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Welcome

Welcome to the Book of Abstracts for the 44th International Conference on Mathematical Methods in Economics (MME 2026). We are pleased to present a collection of selected contributions from researchers, academics, practitioners, and students working in the field of mathematical methods, economics, operations research, econometrics, optimization, and related areas.

MME 2026 continues the long tradition of supporting professional exchange and research cooperation. We hope that the conference will provide a stimulating platform for presenting new ideas, discussing current research challenges, and creating new academic connections.

We would like to thank all authors, reviewers, members of the program committee, and organizers for their valuable contribution to the preparation of the conference and this book of abstracts.

General Chair of MME 2026
František Zapletal
VSB – Technical University of Ostrava, Czech Republic

Invited Plenary Lectures

Dynamic Universal Approximation and Optimal Control for Non-Markovian Systems Via Signature Stochastic Differential Equations

Christa Cuchiero

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Many applications in generative time series modeling, particularly in finance, require stochastic dynamics that are genuinely path-dependent and non-Markovian. Classical Markovian state-space models are often too restrictive to capture memory effects, delayed responses, volatility feedback, and other features generated by the past trajectory of the system. From a numerical perspective, the most natural route is to lift path dependence to an enlarged state space, thereby obtaining a Markovian approximation of the original dynamics. Among such lifts, signature stochastic differential equations (SDEs) provide a canonical and model-agnostic choice, building on the strong algebraic and approximation-theoretic properties of path signatures, which form a universal and non-parametric feature set for paths. We explain how this leads to dynamic universal approximation results for generic non-Markovian SDEs. We also show how the resulting finite-dimensional signature SDEs can be used in optimal control problems with path-dependent dynamics and objectives, reducing, for instance, the infinite-dimensional Hamilton-Jacobi-Bellman PDE to a much simpler Riccati ODE.

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Who Sets the Price? Mathematical Models of Price Formation, Flexibility and Strategic Bidding in Electricity Markets

Stefan Trück

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The transition towards renewable electricity generation is fundamentally changing how wholesale electricity prices are formed. This presentation examines the evolving role of marginal generation technologies, the value of operational flexibility, and the strategic bidding behaviour of market participants in the Australian National Electricity Market. Using high-frequency market data and advanced econometric methods, we quantify flexibility premiums and show how generation portfolio composition influences bidding strategies and market-clearing prices. Finally, we introduce a theoretical model that explains the strategic interaction between flexible and renewable generation assets in competitive electricity markets. The findings provide new insights into electricity price formation and have important implications for market design, regulation, and the ongoing energy transition.

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Abstracts

Farkas' Lemma and the Bondareva-Shapley Theorem in the Infinite Case

David Bartl

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We present a generalization of Farkas' Lemma to handle infinite systems of linear inequalities in a purely algebraic way in an infinite-dimensional vector space, and we apply this result to show that the (additive) core of a cooperative TU-game with infinitely many players is non-empty if and only if the game is balanced; that is, we establish a generalization of the Bondareva-Shapley Theorem in a purely algebraic way, too. In detail, this generalization of Farkas' Lemma can be used to handle linear programming problems with an infinite number of linear inequality constraints, the primal variable space being any vector space of finite or infinite dimension over some linearly ordered (commutative or skew) field, such as that of the real numbers $\mathbb{R}$; no additional structure (such as topology or ordering) is assumed on the primal variable space. The objective function of the LP problem can attain its values in another linearly ordered vector space, whose structure may be richer than that of the original field. A constraint qualification, and yet a restriction, is put on the infinite collection of the constraints, however.

Keywords: Bondareva-Shapley Theorem, Farkas' Lemma, infinite systems of linear inequalities, infinite TU-games, core and balancedness of TU-games

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System Dynamics Model of Carbon Agriculture as a Complex Problem

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This paper presents a system dynamics stock-and-flow model implemented in Vensim for simulating carbon credit generation on a mixed crop-livestock farm. The model contains four stocks: Soil Organic Carbon (SOC, tCO2e), Soil Health and Fertility Index (0;1), Livestock Unit (LU), and Carbon Credits Available (tCO2e). Farm GHG emissions are computed from six IPCC-based sources: en-teric CH4 with feed quality adjustment, manure CH4 using weighted MCF across four management systems (IPCC, 2006), direct and indirect soil N2O with split emission factors for mineral and organic nitrogen (IPCC, 2019), fuel CO2, upstream fertilizer production emissions, and liming CO2. Credit issuance operates through two channels: verified net sequestration and verified emission reductions against a fixed baseline, each subject to a 5-year MRV (Monitoring, Reporting and Verification) delay. Soil health stock creates a reinforcing loop: improved fertility raises yields and biomass return, enhancing sequestration. Simulations over a 50-year horizon reveal that per-hectare sequestration de-clines from 1.2 to below 0.3 tCO2e/ha/yr as saturation binds, while the MRV delay creates an initial credit gap posing a financial barrier to adoption. Sensi-tivity analysis shows that raising practice adoption from 70% to 90% increases cumulative sequestration by 25% over 30 years, moderated by saturation.

Keywords: Carbon Credits & MRV Delay, Carbon Sequestration, GHG Emissions Soil Health & Fertility, Soil Organic Carbon (SOC), system dynamics modeling

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Solving the Fixed-Destination Open Vehicle Routing Problem Using Open-Source Tools

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Repeated delivery is a practical routing problem for nonprofit organizations, where reliability must be maintained with limited financial and planning resources. This paper addresses the reorganization of daily delivery routes for an urban nonprofit operation and formulates the case as a Fixed-Destination Open Vehicle Routing Problem (FDOVRP). Unlike the classical Vehicle Routing Problem or Open Vehicle Routing Problem, vehicles do not return to the depot after serving customers and the route endpoints are not freely selected by the optimizer. In this case, each vehicle starts at a common depot and must finish at the same predetermined headquarters node. The study combines mathematical modeling with a reproducible optimization workflow. A FDOVRP formulation defines the fixed start and terminal, customer assignment, flow conservation, and capacity constraints. Address data are geocoded with Nominatim and transformed into a directed travel-time cost matrix using the Open Source Routing Machine (OSRM). The full empirical instance is then solved with cuOpt and compared with the original routes used by the organization. The optimized solution reduced total travel time from 14,228.4 seconds to 12,266.5 seconds, saving 1,961.9 seconds, approximately 32.7 minutes, or 13.79%. The results show that meaningful process optimization can be achieved without increasing fleet size or relaxing the perational requirement of a fixed terminal. The paper contributes an FDOVRP formulation and demonstrates a actical, repeatable workflow based on open-source tools.

Keywords: Vehicle Routing Problem, Fixed-Destination Open Vehicle Routing Problem, route optimization, open-source

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Gradual Optimizing a Sustainable Investment Portfolio: Sequential Mean-Semivariance-ESG Model

Adam Borovička

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The two-factor view of investment, as a cornerstone of modern portfolio theory, has recently been challenged by the concept of sustainability. It is therefore advisable to expand an investor's risk-return profile to include an ESG (Environmental, Social, and Governance) perspective. Mean-risk models are then expanded into a three-objective form. This modification also applies to a well-known mean-semivariance model, which does not penalize positive deviations and is not limited by potential non-normality in the return distribution. The mean-semivariance-ESG model, however, reflects all three characteristics simultaneously. The final investment decision is thus largely dependent on the investor's additional preferences, typically in the form of threshold values or the weights of the objectives, which may be uncomfortable for some, particularly less experienced individuals.

Not only in the Czech environment, the growing popularity of sustainability, or social impact, has not yet reached a similar level of importance as return and risk characteristics. Simultaneous consideration of these characteristics may therefore not be a necessary optimization path. This assumption allows for the development of a sequential mean-semivariance-ESG model. First, the set of efficient portfolios is defined using a "classical" mean-semivariance model. Subsequently, an investment with the maximum level of the ESG metric is identified within this space. This approach therefore does not require any additional investor preference in the three-objective space. The user-friendliness of the proposed approach of gradual optimization is demonstrated in a case study on the selection of a portfolio of highly popular mutual funds. The empirical results of non-traditional sequential and conventional simultaneous optimization procedures are critically compared.

Keywords: ESG, mean-semivariance, mutual fund, portfolio, sequential

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Seasonality and Trend in Multiproduct Inventory Volumes Data Testing and Cost Modelling

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We examine multi-product sales seasonality to identify its volatility/dynamics cost and sum with classical stationary single-period inventory expected cost function. Two-way ANOVA is applied to trend and seasonality testing in prod-uct quarterly volume sales that can face both effects, one of them or none. Em-pirical case study of tyres and wheels equipment category for agriculture is ana-lyzed. The minimal expected cost model is formulated. Instead solving it, we evaluate its upper bound as the expected cost of lost sales, overstock and sea-sonality for forecasted sales feasible solution. We show that seasonality cost per product equals 0-7% and increasing in a product price, demand/order and the seasonality deviation. For all product the cost accounts for 3%. Product pooling that compensates interseason variability leads to lower cost.

Keywords: seasonality, trend, two-way ANOVA, sales forecasting, single-period inventory, expected cost of inventory

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Digital Development, Governance Quality, and Income Inequality: Empirical Evidence from Vietnamese Provinces

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This study examines the impact of Information and Communication Technology (ICT) and institutional quality on income inequality cross 63 Vietnamese provinces over the period 2018–2022. The System Generalised Method of Moments (System GMM) is employed as the main estimator to address endogeneity and dynamic effects. The results indicate that ICT development significantly reduces income inequality, as measured by the Gini coefficient. Institutional quality, proxied by the Provincial Governance and Public Administration Performance Index (PAPI), also contributes to lowering inequality. Furthermore, institutional quality strengthens the inequality-reducing effect of ICT through a significant moderating role. Key governance dimensions such as transparency, accountability, and corruption control play a crucial role, whereas citizen participation and public service delivery are not statistically significant. These findings emphasize the importance of combining digital development with institutional improvement to promote inclusive growth.

Keywords: ICT, income inequality, institutional quality

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Some Stochastic Properties of Elo and Related Rating Systems in Sports Statistics

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In many sports disciplines, players are assigned a rating that is defined as a certain function the results of matches the player has played in the past. When a player plays another match, it is assumed that the increase/decrease of their rating after a win/loss depends on the difference between their rating and that of the opponent. The well-known Elo rating system (Elo rating, ER) then defines a rule for updating the player's rating according to the game outcome. If the game outcomes are treated as random variables, ER generates sequences of players' ratings which can be viewed as time series. First we will derive some of the series' statistical properties. For example, we will show what happens if the true probability of winning differs from the probability implied by the player's rating. It turns out that there exists a certain weak form of mean reversion. We also illustrate some undesirable properties, in particular a certain form of asymptotic inconsistency, which in the long run unfairly favors strong players and penalizes the weak. We further show that ER with the logistic link function is equivalent to a special case of a GAS (Generalized Autoregressive Score) time-series model containing the autoregression term and the so-called score term (here, score stands for the gradient of log-likelihood of the outcome generating distribution). This result has interesting consequences: it makes it possible to construct generalized ER systems even for games where the match outcome may be more complex than simple 0-1 win/loss information. For example, these generalizations, called score-based rating systems, include outcomes such as "winning by five goals", "finishing second in a race of six runners", "finishing second with a five-second gap behind the winner", or a match whose outcome is a general permutation of the set of players.

