MME 2025

The 43rd International Conference on Mathematical Methods in Economics

3–5/9/2025

Book of Abstracts

Tomas Bata University in Zlín

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Book of Abstracts

The 43rd International Conference on Mathematical Methods in Economics (MME 2025)

September 3 – 5, 2025

Tomas Bata University in Zlín

Zlín, Czech Republic

43rd International Conference on Mathematical Methods in Economics (MME 2025)
September 3-5, 2025.
Hosted by Tomas Bata University in Zlín, Faculty of Management and Economics, Mostní 5139, 760 01 Zlín
https://mme2025.utb.cz/

Book of Abstracts of the 43rd International Conference on Mathematical Methods in Economics
Publisher: Tomas Bata University in Zlín, nám. T. G. Masaryka 5555, 760 01 Zlín
Editors: Lubor Homolka, Dušan Hrabec
Edition: 1st edition
Publication year: 2025
This publication is not subject to a language check.
All papers have passed a blind peer review process.
All papers adhere to the ethical guidelines of the publisher.
Typeset by LaTeXwith (modified) Book of Abstracts template © José Pedro Costa.
ISBN: 978-80-7678-359-1

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Welcome

It is my great pleasure to welcome you to the 43rd International Conference on Mathematical Methods in Economics (MME 2025), hosted by Tomas Bata University in Zlín. This Book of Abstracts brings together the contributions accepted after a peer-review process and presented at the conference. It reflects the breadth of current research in operations research, econometrics, and mathematical modeling in economics, and serves as a valuable record of the scientific exchange taking place here.

We are proud to host two world-renowned plenary speakers, Professor Stein W. Wallace and Professor Milan Hladík, whose lectures will provide inspiration and valuable insights into the state of the art of mathematical modeling. They will be complemented by Mr. Tomáš Pajonk, an expert from practice who applies advanced methods closely related to the topics of this conference in real-world logistics and decision-support systems. This combination of academic excellence and practical experience will enrich the discussions and strengthen the bridge between theory and application.

As in previous years, the conference also includes the PhD student competition, providing a platform for young researchers to present their work and engage with the scientific community. Beyond the academic program, we invite you to explore the unique industrial and cultural heritage of Zlín. The social events — including the conference excursion to Baťa's landmarks and the traditional conference dinner at Baťa's Villa – will provide excellent opportunities to strengthen professional ties and enjoy the atmosphere of our host city.

I would like to sincerely thank all authors, reviewers, and members of the organizing and program committees for their invaluable contributions. Special thanks go to the Czech Society for Operations Research for their continued support.

I wish you an inspiring conference, fruitful discussions, and a pleasant stay in Zlín.

On behalf of the Organizing Committee,
Dušan Hrabec
General Chair of MME 2025
Zlín, September 2025

Plenary Lectures

Modeling with Stochastic Programming

prof. Stein W. Wallace

There are many deep papers on the mathematics and algorithmics of stochastic programming. But why should we, as operations research people, care? The world is stochastic for sure, but does that imply that we need stochastic models to get good decisions? And if we embark on a genuine application, where real money is involved, what are the modeling questions we need to pose? What are the steps we need to take before we arrive at mathematical and algorithmic challenges?

Interval Linear Programming and Its Applications

prof. Milan Hladík

Interval Linear Programming (LP) provides theoretical foundations and methods for handling LP problems with interval coefficients. While such intervals often represent uncertain input data, we focus on fundamentally different applications. Specifically, we demonstrate how interval LP techniques can be used to address numerical issues in classical real LP, to construct relaxations in global optimization, and to conduct a more comprehensive sensitivity analysis that may involve all coefficients simultaneously.

Good times with Operations Research. The hunt for practical applications

Tomáš Pajonk

Enhanced Novelty Detection in Economic Big Data Using Half-Space Tree

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This study introduces an advanced method for detecting novel patterns in large-scale economic data by leveraging a modified Half-Space Tree approach, which extends the functionality of the well-established Isolation Forest algorithm. The primary contribution of this research lies in enhancing the efficiency and accuracy of anomaly detection in complex economic datasets, encompassing transactional flows, financial market indicators, and consumer behavioral patterns. Given the increasing volume and complexity of economic data in modern financial and commercial systems, traditional anomaly detection techniques often struggle with scalability and precision.

