrencies such as Bitcoin rely on proof-of-work (PoW) consensus mechanisms, which require continuous computational effort and intensive electricity consumption. A growing body of empirical research shows that this energy demand is often linked to fossil-fuel-based electricity generation, thereby contributing to carbon emissions, air pollution, and broader environmental and public-health costs (De Vries, 2020; De Vries-Gao et al., 2022; Guidi et al., 2025). These characteristics raise fundamental questions about the environmental viability and financial resilience of energy-intensive cryptocurrencies in the context of the global energy transition.

In contrast, green cryptocurrencies have emerged as an alternative digital-asset architecture that uses significantly less energy. Cardano (ADA), which is based on the Ouroboros proof-of-stake (PoS) protocol, is a low-energy cryptocurrency that decouples network security from energy-intensive mining. By eliminating computationally costly hashing, PoS-based systems drastically reduce electricity consumption and mitigate dependence on fossil-fuel energy sources, while maintaining security through economic incentives and protocol design (Guo & Yu, 2022). Recent studies in sustainable finance further emphasize that low-carbon cryptocurrencies are more compatible with clean-energy transitions and climate-aligned financial systems (Naifar, 2025).

This study conducts a comparative time-series analysis of traditional and green cryptocurrencies by examining the dynamic behavior of Bitcoin (BTC) and Cardano (ADA) from 2020 to 2025. The analysis explicitly integrates energy-market conditions, clean-energy signals, and security-related uncertainty by including Brent crude oil prices, a clean-energy equity index, and a cybersecurity risk index. Such an integrated framework is consistent with recent evidence showing that cryptocurrency prices and volatility are increasingly interconnected with energy markets, renewable energy dynamics, and cyber risk factors (Naifar, 2025).

Against this background, this study pursues several interrelated objectives. First, it aims to determine whether traditional and green cryptocurrencies exhibit significantly different short-run and long-run sensitivities to fossil-energy conditions and clean-energy signals. Second, it seeks to assess whether these relationships are inherently nonlinear and asymmetric, particularly in response to positive versus negative energy shocks. Third, it aims to examine whether differences in energy dependence are transmitted into distinct volatility, persistence, and security-related risk dynamics. Finally, the study investigates whether the combination of energy structure and security architecture jointly shapes the stability of cryptocurrency markets over time.

Consistent with these objectives, the study formulates and empirically tests a set of hypotheses grounded in the literature on energy economics, financial volatility, and digital security. H1 posits that fossil-energy shocks exert a stronger long-run effect on traditional cryptocurrencies than on green cryptocurrencies. H2 hypothesizes that the impact of energy shocks on cryptocurrency prices is nonlinear and asymmetric, with positive and negative energy shocks generating heterogeneous adjustment dynamics. H3 states that energy-intensive cryptocurrencies exhibit higher volatility persistence and stronger asymmetric risk responses than energy-efficient cryptocurrencies. H4 hypothesizes that green cryptocurrencies are more stable and resilient to energy- and security-related shocks due to their low-energy consensus mechanisms.

Methodologically, the study adopts a nonlinear econometric framework based on Autoregressive Distributed Lag (ARDL) and Nonlinear ARDL (NARDL) models. While the linear ARDL specification captures average short-run and long-run relationships, the NARDL approach allows for asymmetric decomposition of energy variables into positive and negative shocks. This distinction is crucial, as positive and negative fossil-energy shocks may exert qualitatively different effects on cryptocurrency prices and risk dynamics, particularly for energy-intensive PoW systems compared to energy-efficient PoS systems (Guo & Yu, 2022).

To ensure robustness and internal consistency, the analysis incorporates a comprehensive set of diagnostic procedures, including tests for serial correlation, heteroskedasticity, normality, and parameter stability using CUSUM and CUSUMSQ tests. Residual linear dependence is further addressed through ARIMA modeling, while conditional volatility dynamics are examined using a range of GARCH-family models (GARCH, EGARCH, GJR-GARCH, and APARCH). This multi-layered econometric strategy is widely recommended in the recent financial econometrics literature for capturing volatility persistence, asymmetric risk transmission, and market instability in cryptocurrency markets (Naifar, 2025).

The empirical results indicate that Bitcoin exhibits stronger nonlinear sensitivity to fossil-energy-related shocks and higher volatility persistence, reflecting its structural dependence on energy-intensive mining and exposure to energy-market uncertainty (De Vries, 2020; Guidi et al., 2025). In contrast, Cardano exhibits more stable dynamics, a weaker dependence on fossil-energy shocks, and a closer association with clean-energy indicators, supporting its classification as a green cryptocurrency (Guo & Yu, 2022; Naifar, 2025). From a security perspective, these findings suggest that energy-efficient cryptocurrencies may also exhibit greater resilience to systemic risk and to mechanisms that amplify volatility.

Overall, the study provides robust evidence that cryptocurrency design, energy dependence, and security architecture are deeply interconnected and interact nonlinearly. By integrating energy economics, environmental sustainability, cybersecurity considerations, and advanced nonlinear time-series modeling, this research contributes to the growing literature on sustainable digital finance and offers important insights for policymakers, investors, and regulators seeking to align cryptocurrency development with energy transition and security objectives (De Vries-Gao et al., 2022; Naifar, 2025).

[7879] Ignacio Rojas-Valenzuela (University of Granada), Victor Gonzalez Argudo (University of Granada) and Olga Valenzuela (University of Granada). ***Integrated Frameworks for Solar Photovoltaic Power Forecasting: Advanced Methodologies, Hybrid Machine Learning, and Input Data Calibration.***

Abstract. This research integrates advanced frameworks for photovoltaic power prediction, unifying hybrid machine learning with signal processing. Tools such as the Fast Discrete Curvelet Transform (FDCT) and Model Output Statistics (MOS) are utilized to correct biases in meteorological data and extract hidden spatial features. The implementation of metaheuristic optimizers and complex architectures like Bi-LSTM and XGBoost maximizes prediction accuracy for conversion efficiency and operating points. These methodologies facilitate intelligent resource management and maintain electrical grid stability amid the inherent volatility of solar generation.

[7940] Daniele Bregoli (Polytechnic University of Marche), Donato Iacobucci (Polytechnic University of Marche), Paolo Sospiro (ECampus University) and Marco Ciro Liscio (Polytechnic University of Marche).

Trade Integration in the Adriatic–Ionian Region: A Structural Gravity Approach to Macro Regional and Functional Regionalisation.

Abstract. This research investigates the degree and spatial structure of trade integration within the EU Strategy for the Adriatic and Ionian Region (EUSAIR). The analysis builds a panel of bilateral trade flows among EUSAIR economies at the most disaggregated regional level available, using Eurostat regional data for EU members and a set of gravity-based and entropy-type procedures to disaggregate national trade for non-EU Western Balkan countries into pseudo-regional units. A structural gravity model is first estimated to quantify a “macro-regional effect”, i.e. the extent to which intra-EUSAIR trade exceeds gravity benchmarks once economic size, distance and multilateral resistance are controlled for.