Keywords: time series, sports rating systems, generalized, autoregreesive score, Elo rating

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Spatial Patterns of Household Internet Access in EU Regions: An ESDA Approach

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This paper uses Exploratory Data Analysis (EDA) and Exploratory Spatial Data Analysis (ESDA) to analyse regional disparities in household internet access across European Union regions in 2025. The aim of the paper is to identify spatial patterns, evaluate spatial autocorrelation, and detect clusters of regions with similar levels of internet accessibility. The analysis is based on Eurostat regional data and was carried out using the GeoDa software environment. The methodological framework combines descriptive visualisation techniques with spatial statistical methods, including the Moran's I statistic, the Moran scatterplot and Local Indicators of Spatial Association (LISA). The results reveal significant territorial disparities in household internet access and confirm statistically significant positive spatial autocorrelation (Moran's I ≈ 0.441), indicating moderate to strong spatial clustering of internet accessibility across EU regions. High-access regions are concentrated in Northern and Western Europe, while low-access clusters are primarily located in Southern and Eastern Europe. These findings suggest that digital inequalities within the European Union have a strong geographical dimension, highlighting the importance of spatial analytical approaches for evaluating regional digital cohesion and territorial disparities.

Keywords: spatial autocorrelation, EU regions, household internet access, regional disparities

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Deep Reinforcement Learning for Perpetual Futures Market Making

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This paper studies market making in BTC and ETH perpetual futures with a simple event-driven reinforcement-learning setup. PPO chooses quote skew and quote width, while the environment tracks execution gains and inventory losses separately. A temporary reduction of the adverse-fill penalty is used as an intended stabilizing device during early training. Across simulated and historical data, PPO quotes more selectively, carries smaller inventory, and usually ends with better portfolio value than a zero-action baseline. BTC is tighter than ETH, so the same control logic requires market-specific calibration, yet the qualitative policy behavior remains consistent across both markets. The results are therefore encouraging in a narrow sense: a compact and interpretable RL policy can improve inventory control and overall portfolio outcomes in two different crypto perpetual environments, even though robust profitability claims remain out of scope

Keywords: deep reinforcement learning, market making, perpetual futures, Proximal Policy Optimization

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Investment Timing and Strategic Interaction in Cross-Border M&A: A Real Options Perspective

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Cross-border mergers and acquisitions (M&A) are exposed to firm-value fluctuations, exchange-rate risk, and uncertainty over technological synergies, making acquisition valuation and timing dynamic. The objective of this paper is to develop an integrated real-options framework that jointly analyzes optimal investment timing and strategic interaction in cross-border M&A. The acquisition opportunity is formulated as a pre-commitment option to defer and is solved using the Least-Squares Monte Carlo (LSMC) method. The benchmark model is implemented on a discrete monthly grid with risk-neutral drift restrictions for traded market-based variables. A bargaining mechanism is further introduced to capture surplus sharing between the acquiring and target firms. Using the Siemens–Altair acquisition as an illustrative high-technology cross-border case, the results show substantial option value and delayed, state-dependent acquisition commitment. The baseline acquisition option value is approximately EUR 1.22 billion, with an average exercise time of 1.5410 years and an exercise probability of 39.51%. Sensitivity and robustness analyses indicate that the main findings are driven primarily by firm-value dynamics, volatility, and technological synergy, while bargaining reduces the value retained by the acquirer with limited impact on timing. The paper contributes to the M&A literature by integrating real-options timing, exchange-rate exposure, technological uncertainty, and strategic bargaining within a unified framework

Keywords: real options, mergers and acquisitions, game theory

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ANP in Network Revenue Management

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The Analytic Network Process (ANP) is an approach to modeling and solving network models. Revenue management (RM) is a process aimed at understanding, predicting, and influencing consumer behavior in order to maximize revenue. The goal is to sell the right resources to the right customer at the right time for the right price through the right channel. Network revenue management models seek to maximize revenue when customers purchase bundles of multiple resources. An ANP-based framework is presented for structuring RM problems and combining specific methods. RM addresses three basic categories of demand management decisions: pricing, quantity, and structural decisions. Specific models are used to model and solve basic RM decisions. Solution combinations are determined by subnetworks in the ANP model.

Keywords: network revenue management, Analytic Network Process, Sub-networks

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Price of Inertia in Emergency Medical System Adjustment

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Emergency Medical Service systems play a crucial role in providing timely pre-hospital care, making the optimal deployment of ambulance stations essential for minimizing response times and improving accessibility. Traditional location models formulate this task as a weighted p-median problem and seek an entirely new optimal deployment of ambulances. However, these approaches generally overlook practical constraints associated with reorganizing existing systems, where relocating established stations is often costly, politically sensitive, or operationally infeasible. This paper introduces a novel optimization framework for evaluating the Price of Inertia in emergency service planning. The proposed approach preserves the current deployment of ambulance stations and determines the minimum number of additional ambulances required to achieve the service quality of a fully optimized network. The mathematical model is based on an enhanced radial formulation incorporating generalized disutility to account for the stochastic availability of ambulances and allowing multiple ambulances to be located at a single site. The Price of Inertia is interpreted as the operational penalty incurred by maintaining the existing infrastructure instead of implementing the optimal redesign. Unlike conventional measures based solely on performance loss, the proposed framework quantifies inertia in terms of the additional resources needed to compensate for relocation constraints. The methodology provides decision makers with a practical tool for strategic emergency medical service capacity planning by balancing service quality improvements against the costs and challenges of network reconfiguration.

Keywords: location problems, emergency services, optimization, price of inertia

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Dynamic Portfolio Optimization Based on Volatility-Adaptive LSTM and Tail-Dependence Topological Network

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Traditional portfolio optimization relies on covariance structures and has limited ability to capture co-movement under extreme market conditions and higher-order dependencies among assets. This study proposes a dynamic portfolio optimization framework integrating volatility-adaptive deep learning and topological network analysis. Its contribution lies in embedding forward-looking return prediction and higher-order network features into the asset allocation process. A volatility-adaptive LSTM model is developed to generate return forecasts responsive to market uncertainty. A tail dependence network is constructed by distinguishing left-tail and right-tail events in return series, and simplicial complexes are used to extract triangular and void structures among assets. Topological features are incorporated into the objective function as penalty terms, extending the traditional framework. Rolling out-of-sample backtesting compares strategies based on historical and prediction-derived information. Empirical results show that incorporating tail-based topology mitigates risk concentration and improves drawdown, while prediction-based strategies enhance risk-adjusted returns. The findings indicate that combining volatility-aware forecasting with higher-order dependency structures an provide a useful extension for asset allocation under extreme market conditions.

Keywords: long short-term memory, network topology, portfolio optimization, risk management, tail dependence

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Early Warning of Sovereign Credit Risk in BRICS: A Comparative GARCH-Based Analysis

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This paper examines the volatility characteristics and early warning signals of sovereign credit risk in Brazil, Russia, India, and China (BRIC) using the GARCH model. This paper uses differences in 10-year sovereign bond yields relative to U.S. 10-year Treasury yields as a proxy for market-based sovereign credit risk and estimates country-level GARCH (1,1) models for BRIC. The study focuses on transforming GARCH conditional variance into risk warning signals based on quantile thresholds, thereby constructing a simple, transparent, and interpretable framework for monitoring sovereign credit risk. Empirical results indicate that changes in sovereign credit spreads across BRIC countries exhibit distinct characteristics of conditional volatility and cross-country heterogeneity. Further quantile-based early warning results also identify the months of extreme volatility in each country's financial markets. Overall, GARCH-based conditional volatility provides a straightforward early-warning tool for assessing sovereign credit risk in emerging economies. However, its interpretation should take into account cross-country heterogeneity and the limitations inherent in volatility-based modeling.

Keywords: sovereign credit risk, sovereign yield spreads, GARCH conditional volatility, BRIC economies, quantile-based early warning

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A DEA-Bootstrap Framework for Assessing Educational Quality in Industrial Engineering Programs

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Higher education in Colombia has faced various challenges regarding the quality and efficiency of its programs, specifically in degrees such as the Bachelor's in Physical Education and the Sports Degree. General objective: To analyze the value added generated by the Bachelor's in Physical Education and Sports Degree programs at Colombian universities. Method: This study employed a positivist paradigm, a non-experimental approach, and a quantitative methodology. The research was conducted with a population of 332,993 students, of whom 3,936 were enrolled in the Bachelor's in Physical Education program and 2,912 in the Sports Degree program, at Colombian universities who participated in the Saber 11 and Saber Pro standardized tests between 2013 and 2023. Statistical methods such as PCA and cluster analysis were applied for these years, grouping the universities according to their performance. Data was obtained through the ICFES Data portal, and R software was used to analyze and integrate the databases. Main results: The main results showed that some universities with low test scores achieved high efficiency in resource use. However, important areas were identified, such as written communication, which significantly impacted exam results. Conclusion: This study highlights the importance of applying rigorous statistical tools to evaluate the added value of academic programs, achieving continuous and systematic improvement in educational quality and student training.

Keywords: DEA, efficiency, higher education, sports

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Dynamic Relationship of Green Economics: Renewable Energy Consumption, CO2 Emissions, Real GDP and Oil Prices in European Union Countries

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This paper examines the short-run dynamic relationships among economic growth, CO2 emissions, and renewable energy consumption within a Panel Vector Autoregressive (PVAR(1)) framework estimated by GMM. The analysis is complemented by Granger causality tests and orthogonalized impulse response functions (IRFs) to capture direction, magnitude, and persistence of interactions. The results reveal that economic growth exerts a negative short-run effect on renewable energy consumption, indicating that increasing energy demand is still primarily satisfied by fossil fuels. In contrast, economic growth has a positive and statistically significant impact on CO2 emissions, confirming the persistence of the growth–emissions nexus. Furthermore, a bidirectional relationship between GDP and CO2 emissions is identified, suggesting a feedback mechanism where emissions reflect energy-intensive production and simultaneously support economic activity. IRF analysis confirms that these effects are strongest in the initial periods and gradually converge, indicating short-run adjustment and system stability. In general, the findings are consistent with the existing literature and highlight that renewable energy expansion does not automatically follow economic growth but depends on structural and policy factors. The results underscore the need for active policy interventions that focus on decoupling economic growth from environmental degradation and accelerating the transition toward a low-carbon economy.

Keywords: PVAR, economic growth, CO2 emissions, renewable energy, EU countries

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Structural Factors Influencing AI Copyright Literacy: A Quantitative Analysis from an Academic Survey Study

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Artificial intelligence systems are increasingly integrated into academic work. Legal boundaries concerning copyright and AI use are still evolving within the EU and Czech legal context. This situation increases the risk of unintentional copyright violations.

The questionnaire survey, conducted primarily within the academic environ-ment of the University of Pardubice, collected information on participants' AI literacy, their awareness of risk factors, and their knowledge of internal AI regulations.

The main objective is to quantify the effects of selected determinants on AI re-lated behavior and compliance. Dependent variables include AI use intensity, copyright literacy scores, and compliance and disclosure indicators. Independ-ent variables cover demographic attributes and structural characteristics of re-spondents.

The findings indicate that copyright-related AI literacy in the academic environment is not significantly influenced by respondents' individual characteris-tics, but rather by structural factors, especially disciplinary orientation. Policy measures should therefore focus on discipline specific guidelines and institu-tional frameworks.

Keywords: AI Copyright Literacy, AI use intensity, Quantitative Survey Methods, Non-parametric Inference Analysis

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How Robust Is Your Solution? Simultaneous Tolerance Analysis in Linear Programming

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Tolerance analysis is a vital technique in sensitivity analysis used to determine the maximum allowable simultaneous and independent variations of cost coefficients in a linear programming (LP) problem that preserve the optimality of a given solution. While standard approaches often rely on optimal basis invariancy, these methods are computationally efficient but frequently fail to provide the largest possible tolerances, particularly in the presence of degeneracy. In our presentation, we will address the challenge of determining the true maximum tolerances, a problem known to be NP-hard. We strengthen this complexity result by proving that the maximum tolerance is also inapproximable within a specific accuracy.