The proposed modification to the Half-Space Tree framework optimizes the process of isolating anomalous patterns by refining how data points are partitioned within the tree structure, ensuring more robust and reliable identification of outliers. This refinement allows for improved detection of subtle and emerging anomalies that might be overlooked by conventional methods. By incorporating adaptive thresholding and advanced probabilistic measures, the approach enhances the model's ability to differentiate between normal variations in economic trends and truly novel or potentially disruptive events.

In addition to its technical contributions, this research also discusses the broader implications of enhanced anomaly detection in economic big data. By enabling faster and more accurate identification of irregularities, the proposed method can support decision-makers in finance, commerce, and policymaking by providing deeper insights into underlying economic dynamics. Ultimately, this study advances the field of economic data analysis by introducing a novel, scalable, and high-performance solution for detecting previously unseen patterns in complex and evolving datasets.

Keywords: anomalies, novelty search, isolation forest, binary trees, bigdata

Visegrad Four from Crisis to Crisis

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The purpose of this paper is to quantify the impact of the sequence of crises, which began with the COVID-19 pandemic crisis (in Europe in early 2020) followed by the energy crisis and then the crisis related to the war in Ukraine, on the development of the gross domestic product of the Visegrad Four countries. An important objective is also to compare this impact with the consequences of the financial crisis that began in the fall of 2008, which transformed into an economic crisis.

Data on annual gross domestic product per capita at current prices (in USD) come from the official website of the Organization for Economic Cooperation and Development and cover the period from the beginning of the 3rd millennium to 2023. Using data on annual inflation for individual countries, these data were converted to constant prices with a base in 2000.

Exponential smoothing was deliberately used in the construction of the models of the obtained time series. Based on the models, predictions of the mentioned time series for the next three years were constructed, simulating the situation that would occur under unchanged conditions if the economies of these countries had not re-bounded from the bottom.

Keywords: Brown's linear exponential smoothing, Brown's quadratic exponential smoothing, Holt's linear exponential smoothing, Visegrad Four, gross domestic product, recession and economic crises

Stochastic Bilevel Waste-to-Energy pricing

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Waste-to-energy (WtE) plants offer a way of treating waste while converting it to energy. A vital part of a well-functioning waste management environment is the right price setting of gate fees, i.e., treatment price per amount of waste, for the WtE plants. The amount of waste flowing to some plants depends on the gate fees of competition and the transportation costs from the waste producers (municipalities) to the given plant. Thus, the payoff function of each WtE plant forms a bilevel structure in which the leader (WtE plant) tries to maximize revenue while considering the follower's reaction to the gate fee. All the municipalities that try to minimize their total waste processing costs cooperatively represent the follower. A more robust price setting, which can help to obtain a more realistic and stable outcome, can be provided if stochasticity is included in the problem. The most suitable parameter in the model that can be considered subject to stochastic influences is the amount of waste produced by the municipalities. Building on the heuristic proposed in the literature, the heuristic mathematical programs are enhanced to handle random variables. Each random variable corresponds to fluctuations of the waste production around the mean waste production of each municipality. In the future, the gate fees proposed by the novel stochastic-enhanced heuristics were tested against realizations solved by the original heuristics.

Keywords: Bilevel programming, Probabilistic Constraints, Waste-to-Energy, Price Setting

Portfolio selection in the return and absolute deviation space incorporating ESG indicators

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Investment strategy optimization uses portfolio models that diversify assets to minimize risk and maximize return. The paper defines investment risk as the absolute deviation from the expected return. Given the growing importance of sustainable investing, the model is extended with ESG (Environmental, Social, Governance) criteria to ensure consistency with the principles of socially responsible investing. The application of the proposed approach is demonstrated on Dow Jones Industrial Average (DJIA) stocks, providing a practical insight into integrating ESG factors into investment decision making.