In the second step, the paper derives data-driven functional macro-regions by applying clustering and network community-detection algorithms to trade flows, gravity residuals and regional socio-economic indicators. This regionalisation is used both to compare administrative versus economic integration spaces and to test whether trade is more intense within machine-learned clusters than across them. The empirical strategy thus delivers (i) an estimate of the EUSAIR macro-regional trade premium, (ii) a harmonised regional trade dataset for EU and non-EU partners, and (iii) a typology of functional trade regions within the Adriatic–Ionian area. The research provides new evidence on the depth and geography of economic integration in the EUSAIR, with implications for the design and targeting of macro-regional policies.

[7986] Hinaunye Eita (School of Economics, University of Johannesburg,) and Kesaobaka Mmesele (School of Economics, University of Johannesburg, VAT Registration No. 4900127681). ***The relationship between real exchange rate misalignment and innovation in developing countries.***

Abstract. This study investigates the relationship between real exchange rate misalignment and innovation in developing countries using a panel fixed effects model estimation approach. Empirical results reveal that real exchange rate misalignment has a significant and negative impact on innovation across all measures, suggesting that deviations from equilibrium exchange rates hinder technological progress and innovative capacity. Conversely, economic growth and trade openness emerge as strong positive influences on innovation, underscoring the role of macroeconomic stability and global integration in fostering innovation-driven development. These findings highlight the critical need for sound exchange rate policies and supportive economic environments to enhance innovation and sustainable growth in developing economies.

[8009] Dounia Bourzik (LMA, FSTT, Abdelmalek Essaadi University, Tetouan, Morocco), Aziz Lmakri (AIMCE laboratory, ENSAM, Hassan II University, Casablanca, Morocco), Amal Mellouk (Regional Center for Education and Training Trades, Tangier, Morocco), Abdelhadi Akharif (LMA, FSTT, Abdelmalek Essaadi University, Tetouan, Morocco) and Hassan Oukhouya (LaMSD, MSASE, FSJES, Mohammed First University of Oujda, BV Mohammed VI B.P. 724, Oujda, 60000, Morocco). ***Testing Panel Threshold Regression Models with Bilinear Dependent Errors: An Economic Application.***

Abstract. This paper investigates nonlinear dynamics in panel data using threshold regression models and generalized bilinear processes, providing powerful tools for capturing nonlinearities in economic and statistical relationships. Our framework focuses on detecting threshold effects in short panel settings where errors exhibit a super-diagonal bilinear dependence structure. Following Le Cam's theory, we establish the local asymptotic normality (LAN) property of the model in a neighborhood of the linear null hypothesis and derive asymptotically optimal parametric pseudo-Gaussian tests. We assess the finite-sample performance of the pseudo-Gaussian test through extensive Monte Carlo simulations, consistently demonstrating its superior power across various error distributions. Finally, we illustrate the practical relevance of our methodology by empirically examining the relationship between demographic aging and economic growth, successfully identifying the simultaneous presence of threshold effects and

super-diagonal bilinear dependence in short panel regression models.

[8171] Gianluca Cubadda (Tor Vergata University of Rome), Luca Margaritella (Lund University) and Orest Prifti (Tor Vergata University of Rome). ***Broken Adaptive Ridge in Time Series: the TS-BAR.***

Abstract. The Broken Adaptive Ridge (BAR) model is extended to high-dimensional time series where the number of variables can exceed the sample size, addressing the curse of dimensionality. It is a sparsity-inducing method that iteratively reweights the ℓ_2 penalty to mimic the selection properties of the non-convex ℓ_0 penalization. The BAR benefits from the grouping effect, with highly correlated covariates selected jointly, and the oracle property, performing asymptotically as if the correct model were given. In sparse and high-dimensional settings, Monte Carlo simulations show that the BAR model performs better than the LASSO and its variants. Its superior feature selection and forecasting performance are further confirmed by two empirical applications in macroeconomics and finance.

[8186] Hajer Chibani (Faculty of Economics and Management of Sfax, University of Sfax), Maha Kalai (Faculty of Economics and Management of Sfax, University of Sfax), Layth Sliman (Efrei Research Lab., Paris Pantheon-Assas University, Villejuif, France.) and Kamel Helali (Faculty of Economics and Management of Sfax, University of Sfax). ***Price Shocks and Carbon Emissions: Asymmetric Effects of Oil Markets and Cryptocurrency Mining on Global CO₂ Dynamics.***

Abstract. The accelerating convergence of traditional energy markets and digital financial systems presents unprecedented challenges for global climate governance. While fossil fuel consumption has long been recognized as a primary driver of anthropogenic CO₂ emissions, the environmental externalities of cryptocurrency mining, particularly Bitcoin's energy-intensive proof-of-work consensus mechanism, have emerged as a critical yet underexplored dimension of climate change dynamics (Krause & Tolaymat, 2018; Mora et al., 2018). Despite extensive literature examining oil prices and Bitcoin separately, a significant research gap persists regarding their combined and asymmetric impacts on environmental degradation. This study addresses this gap by investigating both symmetrical and asymmetrical relationships between oil prices, Bitcoin prices, and global CO₂ emissions using monthly data spanning September 2012 to March 2023.

Employing an integrated econometric framework, we apply the Autoregressive Distributed Lag (ARDL) bounds testing approach (Pesaran et al., 2001) alongside Shin et al.'s (2014) Nonlinear ARDL (NARDL) model to capture both short-run dynamics and long-run equilibrium relationships while explicitly modeling positive and negative price shocks. Structural break analysis identifies three critical inflection points (the 2014 oil price collapse, the 2017 Bitcoin boom, and the 2021 post-pandemic rebound) that fundamentally reshaped interactions among energy, cryptocurrency, and the environment. Robustness is ensured through comprehensive diagnostic testing, CUSUM/CUSUMSQ stability checks, and asymmetric causality analysis using Hatemi-J's (2012) nonparametric test.

Our principal findings reveal complex, divergent environmental pathways. Similarly, the ARDL model shows that a 1% increase in Bitcoin prices is associated with a 0.545% increase in CO₂ emissions in the long run (p-value < 0.001), reflecting intensified mining activity during bull markets. Conversely, a 1% rise in oil prices reduces emissions by 1.703% (p-value = 0.005), consistent with demand destruction and energy substitution effects. Asymmetrically, the NARDL results uncover critical nonlinearities: positive Bitcoin price shocks exert a significantly stronger emissions-increasing effect (coefficient = 0.952, p-value < 0.001) than negative shocks (coefficient = 0.616, p-value = 0.244), indicating that emission reductions during bear markets lag behind increases during bull runs. Similarly, positive oil price shocks substantially decrease emissions (coefficient = -1.862, p-value = 0.001), whereas negative shocks have only weak, statistically insignificant effects (coefficient = -0.787, p-value = 0.308). Hatemi-J causality tests confirm unidirectional causality from positive shocks in both Bitcoin and oil prices to CO₂ emissions, but not from negative shocks—highlighting policy-relevant asymmetries in environmental responsiveness.