To address these computational difficulties, we propose novel characterizations of the maximum tolerance based on both normal and tangent cone properties. Utilizing these characterizations, we develop a new method to derive efficient lower and upper bounds with guaranteed accuracy. Furthermore, we introduce an iterative lower bound method that sequentially improves upon initial tolerances derived from an optimal basis. We demonstrate that our framework can be naturally extended to scenarios involving linear dependencies between cost coefficients. The effectiveness of the proposed bounds and iterative methods is evaluated through a comprehensive numerical study involving randomly generated highly degenerate examples, standard Netlib LP problems, and a production planning case study. The results highlight the limitations of basis-based approaches and the superior performance of the proposed bounding techniques in identifying stability regions for optimal solutions.

Keywords: linear programming, sensitivity analysis, tolerance analysis, robustness

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Mitigating Conflict in Fair Sharing via Resource Design

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The fair sharing problem concerns dividing resources among multiple parties so that each party feels it received a fair share according to its own valuation. We study the problem in a specific setting in which resource availability is interval-based rather than a fixed amount. The aim is then to find the ideal amounts of resources within given interval bounds that would preferably eliminate or mitigate the conflict between receiving parties. The resources are often held by an authority which from their own perspective are subject to given (unit) costs and therefore the authority seeks to set up such an arrangement of the resources within its available budget. We formulate the problem as a multiobjective optimisation problem and consider different fair-sharing problem settings: with or without classic envy-freeness among parties, and with different goals – utilitarian or egalitarian. We present an illustrative computational example on the synthetically generated data. The results suggest that, by identifying an appropriate resource structure within the admissible bounds, it is possible to improve the attained level of fairness relative to the original configuration.

Keywords: fair sharing, multiobjective optimisation, resource design

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Granularity-Adjusted ACD Model for Trade Duration Heaping in Foreign Exchange Markets

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We develop a granularity-adjusted autoregressive conditional duration (GA-ACD) model to account for the concentration of trade durations at integer values in high-frequency foreign exchange data. The model introduces a two-part mixture distribution comprising a generalized gamma component for ordinary durations and a heaping component that reallocates probability mass around integer times through a truncated normal distribution. This specification captures temporal granularity effects while preserving a flexible duration distribution. Conditional dynamics are modeled in a score-driven framework, which allows the scale parameter to evolve over time in response to past durations and permits maximum likelihood estimation of all parameters. Empirical results indicate that integer-duration clustering is widespread across major currency pairs, whereas more exotic pairs exhibit more varied heaping patterns. Relative to the standard ACD model, the GA-ACD model provides a substantially improved fit, capturing both the distributional shape and the conditional hazard structure of trade durations more accurately.

Keywords: high-frequency data, Autoregressive Conditional Duration models, score-driven models, foreign exchange markets, trade duration heaping

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Mathematical Foundations of Modern Scientometric Indices

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Measuring the quality of scientific output remains a highly relevant and widely discussed topic. The pioneering approach to comparing researchers was introduced by [**?**] specifically for the field of physics. This metric, globally recognized as the h-index, has gained immense popularity across diverse scientific disciplines. Due to its versatile mathematical domain, the index effectively merges a researcher's productivity and impact—represented by non-negative integers—into a single numerical value.

Mathematically, [**?**] demonstrated that the h-index is a special case of the discrete Sugeno integral with respect to the counting measure. However, despite its popularity, the h-index exhibits several limitations, as detailed by [**?**]. To address these flaws, the authors proposed enhancements known as the *upper* and *lower* 2-h-index. Other notable alternatives in the literature include indices by [**?**, **?**], which connect to the Sugeno and Shilkret integrals, and a measure-modified approach by [**?**]. Comprehensive generalizations of these findings are provided by [**?**].

Keywords: scientometry, indices, nonadditive integrals

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Assessing SDG 11 Efficiency in Czech Regions: An Iterative BoD-DEA Approach with Weight Restrictions

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Assessing Sustainable Development Goals (SDGs) at the regional level requires robust quantitative tools capable of aggregating multidimensional indicators into meaningful composite indices. This paper focuses on SDG 11 (Sustainable Cities and Communities) and evaluates the technical efficiency of the 14 Czech regions over the 2016–2023 period. Given the broad framework of SDG 11—encompassing housing, transportation, environment, and public services—constructing a robust model necessitates a systematic selection of representative indicators from an extensive initial dataset. The indicators were selected based on a literature review and categorized into seven sub-domains reflecting targets 11.1–11.7. To maintain the model's discriminatory power, an algorithm was employed to systematically select one variable from each sub-domain, generating all possible indicator combinations. These combinations served as input data for a Benefit-of-the-Doubt (BoD) DEA model assuming constant returns to scale (CRS). Each combination formed an individual model, with the final efficiency score calculated as the arithmetic mean of all iterations. To ensure a balanced perspective, weight restrictions were incorporated, limiting the influence of each indicator to a range of 5% to 30% of the overall assessment. Empirical analysis reveals high efficiency levels in the Karlovy Vary Region and widening gaps between the most and least successful regions, as well as distinct disparities between eastern and western parts of the country. In 2023, the Karlovy Vary Region achieved the highest efficiency (0.97), while the Olomouc Region recorded the lowest (0.37). This study contributes to the discussion on enhancing the discriminatory power of models in the field of sustainable development and provides a framework for data-driven regional management.

Keywords: sustainable development, SDG 11, DEA, benefit of the doubt, regional efficiency, Czech Republic

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Asymmetric Evaluation of Experts Opinions Considering Their Relevancies to the Evaluated Proposals or Candidates

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In multi-criteria decision-making, criteria weights are typically assigned by experts. On the other hand, we have situations that should reflect differences in experts' competence, reliability, or prior achievements in relation to the alternatives or candidates under consideration. Addressing this issue is both important and challenging, particularly because conventional aggregation operators, such as the weighted arithmetic mean, may be insufficient for capturing such expert-dependent distinctions. In this paper, we propose an approach in which experts are divided into two categories: top experts and regular ones. Their opinions, votes, or assigned scores are aggregated by means of an asymmetric conjunction operator. Under this approach, the agreement of a majority of top experts is treated as a primary requirement, while the agreement of a majority of regular experts provides additional support. The applicability of the proposed method is demonstrated through voting and evaluation examples. The paper concludes by outlining the advantages of the approach, its limitations, and possible directions for further research.

Keywords: alternatives, asymmetric aggregation, experts categories, experts votes

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Strategic Behavior under Production Quotas: The Case of OPEC

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This paper analyzes the strategic behavior of OPEC member states in an environment of production quotas using a static non-cooperative Cournot–Nash game-theoretical model. Unlike aggregate approaches, OPEC is modeled as a set of heterogeneous producers with different costs and fiscal pressures. The results show that quotas without enforcement lead to overproduction and falling prices, while penalties for violations partially stabilize the market. The disciplining role of the dominant producer proves to be an insufficient substitute for formal mechanisms in a static framework. Fiscal pressure encourages overproduction, while increasing cost convexity acts as an endogenous stabilizing factor. The study offers an analytical framework for examining internal tensions within OPEC and highlights the limitations of static models in analyzing cartel coordination.

Keywords: game theory, OPEC, Cournot-Nash, oil market

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Two-Stage Serial DEA Models: A Review and Super-Efficiency Extensions for Complete Ranking

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This study focuses on examining efficiency and performance within two-stage serial data envelopment analysis (DEA) frameworks. A widely used method for assessing this type of network process is the model introduced by Kao and Hwang (2008). However, a notable limitation of this model is that it often fails to identify any decision-making unit (DMU) as fully efficient in typical applications. To address this issue, alternative models have been developed specifically to overcome this shortcoming. The primary objective of this paper is to provide a comprehensive review of the key models applicable to two-stage serial network processes. Additionally, wherever feasible, the study proposes extending these models by incorporating a super-efficiency feature, enabling a complete ranking of all DMUs. To demonstrate the practical application of these approaches, the paper presents an empirical evaluation involving 22 DMUs, each characterized by two inputs, two intermediate measures, and two outputs. The results highlight the differences among the models and illustrate the benefits of including super-efficiency in network DEA analysis.

Keywords: data envelopment analysis, two-stage model, super-efficiency ranking

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Minimal Change of Ambulance Deployment to Reach Given Quality of Service

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This paper reformulates the original problem of optimal ambulance location with the aim of minimizing the average response time of the associated emergency medical care system. The reformulation consists in taking into account the existing ambulance location, which should be changed as little as possible. In this way, the change in the original fleet location is minimized, assuming that a given reduction in the average response time of the system is achieved. Since the reduction is limited by the optimal average response time obtained by unrestricted reallocation of the ambulance fleet, the prescribed value of the response time reduction is chosen from values between the current and the optimal response times. The computational study indicates the magnitude of the ecessary changes in the current ambulance location and the required improvement in the average response time.

Keywords: location science, mathematical modelling, optimal ambulance deployment, quality of service access

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Robust Regression of Human Resources and Labor Market Dimensions of TTDI

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This paper investigates the performance of a robust regression framework based on recently proposed methods, including least weighted squares (LWS), its regularized extension LWS-lasso, and a robust coefficient of determination. Although these methods have recently been introduced, their statistical properties and practical performance under data contamination have not yet been systematically investigated. We study the behavior and stability of these methods under contamination by outliers and local noise, comparing their performance with competing estimators. The analysis highlights the advantages of robust approaches in regression settings where classical methods may lead to unstable conclusions. As an empirical illustration in the context of composite indicators, we apply the framework to the Human Resources and Labor Market sub-pillar of the Travel and Tourism Development Index for 119 countries.

Keywords: robust linear regression, least weighted squares, robust coefficient of determination, outliers, multicollinearity, human resources

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Predicting Prices and Discovering Structure in Magic: The Gathering Card Data

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The secondary market for Magic: The Gathering cards represents a mature example of a collectibles market where prices are shaped by a combination of intrinsic card properties, gameplay relevance, and external demand signals. This paper presents an analysis of Magic: The Gathering card data with two complementary objectives: (i) predicting card prices on the secondary market using machine learning models, and (ii) identifying latent structural groupings of cards through clustering techniques.

Using publicly available card metadata from the Scryfall bulk dataset augmented with secondary market price information, we construct a feature–rich dataset capturing card rarity, mana cost, color identity, card type, and textual characteristics derived from rules text. For price prediction, we build linear regularized regression model. To explore the underlying structure of the card space, we apply a price-driven segmentation based on a regression tree model.

Keywords: collectible card games, secondary market pricing, regression tree, market segmentation

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The Economic Impact of Natural Disasters on NUTS2 Regions in EU

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We explore the association between acute physical risk and economic growth in NUTS2 EU regions. Information on natural disasters is obtained from the EM-DAT dataset. The regressor of main interest is the number of climate-related disasters in the region during the year. Regional economic data are sourced from the Eurostat database. The baseline fixed-effects model showed a weakly significant positive effect of natural disasters on GDP per capita growth in NUTS2 regions. However, the results are not robust against cross-sectional dependence and serial correlation. To address these problems, we use common orrelated effects estimators and find that, after accounting for them, the effects of natural disasters on NUTS2 EU regions are not statistically significant.