Keywords: portfolio, ESG, optimization

Revisiting the Almost Ideal Demand System with Respect to Substitutability and Complementarity: Suitability for Simulating Consumer Behavior

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This paper investigates the suitability of the Almost Ideal Demand System as a foundation for simulating consumption behavior conditional on known relationships between products. It derives the system's exact Marshallian demand functions and corresponding cross-price elasticities, assessing how these align with established theoretical definitions of complementarity and substitutability; namely the q, p, gross, and net perspectives. While the Almost Ideal Demand System satisfies core axioms of consumer theory and offers interpretable parameter structure, its lack of an explicit utility function limits its connection to preference-based definitions. The paper concludes that although the system is analytically elegant, alternative formulations, such as quadratic utility functions with interaction terms, may offer better operational grounding for simulations involving context-sensitive product relationships.

Keywords: Almost Ideal Demand System, Consumer, Cross-price elasticity, Substitutes, Complements

Efficiency of Regional Transport Systems

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The paper compares the efficiency of 13 regional transportation systems in the Czech Republic. The comparison is based on a two-stage Data Envelopment Analysis using slack-based models. In the first stage, technical efficiency is evaluated, i.e. how efficiently regions are able to arrange transport services from bus and rail operators. The second stage examines service effectiveness, i.e. how efficiently the transport services are used by passengers. At the same time, the influence of external factors such as population density, the density of the road and rail network and the level of motorization of the population on both scores is examined. The research is based on data from 2023. The results show considerable variation between regions. In terms of technical efficiency, five regions (Karlovy Vary, Liberec, Olomouc, Pardubice, Usti and Labem) scored highest. In the second phase, only two systems (South Moravian and Moravian-Silesian regions) achieved the maximum score. Further research showed that the density of transport infrastructure influences the level of technical efficiency. Service effectiveness is positively influenced by population density and inversely proportionally by the density of transport networks and the level of motorization of the population.

Keywords: data envelopment analysis, integrated transport systems, public transport, service effectiveness, slack-based measure model, technical efficiency

Evaluation and Ranking of Scientific Journals

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The quality of scientific journals is judged by various metrics and indices that often lead to quite different rankings of the journals. The aim of the study is to propose a new ranking of the journals considering several main metrics such as article influence score (AIS), journal impact factor (JIF), Scimago Journal Rank (SJR) index, academic journal guide (AJG) evaluation, the UT Dallas ranking, and h-index of the journals. The results given by metrics are evaluated and aggregated using an original aggregation ranking optimization procedure and data envelopment analysis models. The study is carried out on a set of more than 100 journals of the Web of Science category Operations Research & Management Science.

Keywords: data envelopment analysis, ranking, aggregation, impact factor

Delta-equilibrium in Price-setting Games

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This paper investigates a newly introduced class of price-setting games, focusing on the existence of Nash Equilibrium for them. It explores the possibility that no stable price equilibrium exists from a mathematical perspective. To address this, the concept of classical Nash equilibrium is replaced with δ-equilibrium, a strategy profile that can approach Nash equilibrium arbitrarily close in the sense of a limit. This adaptation aligns with practical applications where prices are set in specific currencies with minimal granularity. The work quantifies fundamental limitations affecting the existence of classical Nash equilibrium. The studied games involve markets where producers aim to maximize profits while customers minimize their total costs to fully satisfy demand without exceeding the capacities of producers. The paper examines the existence of δ-equilibrium under varying assumptions regarding capacity and transportation, contributing to the understanding of equilibria in a price-setting context.

Keywords: pricing, game theory, Nash equilibrium, bilevel programming

The Share and Intensity of the Digital Transformation Process in EU Countries

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The process of transforming business activities involves not only the implementation of new technologies and changes in organizational culture but also modifications in processes and business models. The benefits include increased efficiency and productivity, improved data-driven decision-making, innovation, and enhanced competitiveness in a turbulent market. This study examines the impact of selected digital technologies on the Very High Digital Intensity Index in EU countries in 2023. The selected digital technologies considered include cloud services, artificial intelligence, internal process integration, customer process integration, e-commerce, and data analytics. For the evaluation of European countries, enterprises with more than 10 employees were taken into account. Robust estimates of cross-sectional regression models were conducted for comparison of two sectors: Manufacturing and Information and Communication. The results indicate that the average value of digital intensity is lower in the Manufacturing sector. In the Information and Communication sector, the most implemented technologies were cloud services, internal process integration, and data analytics, which differs from the Manufacturing sector, where the highest share of companies utilized internal process integration and customer collaboration technologies. The high level of digital transformation intensity was primarily driven by the use of artificial intelligence technology.