These findings carry profound implications for climate policy architecture. First, regulatory frameworks must evolve beyond traditional energy sectors to encompass digital asset ecosystems, particularly by incentivizing proof-of-stake migration and mandating the integration of renewable energy for mining operations. Second, carbon pricing mechanisms should account for asymmetric price-emission dynamics, recognizing that emission reductions from falling oil prices are less pronounced than increases from price declines. Third, international climate agreements (e.g., the Paris Agreement) require explicit provisions addressing cryptocurrency's carbon footprint, especially given cross-border migration patterns in mining. Ultimately, this research establishes that effective climate mitigation requires coordinated governance of both fossil fuel markets and digital financial infrastructure, a paradigm shift essential to achieving net-zero trajectories amid accelerating financial digitization.

[8224] Eero Pätäri (LUT University), Sheraz Ahmed (LUT University), Pasi Luukka (LUT University) and Julian Scott Yeomans (York University). ***Predictability of Stock Returns: A Multi-Criteria Portfolio Selection with a Refined TOPSIS.***

Abstract. This paper refines the TOPSIS method for multi-criteria portfolio selection by integrating technical indicators derived from the time-series of stock returns, such as momentum, short-term reversal, seasonality, volatility, and the highest average daily return over the previous month. A novel factor-momentum weighting scheme within a similarity-based TOPSIS framework significantly outperforms the standalone method, the market model, and 10 TOPSIS variants using a US stock dataset (1964–2021). While high turnover reduces abnormal profits from individual strategies due to transaction costs, applying cost-mitigation methods to top quantile portfolios yields robust post-cost outperformance for the enhanced method. These results provide practical guidance for fund managers seeking to diversify styles through blended prior-return factor investing strategies.

[8320] Nesrine Djebali (Faculty of Law, Economics and Management of Jendouba). ***Assessing the determinants of banking stability in the MENA region: what role for economic and financial freedom?.***

Abstract. The main objective of this paper is to investigate the effects of economic freedom and financial freedom on bank stability in 12 Middle-East and North Africa region countries during the period 2005–2020. Using an empirical approach based on the System Generalized Method of Moments, our results reveal that economic freedom, financial freedom, investment freedom and business freedom increase bank stability. A high degree of economic freedom promotes innovation and entrepreneurship and, hence, leads to economic growth and better banking stability. In contrary, we confirm that monetary freedom negatively affects bank stability. The same result was confirmed for the two sub-samples of Middle Eastern countries and North African countries.

[8353] Nasibeh Esmaeili (Assistant Professor, Department of Demography, Faculty of Social Sciences, University of Tehran, Iran.) and Gholamreza Ghaffari (Professor, Department of Sociology, Faculty of Social Sciences, University of Tehran, Tehran, Iran). ***Forecasting Urban Housing Tenure Patterns in Iran Using Deep Neural Network Modeling (2024–2033).***

Abstract. Housing, as a fundamental human necessity, lies at the intersection of social justice and sustainable urban development, with housing tenure representing a critical analytical dimension within this field. Accurately tracing historical shifts in tenure patterns and anticipating their future trajectories equips policymakers and urban planners with indispensable strategic intelligence for crafting macro-level development policies. This study examines the evolutionary dynamics of urban housing tenure in Iran over the past five decades (1974–2023) and presents a forward-looking projection for the next ten years (2024–2032) through a deep learning-based forecasting approach. A 50-year time-series dataset, compiled from the Statistical Center of Iran, was analyzed using a four-layer Deep Neural Network (DNN) model developed in MATLAB. The results indicate that homeownership has persistently remained the dominant tenure form among urban households, currently encompassing approximately 69% of the population, while government housing accounts for the smallest proportion. Nevertheless, a dynamic analysis of trends spanning 1974 to 2023 reveals substantial structural realignments. The most dramatic transformation occurred in mortgaged housing, which surged by 18-fold, followed by a 30% increase in government housing. Conversely, homeownership and rental housing experienced declines of 5.5% and 8.5%, respectively. According to the Deep Neural Network forecasts, the next decade is projected to witness a continued expansion of mortgaged housing among urban households, accompanied by a relative decline in homeownership and rental tenure shares. It is important to note that in the forecasting of complex socio-human systems, analytical emphasis should be placed on directional trends and overarching patterns of change rather than on absolute numerical precision.

[8448] Akshay Murthy (Liberty High School, 15250 Rolater Rd, Frisco, TX 75035), Jonathan Yan (Sage Hill High School, 20402 Newport Coast Dr, Newport Coast, CA 92657) and Eugene Pinsky (Boston University Metropolitan College). ***Comparing Standard Deviation with Alternative Volatility Metrics in Financial Time-Series Forecasting and Trading with Bollinger Bands.***

Abstract. The implementation of Bollinger Bands to create trading signals has been a popular mean-reversion strategy, and typically, traders have used standard deviation (SD) from the mean to generate bands. However, this traditional use of SD, along with the mean as a dispersion metric, can misjudge true extrema and make trading signals less reliable, as both are sensitive to market jumps. This suggests that more robust volatility metrics and measures of centers may improve the quality of bands generated and overall trading performance. In this study, we test the performance of various Bollinger Bands trading strategies with SD, Interquartile Range (IQR), Average True Range (ATR), and Mean/Median Absolute Deviation (MAD) from the mean and the median. Because sectors generally indicate the trend of an individual stock, we backtest over 25 years across 10 different sectors, evaluating the final portfolio value of a Bollinger Bands trading strategy conditioned on a particular volatility metric. Our results show that an IQR-conditioned Bollinger Bands strategy is, on average, most profitable, outperforming both SD- and MAD-based strategies. These findings demonstrate that range-based dispersion metrics may serve as more robust indicators of risk and should be examined more closely in mean-reversion-based trading strategies.

[8468] Jose Alberto Zamora-Justo (Unidad Profesional Interdisciplinaria de Biotecnología - Instituto Politécnico Nacional), Pilar Ortíz-Vilchis (Escuela Superior de Medicina - Instituto Politécnico Nacional), José Luis Del-Rio-Correa (Universidad Autónoma Metropolitana Unidad Iztapalapa) and Alejandro Muñoz-Diosdado (Unidad Profesional Interdisciplinaria de Biotecnología - Instituto Politécnico Nacional). ***Persistence Analysis of Physiological Time Series of Subjects with Different Chronic Disease Risk Profiles.***

Abstract. Heart variability series exhibit complex behavior best understood through nonlinear dynamical techniques. This research evaluates the utility of four Hurst exponent estimators for assessing persistence and antipersistence in RR time series from healthy subjects and those with Congestive Heart Failure (CHF) across varying conditions, including sleep, wakefulness, rest, and exercise. Healthy young subjects at rest display persistent RR series, whereas both CHF patients and healthy subjects during physical activity exhibit antipersistent RR series. Compared with sedentary subjects, physically active individuals maintain stable H-values, whereas sedentary subjects exhibit significant changes during physical activity, resembling CHF behavior. Overall, the results support the use of Hurst exponent methodologies as information-based biomarkers that can reveal relevant aspects of physiological status and potentially contribute to risk assessment, classification, and monitoring strategies in chronic disease research.