Keywords: climate risk, economic growth, natural disaster, panel data

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Missing Data and Inference in Survey-Weighted Ordered Logistic Models

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This paper examines how alternative missing-data treatments influence statistical inference in survey-weighted ordered logistic regression models. Using pooled data from the Health Behaviour in School-aged Children (HBSC) study across 22 European Union Member States, the analysis compares complete-case estimation with two multiple imputation approaches: Multiple Imputation by Chained Equations (MICE) and a machine-learning-based framework combin-ing Light Gradient Boosting Machine with predictive mean matching (LGBM-PMM) implemented via the miceforest package. The comparison focuses on co-efficient stability, inferential consistency, estimation precision and measures of missing-data uncertainty. All 18 substantive coefficients retained their signs across the three specifications, while one coefficient that was not significant in the complete-case model became statistically significant under both imputation approaches. LGBM-PMM produced higher standard errors on average and sub-stantially greater missing-data uncertainty, reflected in a higher average RVI and a larger maximum FMI, than conventional MICE. The findings indicate di-rectional stability but not complete inferential equivalence across missing-data treatments and support the comparison of alternative imputation approaches as a sensitivity analysis in incomplete complex survey data.

Keywords: missing data, multiple imputation, machine-learning imputation, complex sur-vey data, survey-weighted ordered logistic regression

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Integrated Job Shop Scheduling and Bin Packing Problem

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Production scheduling in customised manufacturing represents a critical challenge within manufacturing systems management. Among various operational models, the Job Shop Scheduling Problem (JSSP) is widely utilised due to its ability to handle heterogeneous job routing. While JSSP typically involves single-piece or small-lot production, it frequently incorporates batch-processing stages, such as raw material cutting, chemical treatment, or packing. Existing scheduling models often simplify batching into a one-dimensional capacity constraint; consequently, the multi-dimensional complexities of spatial product placement within a batch are neglected.

This paper addresses the integration of an orthogonal free-space 2D Bin-Packing Problem (2D-BPRF) into the JSSP framework. It proposes an extension of standard models for both domains, enabling the JSSP to formally accommodate the simultaneous processing of multiple jobs within a single batch based on spatial feasibility.

Furthermore, a multi-stage constructive heuristic is proposed to generate feasible schedules by integrating sequencing, batching, and spatial allocation logic. The performance of priority-based dispatching rules is evaluated against an Evolutionary Algorithm to assess trade-offs between computational efficiency and solution quality, as measured by job tardiness. To validate the methodology, new benchmark instances were synthesised from JSSP and 2D-BPRF data, addressing both real-world constraints and theoretical optimisation needs.

Keywords: Job Shop Scheduling, 2D Bin packing, Evolutionary Algorithm, heuristics

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Spatial Dynamic Model on Hierarchical Panel Data: Basic Log-likelihood Properties

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This paper develops a hierarchical panel data model with spatial dependence in both the dependent variable and the random component. The specification allows spatial dependence to vary across first-level cross-sectional units and incorporates spatial and spatio-temporal dynamics, as well as time-invariant fixed effects. The corresponding log-likelihood function is formulated, and its key analytical properties are derived, including the score vector and Hessian matrix. The asymptotic distribution of the score is then established, together with the Fisher information matrix. These results provide the theoretical basis for ongoing work on bias correction for the associated quasi-maximum likelihood estimators.

Keywords: spatial and temporal dynamics, spatial heterogeneity, hierarchical panel model, maximum likelihood estimation, fixed effects

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The Use of a Two-Step Decomposition Approach in Service Vehicle Routing Planning

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Route planning for service vehicles is one of the core responsibilities of every dispatcher. Given that individual routes are desirable to be optimally designed based on selected criteria, it is advisable to use quantitative decision-support tools for this purpose. When planning a single route, it is generally assumed that the total demand from customers located at the various nodes of the transport network is less than or equal to the capacity of the service vehicle. However, in many realworld cases, this condition cannot be met, and it is necessary to use one of the appropriate approaches to solve the problem. This paper focuses on the use of a two-step decomposition approach, which falls within the subset of methods known as Cluster First – Route Second. Using this approach, it is possible to decompose the initial set of requirements into subsets within which partial routes are then proposed. The two-step decomposition approach is implemented using linear programming and is tested on both sample and real-world data. The results of these computational experiments are presented in this paper.

Keywords: vehicle routing planning, cluster first-route second, linear programming, waste management, optimization

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The Impact of GDP, Inflation, Industrial Employment, and Trade Openness on Foreign Direct Investment in the Visegrad Group Countries

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This paper analyses the impact of selected macroeconomic indicators on foreign direct investment (FDI) in the Visegrad Group countries (the Czech Republic, Hungary, Poland, and Slovakia) during the period 2000–2025. The analysis applies the Panel ARDL model together with country-specific Bounds tests to investigate both short-run and long-run relationships between FDI, GDP, inflation, employment in in-dustry, and trade openness. Panel unit root tests confirm that the variables are inte-grated of order I(0) and I(1), supporting the application of the Panel ARDL method-ology. The long-run results indicate that GDP and employment in industry positively affect FDI, while trade openness has a negative effect and inflation is not statistically significant. In the short run, inflation negatively affects FDI, whereas trade openness has a positive impact. The error correction term is negative and statistically signifi-cant, confirming the existence of a stable long-run equilibrium. Country-specific Bounds tests confirm cointegration only for the Czech Republic and Slovakia, high-lighting heterogeneous long-run relationships across the V4 countries. The study con-tributes by combining pooled Panel ARDL estimation with country-specific Bounds tests, providing updated evidence on the macroeconomic determinants of FDI and emphasizing the importance of country-specific investment policies.

Keywords: ARDL model, foreign direct investment, inflation, trade openness, V4

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Econometric Modelling of Tourism Demand in Collective Accommodation Facilities: Evidence from Czech Tourism Data

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Tourism demand in collective accommodation facilities represents an important indicator of economic activity and regional development. The aim of this paper is to analyse the determinants and dynamics of tourism demand in the Czech Republic using an econometric approach. The analysis is based on quarterly data on the number of guests and overnight stays in collective accommodation establishments obtained from the Czech Statistical Office for the period 2010–2024.

To examine both short-term dynamics and long-term relationships, the Autoregressive Distributed Lag (ARDL) model is employed. The model specifies tourism demand as a function of its own lags and selected macroeconomic variables, including gross domestic product, price level, and international tourism flows. The ARDL framework enables the identification of cointegration relationships and the estimation of both long-run equilibrium effects and short-run adjustments through an error correction mechanism.

The results indicate the existence of a stable long-run relationship between tourism demand and macroeconomic factors, while short-term dynamics are significantly influenced by seasonal fluctuations and external shocks. The findings provide valuable insights into the behaviour of tourism demand in the accommodation sector and can support decision-making in tourism policy and regional development.

Keywords: ARDL model, macroeconomic factors, time series analysis, tourism

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Performance Dynamics of Czech Breweries: An Updated DEA-Based Assessment

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The Czech brewing sector has experienced considerable structural and economic shifts in recent years, significantly influenced by the COVID-19 pandemic. This paper investigates the efficiency development of Czech breweries over the period 2018–2023 using Data Envelopment Analysis (DEA). Expanding on earlier studies focused on prior timeframes, the research offers a contemporary perspective on technical efficiency within the industry.

The analysis is based on a dataset combining financial and operational indicators from a sample of Czech breweries. Input-oriented DEA models assuming both constant and variable returns to scale are applied to assess relative efficiency levels and identify performance patterns. The results reveal evolving efficiency trends, highlight persistent inefficiencies, and capture the sector's response to recent external shocks.

Keywords: brewing industry, Czech breweries, efficiency analysis, DEA, technical efficiency, financial performance

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Metrics in Scrum: Quantitative Model for Evaluating Metrics Capability in Scrum Teams

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Scrum is the leading agile method for software development and a suitable alternative to traditional project management. However, Scrum teams often struggle with metrics selection and utilization to evaluate and improve their efficiency. A gap exists between the metrics recommended in the literature and those that teams actually utilize in practice. This pilot study addresses this gap by proposing a quantitative metrics capability model that uses 21 key Scrum efficiency metrics identified in prior research. The model evaluates metrics capability across three categories: Sprint, Team, and Tech, and defines four levels of metrics maturity: low, medium, advanced, and high. We conducted a pilot study with 15 Scrum teams to refine our framework, using an online application called Metrics in Scrum. Empirical metric weights derived from team responses diverged substantially from literature-based weights. These findings reveal that teams prioritize different metrics than the literature suggests, and our refined model now reflects real-world practice more accurately. The tool is available online and enables Scrum teams to assess their current metrics maturity and identify areas for improvement.

Keywords: empirical validation, metrics capability model, metrics utilization, Scrum, Scrum metrics, team efficiency

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Ambulance Fleet Minimization without Loss of System Quality

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Most problems dealing with the design of emergency medical care systems are formulated in such a way that a limited number of ambulances is given and the goal is to deploy the ambulances at a set of possible locations such that the average response time of the system is minimal. In this paper, the reverse approach is studied. A desired limit on the average response time is set, and a minimal number of ambulances is sought to ensure that the average response time is below this limit. The presented computational study considers only those values of the time limit that lie between the current average response time and the time that can be achieved by optimally deploying the current number of ambulances

Keywords: prehospital urgent healthcare management, strategic decision, optimization, radial approach, generalized model

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A Multilevel Analysis of Post-Harvest Food Loss in Sub-Saharan Africa: Commodity, Food Supply Stage, and Regional Interactions

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Post-harvest food loss (PHL) is widely recognised as a critical constraint on food security in sub-Saharan Africa (SSA), where an estimated 20% of agricultural output is lost through supply-chain inefficiencies. This study analyses how losses emerge through the multilevel interaction of commodities, food supply chain stages, and regions using a multilevel linear mixed-effects model (LMM) applied to 2,461 observations from 36 SSA countries covering five cereal commodities across seventeen food supply chain stages (FAO Data Lab, 2019–2024). The food supply chain stage is the strongest predictor of PHL: processing losses exceed 15% in Western and Central Africa, storage losses are highest in Eastern Africa (4.26%), and farm-level losses remain above 4% across all regions. The commodity–stage interaction shows that all five cereals exhibit their highest predicted losses at the Farm–Farm stage, with secondary peaks for maize and rice at husking and harvesting, and for millet and sorghum at threshing and winnowing. These findings contradict the assumption that a uniform post-harvest intervention is sufficient and demonstrate that effective policy must be stage-specific and region-specific, with direct implications for SDG 2 (Zero Hunger) and SDG 12.3 (reducing food loss and waste by 2030).

Keywords: post-harvest food loss, sub-Saharan Africa, mixed-effects model, cereal commodities, SDG 2, SDG 12.3

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Comparative Analysis of Mathematical Programming and Metaheuristic Approaches for the Vehicle Routing Problem with Multiple Soft Time Windows

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This paper presents a controlled experimental comparison of a Mixed-Integer Linear Program (MILP) solved by Gurobi, a restricted route-pool Lagrangian procedure (LR), a Genetic Algorithm (GA), and Simulated Annealing (SA) applied to the Vehicle Routing Problem with Multiple Soft Time Windows. The benchmark is the published C101-MTW multiple-time-window extension of the Solomon C101 instance, restricted to nested customer subsets of size $N \in \{10, 25, 50\}$.

All stochastic methods are evaluated over ten seeded runs per instance size under identical cold-start wall-clock budgets.

The MILP incumbent provides the best objective value at every size, although it does not certify global optimality and its LP-based lower bounds remain weak.

Among the heuristics, GA attains the lowest mean relative deviation from the MILP incumbent at $N = 10$ (0.10%) and $N = 25$ (2.56%), with seed-paired advantages over SA that are large and statistically significant; at $N = 50$ the deviations of GA (5.02%) and SA (4.93%) are statistically indistinguishable.

LR exhausts its budget during route-pool generation at $N \geq 25$ and returns its constructive fallback solution.

The study offers a reproducible protocol and size-dependent guidance for method selection under moderate computational budgets, with conclusions restricted to the studied instance family.