Keywords: Digital intensity index, digital technologies, EU countries, Manufacturing sector, Information and Communication sector

Stochastic PROMETHEE: Optimal Portfolio Using Mean-Variance Model

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The PROMETHEE method is one of the most popular multi-criteria decision-making methods, providing a ranking of alternatives. By combining the original PROMETHEE ranking algorithm with integer programming, it can also be applied to portfolio selection (the so-called PROMETHEE V method). However, there have been very few approaches to incorporating random variables into PROMETHEE, and no stochastic extension of PROMETHEE V exists. The aim of this research is to introduce the stochastic PROMETHEE V method. The proposed algorithm employs Monte Carlo simulation to compute the random net flows of alternatives. Subsequently, the optimal portfolio is determined using stochastic optimization, specifically the mean-variance model. The findings will be supported by numerical experiments demonstrating that the risk associated with performances of alternatives can influence the final decision.

Keywords: mean-variance, multi-criteria decision-making, stochastic programming, PROMETHEE, optimal portfolio

Assignment Mutation in Evolution Algorithm to Improve Solutions in Flexible Job Shop Scheduling

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The Flexible Job Shop Scheduling Problem (FJSP) is widely recognised for its ability to model complex manufacturing environments. A key challenge in FJSP is the assignment of operations to available machines, as machine selection directly influences production efficiency, resource utilisation, and overall scheduling performance. Besides the crossover operator, which influences machine assignments, mutation plays an important role in the Evolution algorithm. Random mutation is usually used as a tool that prevents optimisation from getting stuck in local optima and enriches the population of solutions so that they do not converge to one solution. This article focuses on enhancing the machine selection process within evolutionary algorithms by introducing mutations that are not strictly random. It uses information about a particular scheduling instance to suggest changing machine assignments. The research evaluates the impact of assignment mutation on convergence and computational efficiency in comparison with a simple evolution algorithm without mutation and with a standard random mutation technique. To validate the approach, known FJSP benchmark instances are used. The experimental framework assesses how different deterministic-based mutation strategies influence scheduling outcomes, providing insights into their practical applicability in real-world flexible job shop environments.

Keywords: Flexible Job Shop Scheduling Problem, Evolution Algorithm, Mutation, Machine assignment

On the Efficient Design of a Network Under Multiple Criteria

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The problem of searching for a maximum flow between a source and terminal in a network with limited edge capacities is a classic problem of graph theory. We assume that the edge capacities are not explicitly given but subject to a predefined lower and upper bound. We aim to design a network that would enable maximum flow between two vertices while additional criteria may be considered, such as the cost of edge capacity building or flow risk mitigation. We propose a methodology for constructing the optimal edge capacities with respect to a given budget. The optimal edge capacities represent an efficient design in a multi-objective sense. Our approach is inspired by the DeNovo optimisation framework with specific adjustments. We demonstrate our methodology using an artificial example. A comparison with traditional multiobjective approaches is shown, and it turns out that none of them can be considered superior to the others, as is usual in multiobjective optimisation. The added value of our approach is that it acts as a decision-making support, providing the information on the required budget increase if better criteria values are desired.

Keywords: DeNovo optimisation, efficient design, metaoptimisation, multiobjective optimisation, network flow

Mean-CVaR Portfolio Choice Problem With Endogenous Randomness

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Portfolio optimization problems include a random element corresponding to the losses or returns of various assets. The usual assumption is that the randomness is exogenous, meaning that the distribution of losses can not be influenced by the investor's decisions. However, there may be cases where this assumption is not completely sound, for example when we deal with a combination of a large investor and a company with a small market capitalization. We present a portfolio optimization problem with endogenous randomness, minimizing the CVaR risk measure, while assuming that a large enough investment in an asset can influence its loss distribution and improve performance. After discretization of the investment effects, various partitions of the feasibility set can be constructed based on the investor's budget and asset's market capitalization. We study the possible changes in portfolio composition under different budgets.