[8529] Hossein Tabasi (Shoolini University of Biotechnology and Management). ***A Review of Cryptocurrency Price Prediction Using Machine Learning: Advantages, Challenges, and Future Scope.***

Abstract. Prediction of cryptocurrency prices remains a difficult problem because cryptocurrencies exhibit volatility, non-stationarity, and significant sentiment effects. This critical narrative review analyzes 18 applied and review papers mostly published during 2018–2026 and connects their findings to liquidity, regulation, and blockchain network effects. It concludes that research is too focused on RMSE and MAE at the expense of practical economic validity. Model performance varies according to the underlying asset, prediction horizon, and specific application goals: SARIMAX remains competitive for daily directional signals, GRU/LSTM/Conv-LSTM models perform well when temporal dependence is strong, and multimodal architectures improve performance when sentiment, search volume, and onchain data are properly lagged. Contrary to an overly simple interpretation of the evidence, the most accurate statistical model is not necessarily the best trading model. This paper calls for methodological improvements: walk-forward validation, proper leakage management, ablation, error uncertainty, and trading performance evaluation adjusted for transaction costs

[8540] Dimitra Kyriakopoulou (National and Kapodistrian University of Athens). ***A Shrinkage Factor-Augmented VAR for High-Dimensional Macro–Fiscal Dynamics.***

Abstract. We develop a ridge-regularized Factor-Augmented Vector Autoregression (FAVAR) framework for modeling macro-fiscal dynamics in settings where the number of predictors is large relative to the available sample. Rather than relying on an unrestricted factor decomposition, the high-dimensional information set is summarized through two economically interpretable latent factors, namely a real activity factor and a nominal-financial factor, extracted from separate data blocks. These factors are embedded in a regularized VAR together with key observable macro-fiscal variables, including real GDP growth, inflation, the primary balance, and the interest-rate-growth differential, allowing macroeconomic conditions to be linked to sovereign debt dynamics through a nonlinear accounting identity. In an application to Greece, the extracted factors capture major business-cycle, inflationary, and financing episodes, while impulse responses are economically plausible and dynamically stable. Recursive out-of-sample forecasting exercises show that the model performs comparatively well for inflation and financing conditions at selected horizons, while simple autoregressive benchmarks remain difficult to outperform for persistent real activity variables. Overall, the results highlight the usefulness of combining structured factor extraction with ridge regularization to obtain a parsimonious and interpretable framework for macro-fiscal modeling, scenario analysis, and debt sustainability assessment.

[8546] Simiso Msomi (University of KwaZulu-Natal). ***Exchange rate prediction using machine learning techniques.***

Abstract. The exchange rate is said to be disconnected from its fundamentals. As such, a large body of the literature shows that no model can outperform a random walk. However, the emergence of machine learning techniques provides new insights into the investigation of the behaviour of the exchange rate in response to its fundamentals. In this study, variables shown in the literature to be strongly correlated with the exchange rate are used to predict its behaviour. While many studies have used machine learning to predict target variables, less attention has been paid to evaluating the performance of individual models. In this study, the performance of various machine learning models is evaluated and compared.

[8555] Swaroop Gulhane (Vishwakarma Institute of Technology(VIT)), Shivam Gujar (Vishwakarma Institute of Technology(VIT)) and Rohan Dhotre (Vishwakarma Institute of Technology(VIT)). ***CampusLearn+ Free Classroom For Extra Growth.***

Abstract. Abstract—Managing room booking systems in Academic Institutions remains an unsolved problem. Inefficient systems lead to resource misallocation and scheduling conflicts. This study aims to develop a web-based Campus-wide Room Booking System to increase efficiency in booking rooms for classes, meetings, and events. 'Roomify' incorporates automated booking, an admin control panel, issue tracking, notifications, and an inventory control system, among others. Existing systems do not provide real-time data, which results in double bookings and inaccessible rooms. We eliminate these problems using realtime systems to prevent booking conflicts, provide availability assessments, and monitor maintenance. We anticipate that educational institutions and other organizations will adopt Roomify as a scalable solution to future challenges in resource booking. With intelligent analytics, it will provide ease of use, transparency in operations, and access-20uplifting resource utilization and management. Index Terms—Educational Facility Management, Responsive User Interface, Dark Mode Implementation, Academic

Resource Scheduling, Web-based Reservation System,
Classroom Booking System.

[8583] Marco Costa (University of Aveiro) and Magda Monteiro (University of Aveiro). ***Addressing Parameter Estimation Bias in Kalman Filtering Using GMM.***

Abstract. Parameter estimation in linear state-space models is fundamental to filtering, smoothing, and forecasting. Standard approaches, including Gaussian maximum likelihood and Fisher scoring, rely strongly on distributional assumptions and are well known to induce bias in both parameter estimates and Kalman filter outputs when these assumptions are violated or when parameters are estimated rather than treated as known.

This presentation proposes a double-iterated Generalized Method of Moments (GMM) estimator aimed at mitigating parameter estimation bias in state-space models. The methodology explicitly leverages the internal structure of the Kalman filter and smoother by exploiting discrepancies between predicted and updated state estimates to construct moment conditions that reflect the bias arising from parameter estimation. A first-order approximation of the Kalman predictors with respect to the parameter vector yields a bias representation involving an unknown bias vector, which is estimated via GMM.

The resulting estimation procedure is fully iterative. An outer iteration updates the structural parameters of the state-space model, while an inner GMM loop estimates and corrects the bias at each step. This double-iteration scheme produces bias-corrected parameter estimates and improved state predictions, without requiring strong distributional assumptions.

[8590] Massimiliano Zanin (IFISC (CSIC-UIB)). ***irreversibility: A Python Package for Assessing and Manipulating the Time Irreversibility of Real-World Time Series.***

Abstract. [Note: this is intended to be a Published Paper Showcase, for the paper

Zanin, M. (2025). *irreversibility: A Python Package for Assessing and Manipulating the Time Irreversibility of Real-World Time Series*. *Entropy*, 27(11), 1146.

This is also strongly connected to the papers:

Zanin, M., & Papo, D. (2021). Algorithmic approaches for assessing irreversibility in time series: Review and comparison. *Entropy*, 23(11), 1474.

Zanin, M., & Papo, D. (2025). Algorithmic Approaches for Assessing Multiscale Irreversibility in Time Series: Review and Comparison. *Entropy*, 27(2), 126.

Time irreversibility refers to the property of some dynamical systems and time series of being statistically different when observed backward in time. While the theoretical foundations of irreversibility date back to the origin of statistical physics, the analysis of such property in real-world time series has only recently gained momentum. We present *irreversibility*, an open-source Python (version ≥ 3.11) package aimed at providing a large set of irreversibility metrics and tests and at facilitating their use. Besides the tests themselves, it includes a set of utilities, like functions to downsample and manipulate the time series, and to optimise the parameters of the metrics. By providing a unified software package, *irreversibility* simplifies the analysis of real data, allowing the researcher to compare multiple tests and obtain a better and more reproducible view of the underlying system. In this contribution we explore the features of the package and provide examples of its use.