Keywords: Vehicle Routing Problem, Soft Time Windows, Branch-and-Bound, Lagrangian Relaxation, Genetic Algorithm, Simulated Annealing, Solomon Benchmark

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Firm Level Evidence on Investor Sentiment and Cross Sectional Stock Market Characteristics

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This study examines the relationship between investor sentiment and stock characteristics, focusing on returns, volatility, and trading volume across firm size and industry dimensions. Using weekly data from 2000 to 2025 and firm-level OLS regressions, we analyze Russell 1000 and 2000 constituents classified by GICS sectors. The results reveal significant heterogeneity: sentiment effects vary systematically across sectors and between big and small size firms. The findings indicate that sentiment influences are structurally distributed rather than uniform, highlighting the importance of considering cross-sectional market characteristics.

Keywords: investor sentiment, behavioral finance, Russell 1000, Russell 2000

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Counting Passengers in Public Transport Buses Using Door Optical Sensors

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In many Slovak cities, public bus transport was only boarded through the front doors and tickets were purchased from the driver. Based on data on tickets sold, it was possible to calculate the load of trips with great accuracy, and there were a number of models for calculating the Origin-Destination (OD) matrix. Nowadays, more and more passengers are using prepaid time tickets. Therefore, measuring transport demand can no longer rely only on the sale of single tickets and other methods need to be prepared. One such method is to place optical sensors in the vehicle doors that will count the number of passengers. However, some errors can occur, which results in some subsequent problems. For example, it may happen that the vehicle has a negative number of passengers or that not all passengers get off at the final stop. In our paper, we will present a method for best correcting passenger counting errors to ultimately refine the estimate of the number of passengers in the OD matrix.

Keywords: public transport, Origin-Destination matrix, optical sensors, mathematical programing

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Fixed Interval Scheduling with Heterogeneous Machines with Random Delays - Distributionally Robust Case

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We study a special case of the fixed interval scheduling problems (FIS) with random delays. In the original FIS problem, the processing intervals of the jobs are given. In stochastic case, random delays in finishing times may occur. Moreover, we are interested in the case with heterogeneous machines, i.e., we consider multiple machine types and job classes, where each class can be processed by particular machine types only. Especially, we focus on the distributionally robust version of the problem, where a given amount of distribution of delays of jobs is stressed. The original and stressed distributions depend on the type of machine to which this job is assigned. We propose a deterministic reformulation of the problem under the assumptions of the stressed distribution and the structure of the multivariate distribution of the job processing delays. We suggest two possible ways to solve this problem and compare them on generated instances of the problem.

Keywords: fixed interval scheduling, uncertain finishing times, distributionally robust problem

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Structural Modelling of Sustainability Perception: Triangulation of Survey Data and Regional Indicators

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This paper analyses regional and intergenerational differences in the perception of the three pillars of sustainability, environmental, social, and economic, within the context of the Czech Republic. The objective is to compare the subjective interpretations of these dimensions across various socio-demographic groups, with a specific focus on regional disparities. The methodology employs a triangulation of survey data (n = 500), analysis of regional ESG indicators, and policy documents. The structure and reliability of the proposed model are evaluated using quantitative methods of statistical modelling, specifically Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

The results indicate that perceptions of sustainability are heterogeneous and influenced by factors such as age, gender, and educational attainment. In regions with a traditional industrial orientation (e.g., Karlovy Vary, Ústí nad Labem, and Moravian-Silesian regions), a significant emphasis on the economic pillar was identified. Conversely, in economically advanced centres like Prague, a balanced approach toward all dimensions prevails. Comparative analysis indicated that the Venn diagram model provided a more nuanced representation of sustainability perception than the traditional Parthenon model.

Keywords: sustainability, three pillars, regional analysis, factor analysis, perception

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Comparison of Bootstrap Methods in Robust SSD Portfolio Optimization

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This paper explores the use of alternative bootstrap approaches for calibrating robustness in a second-order stochastic dominance (SSD) portfolio optimization framework. Classical SSD models impose strict dominance constraints that are often overly restrictive in finite samples and sensitive to sample noise. To address this issue, two bootstrap methods for determining statistically insignificant levels of dominance violation are investigated. The first is random-weights approach, which approximates the distribution of the dominance statistic across randomly generated portfolios, and a benchmark-based approach, which derives critical values directly from the empirical benchmark distribution. These thresholds are incorporated into the SSD model to relax the dominance constraints in a controlled manner. The approaches are evaluated across multiple rolling windows and varying sample sizes, with performance assessed out-of-sample in terms of returns and violation frequency. Results show that the benchmark-based bootstrap yields critical values that track out-of-sample dominance violations more closely than the random-weights approach, at the cost of a less restrictive, but more realistically calibrated, dominance constraint.

Keywords: bootstrap methods, portfolio optimization, stochastic dominance, robust optimization

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Path Dependent Arbitrage Portfolio Strategies

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This study investigates portfolio strategies aimed at optimizing both the expected first passage time of wealth toward predefined benchmark levels and the expected current maximum and minimum of the wealth process. Assuming that returns follow Markov processes, approximated through homogeneous Markov chains, the research identifies potential arbitrage opportunities by exploiting momentum anomalies.

The empirical analysis is conducted on the components of the S&P 500 index over a 20-year period (2002–2021) using a rolling window approach, covering three major financial stress periods: the 2008 subprime mortgage crisis, the 2011 European sovereign debt crisis and the 2020 COVID-19 pandemic. The results demonstrate that the temporal frequency of data significantly impacts strategy effectiveness. Specifically, when using daily data, reverse arbitrage proves to be the most effective strategy for wealth generation. Conversely, with weekly returns, "winner" portfolios outperform, and reverse arbitrage loses its efficacy. For monthly data, the success of the strategy is strictly dependent on the chosen time horizon. Overall, arbitrage strategies based on winner-loser dy-namics emerge as the most robust and effective approaches during periods of profound market crisis.

Keywords: path-dependent strategies, Markov chains, reverse arbitrage, momentum, first passage time.

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The Nonvacuity of the Core: An Alternative Proof for Schmeidler's Theorem

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In this paper, we rigorously show that Cornet's result (Theorem 1 on p. 716 in Bernard Cornet: "Characterizing arbitrage-free Choquet pricing" Mathematics and Financial Economics, (2025) 19:711–733) implies the Schmeidler's theorem (the Bondareva-Shapley Theorem for infinite games) in its full generality given in Theorem 4 on p. 155 in Bartl, D. & M. Pinter: "On balanced games with infinitely many players: Revisiting Schmeidler's result" Operations Research Letters, (2023) 51 (2), 153-158.

Keywords: TU-games, Bondareva-Shapley Theorem, Core, No-Arbitrage, pricing function

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Choosing a Value-at-Risk UC Backtest across Standard Tolerance Levels: An Exact-Size Power Analysis

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We compare the finite-sample power of three unconditional coverage (UC) backtest configurations for Value-at-Risk: Kupiec, Pérignon–Smith, and a three-threshold Kratz–Lok–McNeil-type likelihood-ratio test. All use a unified exact Lehmann γ-randomization framework; size is analytical for Kupiec and calibrated to the stated enumeration tolerance for the multilevel tests, while powers are computed by finite-sample summation without Monte Carlo uncertainty. The data-generating process is a Student-t distribution calibrated to daily DAX log-returns over 2021–2026; misspecification shifts the degrees-of-freedom parameter at fixed location and scale, producing non-linear spillovers across $q \in \{0.01, 0.025, 0.05\}$ for $T \in \{100, \ldots, 1000\}$. Three findings emerge. First, the exact two-sided uniformly most powerful unbiased (UMPU) Kupiec construction removes the power-less-than-size pathology of discrete regulatory settings; the same pathology afflicts the deep-pair multilevel construction at T=100. Second, multilevel dominance is not uniform: the three-threshold test wins in shallow tails at longer windows but is outperformed by single-threshold Kupiec configurations in deeper regimes. Third, under risk overstatement, power is non-monotone in q and often strongest at the FRTB-equivalent anchor q=0.025 rather than at the deepest Basel level. Conditional on the examined fixed-scale deformation, the required windows for power 0.80 exceed the standard regulatory window several-fold.

Keywords: VaR backtesting, model risk, randomization, unconditional coverage, test pow-er, single-level and multinomial tests.

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Roughness and Jump Risk in Cryptocurrency Option Smiles: An Econometric Comparison

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We calibrate four parsimonious option-pricing models — Heston, Bates, rough Heston, and SVCJ — to 1,989 fifteen-minute Deribit BTC and ETH implied-volatility snapshots over a 21-day window, using a Fourier–cosine pricer, and compare their performance under three evaluation protocols: in-sample RMSE, chronological time-series out-of-sample, and within-snapshot cross-maturity out-of-sample. The model ranking is not invariant. Jumps dominate in sample on BTC while roughness dominates on ETH; the time-series out-of-sample leader differs from the cross-maturity leader in the XM subset. We find that roughness and jumps appear complementary across assets but act as competing representations within an asset, and that model selection on crypto option surfaces must be protocol-aware.

Keywords: option pricing, rough volatility, stochastic volatility with jumps, calibration, Fourier–cosine method, cryptocurrency options

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Regional Apartment Price Disparities in the Czech Republic: Clustering, Supply Elasticity, and Labour Market Analysis with a Focus on the Moravian-Silesian Region

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This paper examines spatial heterogeneity in apartment prices across Czech districts using a longitudinal dataset of daily advertised listing prices covering 77 districts from August 2018 to March 2026. The central question is whether classical bid-rent theory adequately explains regional apartment price disparities in the Czech Republic, and where it breaks down in structurally depressed regions. Two analytical dimensions are investigated. First, K-Means clustering based on three features—long-run mean price per m², total price growth, and average monthly listing volume—identifies five structurally distinct market segments. The resulting clusters capture both price levels and market dynamics, revealing that historically depressed districts (Ostrava, Most, Karviná) form a distinct group characterized by low absolute prices but the fastest price growth (+261% on average), consistent with price convergence. Second, the analysis is applied to the Moravian-Silesian Region as an exploratory case study, integrating commuting distances to Ostrava, labour market indicators (unemployment rate, median wage), and housing affordability via price-to-income ratios. Findings demonstrate that proximity to the regional employment center explains apartment prices only partially—structural factors, including post-industrial stigmatization, unemployment persistence, and amenity premiums, emerging as dominant determinants. The results challenge the classical monocentric bid-rent framework and highlight the complexity of housing market dynamics in post-industrial regions.

Keywords: apartment prices, K-Means clustering, housing affordability, Moravian-Silesian Region, Czech Republic, post-industrial regions

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Analysis of Productivity in an Automated Production Line and Modeling Its Dynamics

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This paper presents a data-driven analysis of an automated production line aimed at quantifying productivity and modeling its stochastic dynamics. Shift-level data are preprocessed to ensure temporal consistency. Productivity per shift is analyzed using nonparametric methods, and differences across working days confirm a non-uniform weekly pattern. The typical production level of a particular Czech firm is estimated. The temporal dynamics are modeled as a discrete-time stochastic process with weekly seasonality. The time series is de-scribed by a seasonal ARIMA model applied directly to production levels, cap-turing the recurring dependence structure associated with the five-working-day cycle. The results indicate a stable production level and a weekly dependence pattern, where production on a given working day is related to production on the corresponding working day of the previous week. The estimated typical production per shift is further used to derive component consumption rates and replenishment frequencies, supporting production planning and logistics opti-mization.

Keywords: automated production line, productivity, SARIMA, inventory and supply plan-ning

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Dynamic Cutting Stock Problem

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We study a traditional one-dimensional cutting stock problem in a dynamic setting where customer orders arrive continuously over time. In our work, we propose an algorithmic approach based on the rolling horizon paradigm, enabling repeated re-optimization of cutting plans as the set of orders evolves. The primary objective is to minimize material waste while respecting delivery deadlines, reflecting key requirements of real-world production systems.

We further investigate the management of the proposed plans and analyze the efficiency of the approach under different lengths of time windows used for aggregating incoming demand. To support practical applicability, we design efficient heuristics tailored for dynamic environments. Finally, we discuss the potential integration of more advanced techniques from stochastic optimization, such as scenario generation for future demand, to further enhance decision-making under uncertainty.

Keywords: cutting stock problem, stochastic optimization, rolling horizon

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Mixed-Integer Programming for Conference Scheduling at Scale

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This talk presents a discussion and a computational study of mixed-integer programming formulations for large-scale conference scheduling. The setting assumes that presenters and discussants are already assigned to sessions. Presentations and sessions are hierarchically structured according to research area (i.e., track or stream) and methodology.

The core task is to assign chairs to sessions and to allocate sessions to time slots and rooms while satisfying a wide range of operational and academic requirements and optimization desirable objectives, such as a balanced distribution of tracks across time slots, spatial proximity of rooms within the same track, minimizing transfers between rooms of the same track, ensuring adequate room capacity for each track in each time slot, or maximizing the chair suitability over sessions.

The emphasis is placed on two main aspects:

a) The hierarchical structure of sessions enables a multiphase optimization approach without a significant loss of solution quality. This may reduce the number of variables by one or even two orders of magnitude. The trade-off is the need to move beyond simple assignment constraints and to introduce structurally more complex ones. The benefits and limitations of such formulations are discussed.

b) In practice, conference scheduling inevitably requires incorporating last-minute changes. Due to the nature of MILP solvers, even small changes in input data may lead to substantial differences in the resulting solution. Techniques to limit these deviations and maintain stability of the schedule are therefore examined.

Keywords: MILP, conference scheduling, stability at reoptimization

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Enumerating Weakly Optimal Solutions in 0–1 Interval Linear Programming

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We address the problem of enumerating the set of all optimal solutions in 0–1 linear programs under interval uncertainty. In the setting of interval programming, the coefficients in both the constraints and the objective are not fixed, but may vary independently within prescribed bounds. In this talk, we focus on characterizing the set of weakly optimal solutions, that is, binary vectors that are optimal for at least one realization of the uncertain data.

We develop a finite method for describing the weakly optimal set by deriving a condition for testing weak optimality of a given solution. First, we formulate a general scenario-selection problem: given sets of required and forbidden binary vectors, we ask whether there exists a realization of the interval data such that all required vectors are feasible while all forbidden vectors are excluded. We show that this question can be decided by a mixed-integer linear programming model (with non-interval data). This yields a constructive method for certifying whether a prescribed family of solutions can arise as the feasible set of some scenario.

Building on this framework, we derive a characterization of weak optimality in 0–1 interval linear programming. For a candidate solution, we identify all weakly feasible competitors with strictly better objective value under the objective realization most favorable to that candidate. Testing weak optimality then reduces to solving the scenario-selection problem with the candidate as a required solution and all better competitors as forbidden solutions.

As a result, we obtain a finite description of the set of weakly optimal solutions via enumeration combined with mixed-integer linear programming. The proposed approach yields both a decision procedure for testing weak optimality and a witnessing scenario for each weakly optimal solution.

Keywords: interval programming, integer programming, optimal solution, enumeration

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Evaluating Strikers and Forwards in the Bundesliga with a Two-Stage Decision-Making Framework

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Player performance evaluation in elite football is a central scouting challenge, since transfer decisions carry high uncertainty and substantial sporting and financial consequences. This paper proposes a two-stage framework that couples machine learning with Data Envelopment Analysis (DEA) to evaluate strikers and central forwards in the German Bundesliga between the 2020/2021 and 2024/2025 seasons. In the first stage, a Random Forest regression identifies which SoFIFA attributes drive market value; because market value is the observed price of a player's attribute endowment, the selected attributes represent what clubs actually pay for and therefore constitute an economically coherent input set. In the second stage, these attributes enter an output-oriented BCC model whose outputs are on-field production per 90 minutes, yielding a measure of output obtained per unit of purchased endowment. We report bias-corrected efficiency estimates with confidence intervals obtained by the homogeneous bootstrap, assess the stability of the first-stage selection across 100 replicates, examine the sensitivity of the rankings to the weight restriction, and validate the scores against market valuations and independent FBref production data. Across 248 player-seasons the mean score is 0.797, falling to 0.666 after bias correction; no player is distinguishable from the frontier at 95% confidence, so the frontier is best read as an ordering rather than as a set of attained optima. Efficiency is uncorrelated with market value ($\rho = 0.093$, $p = 0.47$) and moderately correlated with on-field production $\rho = 0.512$, $p < 0.001$), indicating that it carries information price alone does not. We further show that per-90 outputs require a minimum-participation threshold: a single player with eight minutes of play attains the frontier and halves the 2023/2024 season mean.

Keywords: Bundesliga, bootstrap, Data Envelopment Analysis, Machine learning,

player performance evaluation, Random Forest, sports analytics

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How University Students Learn with Generative AI: Usage Patterns, Study Materials, and Risk Awareness

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Artificial intelligence tools are becoming increasingly embedded in university students' study practices, yet their role in the learning process remains insuffi-ciently understood. This study examines how frequently students use AI, what types of study materials they rely on, and whether AI is employed primarily as an autonomous source of information or as a tool for processing user-provided content. Data were collected through a questionnaire survey of 171 students from two Czech universities. The responses were analysed using descriptive statistics, exact binomial tests, paired Wilcoxon signed-rank tests, and logistic regression. The results show that 78.9% of respondents use AI tools at least several times per week, although only 40.9% use them daily. Most students primarily learn from their own materials, prepared using university resources. Students use AI significantly more often to process materials they provide themselves than to generate study content solely from the model's internal knowledge. Frequent or very frequent use was reported by 54.4% and 14.2% of respondents, respectively, and the difference was statistically significant. Daily AI use was also positively associated with paid access and customisation of the AI environment. The findings indicate that the surveyed students predominantly use AI as a learning assistant and content-processing tool rather than as an in-dependent source of knowledge. Higher education should therefore focus on developing critical, transparent, and source-aware AI-supported learning prac-tices.

Keywords: Artificial intelligence, higher education, student learning, study strategies, gen-erative AI, survey research

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Exchange-Rate Regimes and Monetary Policy in Oil-Dependent Economies with Informality: An Agent-Based Approach

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This paper develops an agent-based macroeconomic model to analyze monetary policy effectiveness in an oil-dependent economy with a large informal sector. Building on a New Keynesian DSGE framework that evaluates monetary policy under alternative exchange-rate regimes, the paper extends the analysis by allowing macroeconomic outcomes to emerge from heterogeneous households, formal and informal production sectors, oil-driven fiscal dynamics, foreign-reserve accumulation, and central-bank exchange-rate intervention. The current model incorporates a managed exchange-rate regime in which oil revenues, import pressures, foreign reserves, and liquidity conditions jointly shape exchange-rate and monetary dynamics. The conference version extends this framework to compare three exchange-rate regimes: fixed, managed, and flexible. This allows the paper to examine whether regime choice affects inflation stability, consumption smoothing, reserve losses, informal-sector adjustment, and crisis probability. The main contribution is methodological and policy-oriented: while DSGE models provide a structural equilibrium benchmark, the agent-based approach captures nonlinear adjustment, disequilibrium dynamics, heterogeneity, and the role of informality in weakening conventional monetary transmission. The paper focuses on Iraq as a representative oil-dependent economy, but the framework is relevant for resource-rich developing economies where monetary policy operates mainly through exchange-rate management and liquidity provision rather than standard interest-rate rules.

Keywords: Agent Based Model, monetary policy, oil-exporting economies with informal sector

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Forecast-Informed Supply Chain Finance Decisions: Evidence from US-Listed Retail Firms

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This paper examines supply chain finance and working capital management among US-listed retail firms. Using quarterly panel data from five sample firms, the study first employs fixed-effects specifications to evaluate the within sample associations between inventory, accounts payable, accounts receivable, cash holdings, firm size, and operating cash flow. Walmart is then used as an illustrative case to compare the reported forecasting performance of Seasonal Naive, ARIMA, Prophet, and XGBoost models. The models are evaluated over the common period from 2024Q1 to 2024Q4 using MAE, RMSE, and MAPE. Within this evaluation period, Prophet produces the lowest reported forecasting errors. The resulting operating cash flow forecast and forecast interval are subsequently incorporated into a goal programming decision analysis covering financing volume, payment term adjustment, and the supplier prepayment ratio under alternative demand, interest rate, financing limit, and cash flow conditions. The empirical results indicate that inventory shows the most consistent negative association with operating cash flow in the sample. The scenario results show that financing and payment configurations vary across operating and financing conditions. The contribution of the paper lies in connecting firm-level working capital evidence, short-term cash flow forecasting, and interpretable supply chain finance decision scenarios.

Keywords: supply chain finance, working capital management, operating cash flow, cash flow forecasting, scenario analysis

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Explainable Artificial Intelligence for Dairy Cow Classification: Neural Networks with Permutation Importance and Local Surrogate Explanations

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Explainable artificial intelligence (XAI) is important in precision livestock farming because a prediction must be accompanied by evidence that a farm professional can inspect. This paper evaluates an explainable classification workflow for dairy cow performance and milk quality. Multi-layer perceptron (MLP) classifiers are compared with random forest and gradient boosting models on two balanced, controlled proof-of-concept datasets ($n = 1{,}000$ each). The workflow combines held-out permutation feature importance for global model inspection with a LIME-style local weighted-ridge surrogate for individual predictions. On a stratified 80/20 test split, MLP accuracy was 93.5% for dairy cow performance and 84.0% for milk quality; the tree-based baselines were competitive or marginally stronger. Global results identified milk yield, somatic cell count and feed efficiency as the most influential dairy-cow variables, and temperature, colour and pH as the leading milk-quality variables. Local surrogate plots show the case-specific evidence used for a selected prediction. The study contributes a reproducible and explicitly limited XAI workflow rather than a claim of operational deployment. It also clarifies that explanation outputs are model-dependent associations, not causal recommendations.

Keywords: explainable AI, permutation feature importance, local surrogate explanations, neural networks, dairy farming, precision livestock farming, machine learning

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Drivers of CO2 Reduction in OECD: Financial Structure and FDI via MMQR

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The study analyzes the response of disaggregated level foreign direct investment (FDI) and financial structure on the CO2 inten- sity of 30 high energy-consuming OECD countries. To this end, the study applies the Method of Moment Quantile Regression (MMQR) to the data between 2013 and 2021, and the results revealed that aggregated FDI enhances CO2 intensity, while the results vary at disaggregated levels. For example, FDI in the agriculture, forestry, and fishing sector increases CO2 intensity, FDI in the services sector has an insignificant impact on CO2 intensity, whereas construction, mining and quarrying, electricity and gas, finance and insurance, and manufacturing sectors curb CO2 intensity. The coefficients between financial structure and CO2 intensity are also positive and significant at different quantiles of the model, suggesting that a high percentage of financial expansion is associated with excessive carbon intensity. The results are re-verified by changing quantiles, using another proxy for CO2, and applying a heterogeneous estimator (IVGMM).