[8608] Eda Ustaoglu (Abdullah Gul University) and Suleyman Sisman (Gebze Technical University). *Quantifying demand for housing estates: A comparison of statistical approaches application to Türkiye.*

Abstract. Changes in land use can have negative effects on the environment and society, which puts a lot of pressure on governments. In order to be sustainable, it is necessary to identify both the environmental components and limits that must be preserved for ecosystems to function properly, as well as the resources that can be exploited for development together with their limitations. For sustainable development and environmental protection, precise projections of future built-up growth are crucial. This article looks at how land use has changed for urban purposes and then utilizes several techniques to project residential land uses in the chosen case study area. Türkiye's NUTS3 (nomenclature of terrestrial units for statistics) regions were included in the study that offers a city-level analysis. Regression analysis, trend extrapolation, and land use density measurements are the statistical techniques used to estimate and predict land usage. The results demonstrate that projecting historical changes using the selected approaches results in considerable uncertainty. The spatial arrangement of the research region and the variation in the chosen variables have a considerable impact on the outcomes.

[8810] Njoya Loudi (University of Bertoua) and Dama Die Marcel (Faculty of Economics and Management, University of Douala). *Private ownership vs Informality in developing countries: The corruption Conundrum.*

Abstract. The objective of this study is to investigate empirically the links between property rights and the size of the informal sector, taking into account the presence of corruption. To meet up with our objective, this paper made use of a data set of 112 countries from the CPI, Medina, and Schneider (2018), and the WDI spanning from 1991 to 2019. From our results, we find a negative correlation between property rights and informal sector development. However, this negative relationship becomes positive at a high level of corruption. The results are robust to the use of alternative methods. The policy implications of this research urge policy makers of the developing countries on the need to further-enhance their macroeconomic policies that fights against corruption. These include improvement in political governance, fiscal sustainability and the rules of law. This will help to improve the property rights and reduces the size of the informal sector. Policies, which are growth driven, are encouraged; this will lead to job creation and as a result, a reduction in the social vulnerability among these countries.

[8811] Justin Sun (Canyon Crest Academy). *Estimating Earth's Temperature Response with Transformed and Augmented OLS.*

Abstract. The long-term relationship between radiative forcing and surface temperature is imperative for predicting the impacts of climate change. This study employs multicointegration to characterize this relationship and uses Transformed and Augmented Ordinary Least Squares (TAOLS) to estimate the model. The main goal is to estimate the Equilibrium Climate Sensitivity (ECS), defined as the global mean surface air temperature increase following a doubling of atmospheric carbon dioxide. Our results show that the ECS lies between 2.12°C and 2.49°C, which is lower than the existing maximum likelihood estimate of 2.8°C. TAOLS offers a more robust and accessible tool for climate research, providing novel insights for ongoing debates about Earth's warming trajectory.

[8909] Slawek Smyl (Walmart, USA), Boris Oreshkin (Amazon, Canada), Paweł Pełka (Czestochowa University of Technology) and Grzegorz Dudek (Czestochowa University of Technology). *Any-quantile probabilistic forecasting of short-term electricity demand: Fusing uncertainties from diverse sources.*

Abstract. Power systems operate under significant uncertainty arising from diverse and dynamic factors such as fluctuating renewable energy generation, evolving consumption patterns, and complex market dynamics. Accurately forecasting electricity demand necessitates advanced methodologies capable of capturing these multifaceted uncertainties. Our work develops any-quantile probabilistic forecasting framework, which enables the generation of forecasts for arbitrary quantile levels at inference time using a single trained model. This constitutes a substantial methodological advancement over traditional quantile regression techniques, which typically require training a separate model for each quantile or limiting predictions to a fixed set of predefined quantile levels. We show that integrating this framework into state-of-the-art neural architectures, specifically ESRNN and N-BEATS, yields superior distributional forecasting performance in the context of short-term electricity demand. Additionally, we develop the general Bayesian theory of cross-learning and link its latent objects with the elements of our architectures, providing a Fusion theory foundation for cross-learning from multiple power systems.

[8963] Sopiko Tevdoradze (Georgian International University GIU), Zurab Mushkudiani (Georgian International University GIU), Natia Surmanidze (Ilia State University) and Giorgi Khidesheli (Georgian International University). *Time Series Forecasting of International Tourism Demand in Georgia: Evidence for Sustainable Planning.*

Abstract. Abstract

Tourism is one of the fastest-growing sectors of the global economy and plays a crucial role in economic development, employment generation, and regional competitiveness. In recent years, Georgia has experienced a notable increase in international tourist arrivals, highlighting the importance of reliable forecasting tools for effective tourism planning and policy-making. Accurate tourism demand forecasting enables governments, tourism organizations, and businesses to allocate resources efficiently, enhance infrastructure planning, and reduce uncertainty in strategic decisions.

This study aims to analyze the dynamics of international tourism demand in Georgia and develop a forecasting model using time series analysis. Historical tourism data are examined to identify long-term trends, seasonal fluctuations, and structural changes in tourist arrivals. The research uses statistics published by the Georgian National Tourism Administration to ensure the accuracy of analysis. Time series forecasting techniques are applied to estimate future tourism demand and assess the predictive performance of different models. Recent studies suggest that combining classical time series methods with modern data-driven approaches significantly improves forecasting accuracy in tourism markets.

The results of this research are expected to provide practical insights for tourism stakeholders, supporting evidence-based planning and enhancing the strategic management of tourism destinations. Additionally, these findings can contribute to sustainable tourism policies by enabling more precise predictions of future tourism flows and allowing destinations to respond effectively to global economic changes and tourism market dynamics.

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[9162] Francesca Papagni (University of Bergamo) and Emilio Zanetti Chini (University of Bergamo). *Measuring salience in macroeconomic time series.*

Abstract. This paper proposes a statistical framework to identify and measure salience in time series data. We focus on two fundamental dimensions of salience---surprise and prominence---and translate them into well-defined stochastic features. Surprise arises from localized and unexpected deviations from regular behavior, while prominence is associated with persistence and long-lasting patterns generated by strong temporal dependence. We show that these dimensions affect the spectral representation of a stationary process by introducing specific features. A general spectral model based on a power transformation of the spectral density allows us to interpret the selection of the power parameter from a weighted Whittle likelihood perspective and to detect salience-driven attention and its implications on expectations. Simulation evidence illustrates how the proposed approach discriminates between non-salient dynamics and salient time series behavior. A real-data application on inflation and consumer survey expectations shows how to identify salience-induced biases in inflation forecasts.

[9165] Dorin Radu (Faculty of Civil Faculty Engineering, Transilvania University of Braşov), Marijana Hadzima Nyarko (Faculty of Civil Engineering and Architecture Osijek, Josip Juraj Strossmayer University of Osijek, Croatia), Karlo Emmanuel Nyarko (Department of Computer Engineering and Automation at the Faculty of Electrical Engineering, Computer), Ercan Isik (Civil Engineering Department in Bitlis Eren University, Türkiye) and Eleonora Desnica (University of NoviSad, Serbia). ***Crack patterns using machine learning predictions on damaged unreinforced masonry walls.***

Abstract. Identifying potential crack patterns, discontinuities, and brittle failure modes in unreinforced masonry subjected to seismic and gravitational loads informs effective retrofit solutions. A range of traditional and contemporary materials and techniques provide compatible, reversible, and sustainable conservation options. Steel and timber tie-rods are frequently used to resist the horizontal thrust of arches, vaults, and roofs and to tie together elements like masonry walls and floors. Composite reinforcement—carbon and glass fibers embedded in thin mortar layers—can increase tensile capacity, ultimate strength, and ductility, reducing the risk of brittle shear failure.

This study reviews masonry structural diagnostics and contrasts conventional and advanced strengthening approaches for walls, arches, vaults, and columns. It also summarizes recent work on automated surface crack detection in URM walls, focusing on machine learning and deep learning methods.

[9196] Bo Liu (Huron University College). ***Does speed bump resolve the problems of mini flash crashes? Evidence from NYSE American.***

Abstract. In recent years, the emergence of mini flash crashes has become a distinctive concern within contemporary electronic trading markets, garnering attention from scholars, market participants, and regulators alike. These rapid, unforeseen market disruptions have been attributed to the breakneck pace of trading activity. This study employs data from the NYSE Trade and Quote database (TAQ) to examine the efficacy of implementing a "speed bump" mechanism in mitigating the risks associated with mini flash crashes. Utilizing machine learning techniques to estimate the likelihood of mini flash crashes occurring within the NYSE American market, this analysis offers empirical insights. The findings of this research demonstrate that the introduction of a speed bump mechanism can indeed reduce the probability of mini flash crashes. However, it is noteworthy that this mitigation strategy also leads to an influx of noise traders and bring slow traders back to the market, with positive market sentiment.

[9296] Marta Ferreira (Centro de Matemática, Universidade do Minho). ***Analysis of Extreme Nitrogen Dioxide Concentrations in European Capitals.***

Abstract. This study analyzes nitrogen dioxide (NO₂) concentrations in several European capital cities with the aim of assessing the risk of population exposure and comparing pollution levels across urban environments. NO₂ is a major air pollutant in Europe, largely emitted by road traffic and industrial activities, and is associated with adverse respiratory and cardiovascular health effects. Despite existing European air quality regulations, exceedances of recommended limits continue to occur, particularly during high-pollution episodes. Risk measures are estimated using extreme value theory, which enables inference on the tail behavior of the underlying distributions and allows extrapolation beyond the observed data. This approach is especially suitable for evaluating rare but potentially harmful pollution events that are not adequately captured by standard summary statistics. By focusing on extremes, the proposed methodology provides a robust framework for quantifying high NO₂ concentrations and their associated risks. The results highlight differences in exposure risk across European capitals and emphasize the importance of incorporating extreme value analysis into air quality assessments. Such studies are crucial for supporting evidence-based environmental policies and for identifying the need for targeted mitigation measures to reduce exposure and protect public health.

[9340] Iliuta Cumpanasu (West University Timisoara) and Cristina Strango (West University Timisoara).

Irregular Immigration and Smuggling at the Serbian Romanian Border: A Wavelet Approach.

Abstract. Irregular Immigration and Smuggling at the Serbian-Romanian Border, a Wavelet Approach

The paper analyses the link between irregular border crossings, smuggling crimes, and total irregular immigrants at the Serbian-Romanian border using wavelet methodology. It distinguishes between irregular and smuggled immigrants, covering data from January 2015 to December 2023.

The key findings evidence a positive co-movement between irregular immigrants and crossing cases in the short run, underlining the heightened migration pressure driven by conflicts and instability in migrants' home countries. Variations in smuggling activities and immigration policies demonstrate how smuggling networks adapt to fluctuating demands and law enforcement responses.

In the medium term, irregular crossings correlate with sustained increases in irregular immigration, indicating broader socioeconomic influences. However, a lack of significant long-term co-movement suggests that the dynamics of irregular migration and smuggling are reactive and contingent on immediate circumstances rather than following a predictable trajectory.

The policy implications of these findings are fourfold. First, the results offer valuable insights for stakeholders in border security and migration governance, particularly within the framework of the European Integrated Border Management initiative and the EU's new Pact on Migration and Asylum. Specifically, the observed positive co-movement between irregular immigrants and irregular border crossings highlights the need for enhanced border security measures as well as new border surveillance acquisition and deployment, during periods of increased migration pressure. Targeted efforts should prioritize identifying vulnerable individuals among irregular migrants, such as unaccompanied minors or those in need of international protection, while ensuring the protection of their fundamental rights. Second, the strong coherence between smuggling networks and irregular migration underscores the urgency of dismantling these networks through international cooperation, intelligence sharing, and operational measures. These efforts should be complemented by robust financial policies and collaborative agreements, particularly with non-EU countries of origin and transit. Third, the absence of long-term co-movements (beyond 32 months) suggests that these relationships are highly reactive and predominantly short-term. This finding has important implications for sustainable policy development, as it indicates that policies should not only respond to immediate migration pressures but also incorporate long-term resilience strategies. This includes addressing broader issues such as integration, technology, infrastructure development, and socio-economic support, especially in regions experiencing high levels of migration. Finally, the development of long-term solutions is crucial to avoiding repetitive cycles of short-term crisis management and fostering the sustainable governance of migration flows.

There are several future directions of research. The first direction should focus on a longitudinal analysis of smuggling networks across multiple countries to gain deeper insights into their evolution, organisational structures, and strategies over time. The second direction should examine how specific immigration policies implemented in neighbouring countries (e.g., Hungary and Croatia) affect smuggling routes and the behaviour of smugglers. The third direction should consider expanding datasets to include additional variables, such as demographics (age, gender and nationality), motivations for migration, and the conditions migrants encounter during their journey. Lastly, another important research direction should explore the potential impact of climate change on migration patterns, particularly regarding how environmental changes may compel individuals to turn to smuggling networks as they leave their home countries.

[9355] Juan Carlos Santana-Santana (Universidad de Las Palmas de Gran Canaria), José Juan Hernández-Gálvez (Universidad de Las Palmas de Gran Canaria), José Juan Hernández-Cabrera (Universidad de Las Palmas de Gran Canaria) and José Évora-Gómez (Universidad de Las Palmas de Gran Canaria). ***Propagating Input Uncertainty in Irregular Clinical Time Series.***

Abstract. Clinical time series data derived from electronic health records are inherently noisy, sparse, and irregularly sampled. While automated data extraction enables large-scale analysis, it introduces significant measurement uncertainty. Most existing time series models ignore this input uncertainty, treating observations as ground truth and producing deterministic or overconfident predictions that are highly problematic in clinical settings. To address this gap, we propose the Independent Feature-Specific State-Space Model (IF-SSM), an end-to-end probabilistic framework that explicitly incorporates and propagates input uncertainty through a temporal latent variable model. Rather than synchronizing variables into a single multivariate series, IF-SSM models each clinical characteristic independently, accommodating asynchronous sampling and preventing noise contamination across channels. Our framework employs a continuous-time generative model where temporal evolution scales with irregular time gaps, paired with an uncertainty-gated RNN for variational inference that weights inputs inversely by their measurement variance. Consequently, highly uncertain observations exert proportionally less influence on the learned latent state. By generating full predictive distributions via Monte Carlo sampling, the IF-SSM dynamically adapts its confidence, widening predictive intervals under sparse or noisy inputs and sharpening them when reliable data is available, providing a robust and principled foundation for real-world healthcare forecasting.