Keywords: CO2 intensity, disaggregated level FDI, financial structure, MMQR, OECD

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Radial Basis Functions: Analytical Characterization of Polynomial Augmentation

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Radial Basis Function (RBF) interpolants approximate an unknown function $f(\mathbf{x})$ via a linear combination of conditionally positive definite kernels, $\varphi(\|\mathbf{x} - \mathbf{c}_i\|)$, augmented by a low-order polynomial term, $\sum_{j=1}^{q} a_j p_j(\mathbf{x})$, to ensure the unique solvability of the interpolation matrix and to control the asymptotic behavior of the estimator in the flat-tail regime. Although existing treatments treat polynomial augmentation as a purely numerical regularization device, we derive closed-form *analytical expressions* for the coefficient vector $\mathbf{a} \in \mathbb{R}^q$, with explicit emphasis on the zero-degree case a_0.

We demonstrate that a_0 is not an artifact of the linear system but rather a global bias-correction term that absorbs the mean of the target function orthogonal to the span of the kernel.

Crucially, our formulation provides an explicit decomposition of the RBF estimator into a parametric polynomial component (global) and a non-parametric kernel residual (local), thereby clarifying the trade-off between polynomial order k and the shape parameter αin determining the estimator's spectral properties and approximation order.

This analytical treatment reframes polynomial augmentation from a mere solvability condition into a structural component of the estimator.

Keywords: Radial Basis Functions, RBF interpolation, Non-parametric interpolation, Polynomial Augmentation, Reproducing Kernel Hilbert Space (RKHS), Multidimensional scattered data

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Fuzzy Multi-Attributes Decision Model for Athletes Position Suitability

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The paper presents a fuzzy multi-criteria decision model to help floorball or ice hockey coaches assign players to positions in the team - defender, forward, and goalkeeper. Inputs include relative results of four cognitive tests and two game situation tests, fuzzified with three-level linguistic variables. Each athlete is evaluated using a weighted sum of these fuzzified tests results, with weights describing the importance of the tests set by the coach according to position specific skills. The Athlete Placement Model provides suitability scores for athletes for each position, supporting decisions on team composition and training.

The numerical results reported in the paper were obtained using a prototype Decision Support System (DSS) in which the Athlete Placement Model is embedded together with the athlete testing tools required to acquire the input variables, complementary educational modules addressed to the athletes themselves and additional tools for coach decision-making. This DSS is intended to support coaches throughout the full cycle of evaluation, role assignment and longitudinal monitoring.

Keywords: data analytics for sports, Multi-Criteria Decision Making, fuzzy approach

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Legitimacy–Cost Gap in Reshoring: Evidence from Central Europe

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This paper examines the discrepancy between normative support for reshoring and consumers' willingness to bear its economic consequences, referred to as the legitimacy–cost gap. Using survey data from 2,000 respondents in Czechia and Slovakia, a gap index is constructed to capture this discrepancy. Its existence and distribution are assessed using complementary mean, median, and proportion-based tests, followed by a categorical analysis of integer-threshold attitude profiles.

The results indicate that normative support significantly exceeds economic willingness and that paradox-type attitudes dominate the sample. Regression analysis further indicates that economic patriotism is positively associated with both normative support and economic willingness, while the relationship between normative support and economic willingness varies across age groups. Older consumers exhibit a stronger association between normative support and economic willingness than younger respondents. Overall, the findings suggest that reshoring enjoys broad symbolic support, whereas consumers' declared willingness to bear its economic costs remains conditional and varies across consumer groups.

Keywords: reshoring, legitimacy–cost gap, economic patriotism, consumer attitudes

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A Systematic Review and Meta-Analysis of the Value of Stochastic Solution in Routing Problems with Stochastic Demands

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To mitigate the risks of unpredictable customer demands in logistics, this study evaluates the benefits of shifting from deterministic routing to stochastic programming. Focusing on vehicle routing problems with stochastic demands (VRPSD), our research quantifies the Value of Stochastic Solution (VSS) in these applications. We have systematically reviewed the literature and assembled a database of quantitative data to propose a comprehensive meta-analysis. This analysis will measure the efficiency gap, define expected savings, and calculate confidence intervals for routing optimization. The resulting insights will serve as a decision-making framework, helping researchers determine exactly when stochastic routing offers the highest return on investment.

Keywords: value of stochastic solution, vehicle routing problem, stochastic demand, stochastic programming, systematic review, meta-analysis

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Student Self-Assessment Accuracy: Insights from a Case Study

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This contribution focuses on how accurately students can assess their own performance during their first attempt at a Linear Programming credit test. The aim is to examine how well students can estimate their score, whether they tend to overestimate or underestimate their results, and which factors influence this accuracy. The analysis is based on data from two versions of a questionnaire linked to students' actual test results. In addition to real and estimated scores, the study considers selected student characteristics, time spent on self-study and the use of study support.

The results show that students can estimate their performance only with limited accuracy, and there are large differences between individuals. A statistically significant relationship was found between actual performance and estimation error: students with lower scores tend to overestimate their results, while more successful students slightly underestimate them. This pattern is consistent with the Dunning–Kruger effect.

The findings also show that the use of study resources is related to both performance and estimation accuracy. Students who reported not using recommended literature achieved higher scores on average and made more realistic estimates of their results. In contrast, students who evaluated the literature (i.e., reported using it) tended to overestimate their performance. A similar pattern was found for individual consultations: students who did not use them performed better and estimated their results more accurately, while those who used them tended to overestimate.

No significant effect of questionnaire wording (framing effect) was found, which suggests that students' self-assessment is relatively stable. The contribution helps to better understand the relationship between academic performance and self-assessment and suggests implications for supporting more realistic self-evaluation in higher education.

Keywords: cognitive bias, Dunning–Kruger effect, academic performance evaluation, self-assessment accuracy, student perception behavioral aspects of learning

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Systemic Risk Detection Using Return Scenario Generation and Moving Averages: Implications for Portfolio Selection

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This paper presents an advanced method for detecting systemic risk by combining simulated returns with signals from moving averages. The proposed approach models the joint dynamics of large cross-sections of equity returns. In particular, we used a two-stage PCA-based factor decomposition, which reduces dimensionality while preserving both common and idiosyncratic sources of variation. The extracted factors, along with the residual components, are modeled using the ARMA(1,1)–GARCH(1,1) model. Based on this framework, future return scenarios are generated via Monte Carlo simulation. To translate simulated market developments into interpretable systemic risk signals, several moving-average trading rules are applied with alternative short- and long-term windows. A period of elevated systemic risk is identified when the proportion of assets generating sell signals exceeds a predefined threshold. In this way, the framework links forward-looking return scenarios with market-wide technical deterioration and provides an operational indicator of stress at the aggregate level. The empirical analysis is conducted using daily stock price data from the S&P 100, FTSE 100, Hang Seng 50, and Nikkei 225 indices, while explicitly accounting for their time-varying composition. The results indicate that the proposed framework captures periods of instability across markets and that the incorporation of technical analysis signals enhances the practical interpretability of the framework outputs. The findings suggest that combining scenario generation with moving-average indicators provides a useful tool for monitoring systemic risk and supporting portfolio and risk management decisions under adverse market conditions.

Keywords: systemic risk, PCA, ARMA-GARCH, moving averages, technical analysis, portfolio selection

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Fractional Economic Dynamics: Deriving Production Functions via Caputo-Type Memory Invariants

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Standard dynamical systems approaches to economic modeling, such as those deriving the Cobb-Douglas and CES production functions from exponential growth trajectories, typically rely on integer-order differential equations. While effective, these models assume that economic output depends solely on the instantaneous state of capital and labor, effectively ignoring the long-term "memory effects" inherent in policy, infrastructure, and technological adoption.

This paper extends the exponential framework by introducing the Caputo fractional derivative into the underlying dynamical systems governing factor inputs. By replacing standard growth rates with fractional-order counterparts of order $0 < \alpha \leq 1$, we model economic trajectories where the rate of change is a non-local function of the system's entire history. We demonstrate that the Mittag-Leffler function emerges as the natural growth solution in this context, providing a nested generalization of the classical exponential model.

Unlike exogenous fractional frameworks, we use this fractional approach to derive a new class of time-independent invariants that serve as generalized production functions. We show that as the fractional order approaches unity, these forms converge exactly to the classical Cobb-Douglas function.

Keywords: Caputo fractional derivative, production functions in economics, mathematical modeling, economic growth models

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Does Energy Efficiency Enhance Technical Efficiency in Agriculture?

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Improving energy efficiency is a central pillar of the European Union's transition toward sustainable and low-carbon agriculture. However, it remains unclear whether efforts of farmers to reduce energy costs also enhance their overall technical efficiency. We focus on the relationship between energy efficiency and technical efficiency at the farm level. Using micro-level data for crop farms in several countries over the period of five years, we estimate a translog stochastic production frontier and a corresponding energy cost frontier. Technical efficiency and energy cost frontier efficiency are derived and their relationship is analyzed using fixed effects models and quantile regressions.

Keywords: technical efficiency, energy efficiency, agriculture

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Logistic Regression Approach to Modeling Operational Risk in Non-Financial Institutions

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Operational risk represents a significant source of potential losses in organizations, with its importance in the non-financial sector increasing due to growing process complexity and digitalization. The aim of the paper is to identify and quantify selected factors influencing the occurrence of operational risk in non-financial institutions. The research is designed as an empirical analysis based on available data on operational loss events and organizational characteristics.

To achieve this aim, an econometric approach based on logistic regression is applied, enabling the estimation of the probability of operational loss occurrence as a function of selected factors. The model includes variables capturing organization size, level of digitalization, quality of internal processes, and organizational complexity.

The results indicate that the probability of operational risk is significantly influenced primarily by the quality of internal processes and the level of digitalization, while the effects of other factors vary depending on the nature of the organization. The findings contribute to a better understanding of operational risk determinants outside the financial sector and provide a basis for more effective risk management in practice.

Keywords: operational risk, logistic regression, risk determinants

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The Impact of Competition and Quality on the Efficiency of Integrated Transportation Systems

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This article examines the technical efficiency and service effectiveness of 14 integrated transport systems in Czechia. The transport systems were evaluated using a non-oriented Network Data Envelopment Analysis (NDEA) model, assuming variable returns to scale, in two variants: fixed-link and free-link. The model consists of two phases. The first phase measures how efficiently regions purchase services from transport operators. The second phase assesses whether transport services are used effectively by passengers. The study also evaluated the impact of competition in the selection of transport operators on technical efficiency and the impact of transport system quality on service effectiveness. The research results showed that the average technical efficiency score is higher than the average service effectiveness score. Transportation systems in three regions (Central Bohemia, Prague, and the Karlovy Vary region) were identified as benchmarks. The fixed-link model has lower discriminatory power and is better suited to operational management of transportation systems. The free-link model also shows the desired change in intermediates and is suitable for future planning of the scope of transportation services.

Keywords: integrated transport system, technical efficiency, service effectiveness, slacks-based measure model, network data envelopment analysis

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Weekday and Daytime Influence on Work Contours in Projects

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A substantial portion of the authors' prior research has been devoted to analysing the distribution of work effort over the duration of individual activities or groups of activities within projects, leading to the formulation of work effort models. In addition to parameters derived from the technology of specific activ-ities (e.g., Front-Loaded, Back-Loaded, Turtle, Bell etc.) and scheduling con-straints derived from the objective (un)availability of resources resulting level-ling process, work effort is also significantly influenced by subjective factors.

Among the principal subjective influences are, in line with approaches such as the Critical Chain method generating Student Syndrome and Parkinson's Law, as well as effects stemming from weekly work cycles namely, variations in work performance and willingness to exert effort across different times of day and days of the week.

This research analyses the evolution of work effort as a function of daytime phase (morning vs. afternoon) and weekday (Monday through Friday), in com-bination with both subjective and objective factors. In addition to the task com-pletion horizon, the temporal dimension of the working week is explicitly con-sidered.