[9412] Hana Sulieman (American University of Sharjah) and Siva Durga Adduri (American University of Sharjah). ***Deep Learning-Based Models for Enhancing Air Quality Forecasting in the UAE .***

Abstract. Air pollution remains one of the most pressing environmental challenges of the 21st century, threatening not only ecosystem integrity but also human health and economic stability. In urban and rapidly industrializing regions, the rise in pollutant emissions from transportation, manufacturing, and construction has led to deteriorating air quality and increased exposure to airborne contaminants. Among the various pollutants, particulate matter (PM) has drawn particular attention because of its ability to travel long distances and penetrate deep into the human respiratory system. PM_{2.5}, comprising particles smaller than 2.5 µm, have been linked in the literature to respiratory and cardiovascular diseases, underscoring its role as a key environmental health hazard (Joshi et al., 2025).

This study examines air quality trends and meteorological interactions in four major Emirates of the UAE: Abu Dhabi, Dubai, Sharjah and Fujairah. PM_{2.5} concentration data were obtained from the National Center for Meteorology (NCM), United Arab Emirates. The dataset consists of daily PM_{2.5} concentration data from January 1, 2018, to December 31, 2024, for six monitoring stations across the four Emirates.

[9516] Jelena Stanković (Faculty of Economics, University of Niš), Vesna Janković-Milić (Faculty of Economics, University of Niš), Ivana Marjanović (Faculty of Economics, University of Niš) and Marina Stanojević (Faculty of Economics, University of Niš). ***Determinants of Urban Recommendability: Identifying Key Smart City Drivers.***

Abstract. Urban systems are increasingly assessed through “smart city” frameworks that conceptualise city performance across interrelated pillars, typically smart living, smart economy, smart environment, smart mobility, smart governance, and smart people (human and social capital). These dimensions correspond to distinct channels through which cities generate utility for residents: the availability of opportunities and services, the quality and accountability of institutions, the accessibility of daily activities, environmental conditions and sustainability, and the social and human capital that supports wellbeing and long-term prospects. While these pillars are widely used for monitoring and benchmarking, less attention has been paid to their role as predictors of residential endorsement in an explicit probabilistic choice framework. This paper proposes a probit-based approach to assess which perceived smart city dimension is most influential in shaping the likelihood that a city is recommended as a place to live. A binary indicator of residential endorsement is employed as the outcome variable (recommendation: yes/no), interpreted as a behavioural proxy for city attractiveness and “selection” in the sense of expressed willingness to endorse the city for living. The explanatory variables are constructed as perceived scores for the smart city dimensions, allowing the probability of endorsement to be modelled as a function of multidimensional urban perceptions. The main objective is to identify the relative influence of each smart city dimension on endorsement when the dimensions are considered jointly. To ensure meaningful comparisons across predictors in a nonlinear probability model, inference is planned to be based on average marginal effects, complemented by scenario-based probability changes under realistic shifts in each dimension (e.g., interquartile-range improvements). This provides an interpretable basis for ranking dimensions by their contribution to the predicted likelihood of recommendation. By linking smart city theory to a probabilistic endorsement model, the study contributes a transparent and policy-relevant tool for understanding which perceived urban domains most strongly shape residents’ stated willingness to recommend a city for living. The approach is designed to support prioritisation in smart city strategies by highlighting the dimensions with the greatest leverage on residential endorsement, thereby connecting multidimensional urban performance to an interpretable outcome that is meaningful for competitiveness, retention, and place-based development.

[9578] Yuvraj Sunecher (University of Technology, Mauritius), Naushad Mamode Khan (University of Mauritius), Muhammed Rasheed Irshad (Cochin University of Science and Technology) and Hendrik Willem Pretorius (University of Pretoria). ***A Non-Stationary BINAR(1) Model with 2 Poisson-Weighted Exponential Innovations.***

Abstract. This paper proposes a novel non-stationary first order bivariate integer valued autoregressive (BINAR(1)) model with Poisson-Weighted Exponential Innovations (BINAR(1)PWE). The marginal and joint moments of the model are derived. The model parameters are estimated using the conditional maximum likelihood (CML) estimation approach and the performance of the estimation method is tested through a numerical experiment. The proposed model is applied on some real life crime data.

[9709] Amine Hedroug (University of Montreal). ***Multi-Objective Hyperparameter Optimization for Recursive Ensemble Demand Forecasting.***

Abstract. Accurate demand forecasting requires not only precise estimates of future values but also reliable anticipation of demand direction. In this work, we propose a recursive ensemble-based forecasting approach tailored to tabular historical data, where both magnitude and directional correctness are explicitly considered during model optimization.

Our framework builds on an ensemble of supervised learning models trained on prior historical data and relevant explanatory variables. Model selection and tuning are performed through automated hyperparameter optimization (HPO), covering architectural and training-related choices, we introduce a composite objective defined as the harmonic mean between an absolute error measure and directional accuracy. This choice reflects a practical constraint of demand forecasting system: a model that minimizes numerical error while frequently mispredictions the direction of change can be misleading for planning and decision-making.

The harmonic mean acts as a balancing mechanism, strongly penalizing models that perform well on only one of the two criteria. As a result, the selected models exhibit more consistent behavior across different demand regimes, particularly around tuning points and short-term fluctuations. Empirical evaluation shows that this objective leads to forecasts that are more stable and obtained through conventional single-metric optimization.

Overall, this work highlights the value of multi-objective optimization for forecasting tasks and provides a simple, extensible methodology for improving the practical reliability of demand forecasting models.

[9746] Nerea Gómez Fernández (Universidad de Valencia) and Juan-Francisco Albert (Universidad de Valencia). ***Carbon Pricing and Its Uneven Impacts: Evidence from the EU ETS.***

Abstract. This paper evaluates the causal effects of the European Union Emissions Trading System (EU ETS) on the transport sector in Europe for the period 2005–2019. To overcome the inherent endogeneity of carbon prices, which reflect both regulatory decisions and macroeconomic fluctuations, the study employs a Structural Vector Autoregressive (SVAR) model identified through an external instrument approach. Specifically, it utilizes the carbon policy surprise series developed by Känzig (2023), based on high-frequency variations in emission allowance futures around 126 regulatory events. The analysis provides aggregate macroeconomic context for the Eurozone's five largest economies (Germany, Spain, France, Italy, and the United Kingdom) before examining sectoral dynamics.

The empirical results reveal that a carbon policy tightening shock immediately increases Eurozone energy prices and headline CPI while inducing a persistent reduction in greenhouse gas emissions and industrial production, with notable country-level heterogeneity. At the sectoral level, the core contribution of this study documents a highly differentiated price response across transport modes. Air and maritime transport prices exhibit the sharpest increases, both rising by approximately 4%, which significantly outpaces the general energy CPI response. Conversely, price adjustments in road and rail transport remain substantially more moderate. Furthermore, the surge in transport costs triggers a temporary contraction in flight volumes, primarily driven by significant reductions in Germany, France, and Spain.