Given that work motivation at the level of the working week relates not to a specific task but rather to engagement with the current project portfolio, the in-fluence of individual task deadlines is assumed to be marginal in this context.

An exploratory study was conducted involving secondary and university students, as well as project professionals, employees, and managers. The resulting model constitutes a comprehensive mathematical representation of the ex-pected work effort of a project worker across a portfolio of tasks, under the constraint of a limited weekly working time capacity.

We assume that the results of the model will be provided to project managers authority to adjust key milestones and deadlines for project tasks and to in-crease the motivation of project resources.

Keywords: resource work effort, work contour, daytime phases contour model, deadline optimization

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Composite-based Analysis of the Relationship between Economic and Social Upgrading

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The methods of factor analysis, rooted in psychometrics, are widely adopted in many disciplines were researchers face the challenge of measuring directly unobservable, multidimensional concepts. In particular, there are some applications of factor analysis in the studies of industrial/economic upgrading. However, in the light of most recent methodological literature, operationalisation of economic upgrading as a latent variable is not a correct approach. Since upgrading is rather a forged concept, this study employs composite-based structural equation modelling methods to explore the potential relationship between economic and social upgrading, where both of these concepts are treated as composites.

Economic upgrading is "a move to higher value added activities in production, to improve technology, knowledge and skills, and to increase the benefits or profits", particularly in the context of participation in global value chains. The most popular framework distinguishes four types of economic upgrading: process, product, functional, and chain upgrading. Social upgrading refers to, i.a., working conditions, wage levels, working hours, employment type etc. Economic upgrading is perceived as a precursor for social upgrading, however, the former does not necessarily lead to the latter.

Since different up- or even downgrading paths are possible, it is worth investigating whether there is a pass-through from economic to social upgrading. Moreover, in our model we distinguish different types of upgrading to check whether they show different association with social upgrading. The analysis uses aggregated data for over 20 European countries, USA, and Japan, derived from ILOSTAT, EUKLEMS, and OECD databases. The results show that mainly the functional upgrading, composed of growth of the high-skilled and medium-skilled labour exports, is positively related to social upgrading. Product upgrading seems to have rather insignificant relation with social upgrading, while upgrading of production process may lead to social downgrading. These relationships between economic and social upgrading are moderated on the country-level by the institutional environment.

Keywords: composite-based SEM, economic upgrading, social upgrading

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Comparison Between Logistic Regression and Machine Learning Methods Using Monte Carlo Simulations

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There have been many benchmarks of classification algorithms over the years, which primarily focused their evaluation on real-world datasets. A less common approach to benchmarking classification methods has been a simulation study, which this paper aims to rectify. Monte Carlo simulations are performed by simulating 500 artificial datasets across different scenarios and varying numbers of observations, on which the classification methods are trained and evaluated. The chosen methods for comparison are logistic regression, random forest, XGBoost, neural network and Gaussian naive Bayes.

Keywords: machine learning, binary classification, comparison, simulation study, benchmark

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An Exploratory Workflow for Stop-Level Novelty Detection in Regional Bus Delay Data

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Public-transport delay records are heterogeneous: individual bus trips may serve different subsets of stops, while their delay profiles vary because of operations, schedules, and data quality. This paper presents an exploratory workflow for stop-level novelty detection in regional bus data from the Zlin Region, Czech Republic. It demonstrates how historical operational data can be prepared to explore potentially unusual local delay behaviour.

Trip instances from 2024 are used as a candidate training period, and subsequent 2025 instances as an illustrative test period. Each trip is represented by arrival delays across up to 53 stop positions, while stops not served by short-turn trips are treated as unobserved. An Isolation Forest filters atypical daily delay profiles to form a conservative candidate set of regular trips. A semi-supervised novelty forest is then trained on the retained stop observations using raw stop position and signed arrival delay in seconds.

The paper examines the resulting stop-level novelty decisions in the test data through delay profiles and empirical delay distributions. This analysis relates historical regular observations to new observations classified as regular or potentially novel, and illustrates how the workflow may support exploratory monitoring, expert review, and the subsequent development of labelled evaluation data for public-transport operations.

Keywords: novelty detection, public transport, bus delays, Isolation Forest, Half-Space Trees, anomaly detection

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Predicting Realized Volatility of Bitcoin and Ethereum with Sample Entropy

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This study uses hourly price data for Bitcoin and Ethereum from 2018 to 2025 to compute sample entropy over rolling windows, which is then employed to forecast next-day realized volatility. We find a positive and statistically significant relationship between sample entropy and realized volatility for both cryptocurrencies, indicating that higher market complexity is associated with increased future volatility. The predictive power of sample entropy varies depending on the choice of rolling window and varies over time, reflecting evolving market conditions. Overall, our findings demonstrate that chaos-based measures can be dynamically utilized to predict realized volatility and suggest potential applications to other economic and financial variables.

Keywords: sample entropy, realized volatility, cryptocurrencies, prediction

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Convergence and Differentiation in Slovak Spa Enterprises: A Cluster Analysis of Financial Indicators

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This study examines the financial performance of spa enterprises in Slovakia using cluster analysis applied to selected financial indicators across five dimensions: profitability (Return on Assets, Return on Sales), efficiency (Assets Turnover), cost efficiency (Personnel Cost Ratio, Cost-to-Sales Ratio, Return on Costs), liquidity (Net Working Capital, Current Ratio), and indebtedness (Equity to Total Liabilities Ratio, Debt Ratio). The analysis was conducted separately for the years 2023 and 2024 in order to identify changes in the internal structure of the sector. The results reveal a reduction in the number of clusters from six in 2023 to five in 2024, indicating a partial convergence of financial characteristics among spa enterprises. A substantial proportion of spas shifted into a single dominant cluster in 2024, suggesting increasing similarity in their financial profiles. At the same time, a distinct subgroup of spa enterprises emerged in 2024, forming a separate cluster after shifting from the previously dominant cluster in 2023, indicating differentiated financial trajectories within the sector. Several entities maintained stable positions across both years, while certain spas consistently formed individual clusters, reflecting unique financial characteristics. The findings suggest a trend toward homogenization within the Slovak spa sector, accompanied by the persistence of specific outliers and emerging subgroups. These insights contribute to a better understanding of the financial dynamics and structural evolution of spa enterprises and may support strategic decision-making and sectoral policy development.

Keywords: spa enterprises, tourism, financial performance, financial indicators, cluster analysis

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Beyond Predict-then-Optimize: Decision-Focused Learning for Grid-Scale Battery Arbitrage

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The integration of renewable energy has introduced extreme price volatility in short term electricity markets, creating arbitrage opportunities for Grid Scale Battery Energy Storage Systems. Traditional trading relies on a two step predict then optimize method, minimizing statistical error before the final optimization step. This approach is suboptimal due to the severe disconnect between statistical accuracy and financial outcomes.

This paper proposes an End to End Optimization framework applied to the Czech day-ahead and Imbalance markets. We encode physical and operational constraints directly into a convex optimization problem acting as the final differentiable layer of a neural network. The model is trained via decision-focused learning. The loss function directly minimizes financial regret rather than standard statistical errors. Empirical evaluations on historical market data demonstrate that our integrated framework yields superior capital preservation and risk mitigation compared to traditional decoupled models, establishing a much safer bidding strategy for highly volatile environments.

Keywords: decision-focused learning, battery storage, energy arbitrage, predict-then-optimize

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Translating Online Search Behavior into Quantitative Portfolio Views: Evidence from Hong Kong

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A growing body of research confirms that investor attention, captured through Internet search activity, carries predictive information for asset returns, trading volume, and volatility. Yet attention signals have been rarely incorporated into portfolio construction frameworks. This study proposes a methodology that operationalizes Google Trends (GT) search data as quantitative investor views within the Black–Litterman (BL) model. Attention is measured as the relative deviation of current search intensity from its eight-week median baseline, consistent with the attention-driven price pressure hypothesis. Panel regression results confirm that attention changes statistically significantly predict next-week stock returns. We then embed this signal into the BL framework to construct GT-augmented portfolios. A rolling-win-dow out-of-sample back test benchmarks the resulting BL+GT strategy against passive and mean–variance-optimized alternatives. The strategy yields higher cumulative returns and lower maximum drawdown, suggesting that search-based attention provides incremental predictive information for portfolio construction.

Keywords: investor attention, portfolio optimization, behavioral finance, Google Trends, Black–Litterman model

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Modeling Number of Advertisements and Asking Prices of Flats with Regression Analysis: Moravian-Silesian Region 2018–2026

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Monthly time series of apartment listings and average asking prices per square meter in six districts of the Moravian-Silesian Region (08/2018–03/2026) are analyzed. To examine the influence of the number of advertisements and mortgage interest rates on offered prices, a system of simultaneous equations is estimated. This approach allows modeling the relationship between apartment supply and price.

Keywords: simultaneous equations, real estate market, average asking prices of apartments, estimates of unknown parameters

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Mean-risk Approach to MCDM-based Evaluation: Experiments with Risk Measures and Ranking Algorithms

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This paper presents a comparative computational study of risk-aware multicriteria decision making under synthetic uncertainty. Building on a Monte Carlo-based mean-risk framework, we combine AHP and PROMETHEE evaluations with two risk measures, Conditional Value-at-Risk (CVaR) and Mean Absolute Deviation (MAD), and analyze how the resulting recommendation weights evolve as the decision maker's risk-aversion parameter increases. A set of scenarios is designed to isolate the effects of mean dominance, asymmetric volatility, and uncertainty placement across strong and weak criteria. The experiments reveal several recurring patterns. First, the influence of risk aversion is typically threshold-like rather than gradual, with allocation changes occurring around distinct switch points. Second, risk aversion becomes relevant mainly when uncertainty is asymmetric relative to the mean advantage of the leading alternative. Third, the strongest destabilization occurs when uncertainty affects the mean-leading alternative or its strong criterion. Across scenarios, CVaR and MAD produce qualitatively similar reallocations, but CVaR usually triggers earlier transitions, whereas MAD leads to more delayed responses. AHP and PROMETHEE mostly agree on the direction of change as risk aversion increases, although they differ in the exact switch points and in the smoothness of weight trajectories. When the optimal weights of all alternatives become nearly equal, the framework indicates the absence of a robust single recommendation rather than a clear winner. The study does not aim at universal generalization; instead, it identifies recurring empirical regularities that can support the interpretation of risk-aware MCDA models and motivate further testing on broader classes of instances.

Keywords: mean-risk, Analytic Hierarchical Process, PROMETHEE, Conditional Value at Risk, Mean Absolute Deviation, Multi-criteria decision-making

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A DEA-Bootstrap Framework for Assessing Educational Quality in Industrial Engineering Programs

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This study evaluates the relative efficiency of industrial engineering programs in Colombia by integrating Data Envelopment Analysis (DEA) with the smoothed bootstrap, which yields bias-corrected estimates and confidence intervals. Under constant and variable returns to scale (CRS, VRS), an output-oriented model relates the generic competencies to the discipline-specific professional competencies measured by the Saber PRO national examination across 92 universities. Because both competency blocks are assessed in the same examination at the end of the program, the model is interpreted as a cross-sectional description of each program's attainment structure rather than as a transformation of entry-level inputs into outcomes. The results reveal wide dispersion in the alignment between the two competency levels, and show that a substantial share of the measured inefficiency is associated with the scale of operation rather than with purely managerial factors. A complementary clustering and principal component analysis organises programs into two action profiles supporting tailored improvement strategies.

Keywords: Educational evaluation, efficiency, Data Envelopment Analysis, bootstrap, learning analytics.

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