Ultimately, these findings underscore the uneven distributional costs of climate regulations across transportation modes and highlight the necessity of designing targeted transitional mechanisms for economies as new sectors are progressively integrated into the EU ETS framework.

[9767] Jesus Riquelme (University Sevilla). ***Disaggregated Electricity Demand Forecasting using Machine Learning for the Day-Ahead Market and Energy Communities.***

Abstract. This work addresses the development and validation of Machine Learning models for electricity consumption forecasting with a focus on disaggregated demand. By utilizing high-resolution historical consumption data and meteorological variables, various architectures—ranging from linear regressions to neural networks and ensemble models—are evaluated to optimize accuracy over a 48-hour prediction horizon. The results highlight that the integration of exogenous variables, such as relative humidity and day-type categorization, along with non-linear models like the MLP (Multi-Layer Perceptron) and stacking techniques, significantly reduces predictive error. This provides a robust tool for energy management in small-scale environments.

[9848] Ganeshan Niroshan (Department of Computer Science and Engineering, University of Moratuwa, Sri Lanka). ***TS2Vec-Ensemble: An Enhanced Self-Supervised Framework for Time Series Forecasting.***

Abstract. Self-supervised representation learning, particularly through contrastive methods like TS2Vec, has advanced the analysis of time series data. However, these models often falter in forecasting tasks because their objective functions prioritize instance discrimination over capturing the deterministic patterns, such as seasonality and trend, that are critical for accurate prediction. This paper introduces TS2Vec-Ensemble, a novel hybrid framework designed to bridge this gap. Our approach enhances the powerful, implicitly learned dynamics from a pre-trained TS2Vec encoder by fusing them with explicit, engineered time features that encode periodic cycles. This fusion is achieved through a dual-model ensemble architecture, where two distinct regression heads—one focused on learned dynamics and the other on seasonal patterns—are combined using an adaptive weighting scheme. The ensemble weights are optimized independently for each forecast horizon, allowing the model to dynamically prioritize short-term dynamics or long-term seasonality as needed. We conduct extensive experiments on the ETT benchmark datasets for both univariate and multivariate forecasting. The results demonstrate that TS2Vec-Ensemble consistently and significantly outperforms the standard TS2Vec baseline and other state-of-the-art models, validating our hypothesis that a hybrid of learned representations and explicit temporal priors is a superior strategy for long-horizon time series forecasting.

[9892] Pedro Macedo (University of Aveiro), Jorge Cabral (University of Aveiro) and Vera Afreixo (University of Aveiro). ***Maximum entropy bootstrap for time series using generalized maximum entropy.***

Abstract. The maximum entropy bootstrap for time series (Vinod, 2006), implemented in the meboot package in R (Vinod and López-de-Lacalle, 2009), is a powerful technique that allows statistical formulations free from restrictive and unnecessary assumptions, by avoiding structural changes, unit root testing, and the usual shape-destroying transformations to achieve stationarity. The algorithm generates a large number of replicates, as elements of an ensemble, which retain the shape of the original time series, as well as the time dependence structure of the autocorrelation and the partial autocorrelation functions.

While the meboot has become a powerful tool for time series analysis, the estimation process in each replicated model is typically carried out using classical techniques, such as the QR decomposition, which may compromise statistical inference in ill-conditioned models (i.e., models affected by collinearity). Given this context, a stable estimation procedure is needed as an alternative to the use of classical techniques.

The generalized maximum entropy estimator (Golan, 2018) provides stable solutions in underdetermined or ill-conditioned regression models, by reformulating the parameters as expected values over bounded support spaces and maximizing Shannon entropy subject to the model and additivity constraints. Since the choice of the supports is always problem-specific and should be carefully chosen in real applications, some ongoing research to overcome this difficulty is discussed, including the development of a new package in R (Cabral et al., 2025).

This work presents and illustrates a two-stage maximum entropy approach (Macedo, 2024), where maximum entropy is used both in data replication (with meboot in a first stage) and in parameter estimation (with generalized maximum entropy in a second stage). Simulation results indicate that the generalized maximum entropy estimator is competitive with classical techniques in cases where data are reasonably well-conditioned and outperforms classical techniques in ill-conditioned scenarios. Some applications in economics and climate change science are also discussed. All these findings support the use of a unified entropy-based framework for improving statistical inference in time series regression models.

Acknowledgements and References

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[9932] Alessandro Cardinali (Universita' di Firenze). ***A Simulation study of Stabilized Logistic Predictions Under Separation.***

Abstract. Logistic regression is widely used for binary risk prediction, but complete or quasi separation can make maximum-likelihood fitting unstable and drive coefficients and fitted probabilities to extreme values. We present a stabilization idea based on suppressing weak-curvature directions in the local likelihood geometry and estimating only on the stable subspace. Using a simple exact-separation example and repeated train/test simulations with perturbed test sets, we show that stabilization yields less saturated probability estimates and substantially improves out-of-sample prediction once the test setting departs from exact separation.

[9979] Diego Nascimento (NEOMA Business School). ***Operations Management in retail with Industrial Statistics: an overview bridging Big Data forecasting and causal TS relation.***

Abstract. In the context of the Industrial process, supply chain forecast and monitoring integration are a competitive advantage in the Industry 4.0 era; nonetheless, it comes along with unique challenges that exponentially provide (un)structured data with great speed, volume, and complex dependence (e.g., spatial or temporal). New trends with AI tools have emerged, leveraging great computational processing power, creating the illusion that quality control/monitoring using SPC tools applied to time series (TS) will be left behind, as the entire process can now be viewed in real-time. This work provides reasoning for revising the causal time series through the visualization of symbolic SPC control charts, enabling the embedding of high-dimensional and complex systems in Big Data scenarios useful for Data Analytics and decision-makers. For that, an example will be presented from a real case of a Brazilian supermarket, using a dataset of 67 GB. For that, some advances on the multivariate TS will be presented, combining functional time series and a Dynamic Bayesian Network class of models. This enables its robust causal discovery (graph market basket), which takes into account the data dependence or marginal asymmetry, as well as coupling/decoupling dynamic TS learning, and its forecasting.

[9980] Bo Liu (Huron University College), Ke Xu (University of Victoria) and Xinwei Zheng (Deakin University). ***Machine Learning-Based Prediction of Mini Flash Crashes.***

Abstract. Mini flash crashes pose a significant risk in modern electronic trading markets, garnering attention from researchers, regulators, and traders. Using NYSE Trade and Quote data, we employ advanced machine learning to gauge their likelihood. Although predicting them is like forecasting earthquakes—unable to prevent, but aiding preparation—our findings highlight identifiable patterns preceding mini flash crashes. Machine learning proves highly effective in this prediction. This insight suggests the potential for an Early Warning System before circuit breakers activation. Additionally, we offer a list of microstructure signals predicting mini flash crashes.

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