Keywords: stochastic optimization, endogenous randomness, conditional value at risk

Cluster Patterns and Coopetition Potential Among EU Countries: An Analysis Based on the Travel and Tourism Development Index

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This study examines the potential for cross-border coopetition—simultaneous cooperation and competition—among European Union (EU) countries in the travel and tourism sector, using cluster analysis based on data from the Travel and Tourism Development Index (TTDI). Specifically, it focuses on 14 indicators within the Travel and Tourism (T&T) Resources dimension for 27 EU member states across three years: 2019, 2021, and 2024. The primary aim is to determine whether countries consistently belong to the same clusters over time or shift between them, which would have implications for formulating coordinated tourism policies. Cluster analysis was conducted using Ward's method, which produces clusters of similar size and shape by maximizing intra-cluster homogeneity. The number of clusters was determined using the Duda-Hart Je(2)/Je(1) index and the pseudo-T^2 stopping rule. A dendrogram was employed to visually represent the hierarchical structure of clusters. In all three years, four distinct clusters were identified. Notably, only four countries changed their cluster affiliation over the analyzed period: the Netherlands in 2019, Cyprus in 2021, and Belgium and Croatia in 2024. The overall stability in cluster membership sug-gests a promising foundation for regional cooperation in travel and tourism development across the EU, even among countries that traditionally compete for similar tourist markets.

Keywords: Travel and Tourism Development Index, Cluster Analysis, European Union, Tourism Resources, Coopetition, Competition, Cooperation

A Dynamic Two-Stage DEA Assessment of Energy Transition Progress in the European Union

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This study evaluates the transformation of EU Member States' energy systems between 2013 and 2023 using a combination of Malmquist Index (MI) and two-stage Data Envelopment Analysis (DEA) framework. The model captures how countries convert resource-intensive and externally dependent energy structures into economic output and, subsequently, into renewable energy adoption across key consumption sectors. In the first stage, input variables include energy consumption per capita and import dependency, whereas outputs reflect the system's economic and environmental outcomes—GDP per capita (desirable) and greenhouse gas emissions per capita (undesirable). In the second stage, GDP per capita is treated as an input enabling investment, while outputs are sectoral renewable energy shares in electricity, heating and cooling, and transport. This structure reflects a sequential interpretation of energy transition: the capacity to generate economic output from energy use, and the effectiveness with which this capacity is reinvested into sustainable energy deployment. The model is applied to data from all EU-27 countries in 2013 and 2023 to assess energy transition progress. The results highlight significant cross-country variation in performance and improvement. Some countries demonstrate high efficiency in both stages, while others either struggle to decouple energy use from emissions or fail to translate economic gains into renewable expansion. The two-stage approach offers nuanced insights into the mechanisms of energy transition and helps identify where policy or investment gaps persist.

Keywords: Dynamic Data Envelopment Analysis, Energy Transition, Greenhouse gas emissions, Malmquist Index, Renewable energy

Efficiency of Green Renovation Subsidies in Czech Districts: A robust DEA Approach

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The New Green Savings Programme (Nová zelená úsporám) has been a key policy for improving energy efficiency in Czech homes, but its uptake varies across districts. This study uses a robust Data Envelopment Analysis (DEA) model to assess the efficiency of Czech districts in converting their demographic, socioeconomic, and housing characteristics into subsidies for home energy renovations. The output variable is the per capita subsidy amount received by each district, while the input variables include demographic and housing factors from the 2021 Czech Census. Housing-specific inputs include the age of buildings, floor area, number of rooms, technical equipment, and heating type, while environmental and socioeconomic variables such as education level, income, and urbanization are also included.

The study finds significant regional disparities, with urban and wealthier districts more effectively utilizing subsidies, while economically disadvantaged and rural areas are less efficient in subsidy uptake. These findings suggest the need for targeted policy interventions to improve equity in subsidy distribution. The study demonstrates the value of applying advanced DEA models to evaluate regional subsidy effectiveness and offers actionable insights for enhancing the design of energy efficiency programs. Additionally, the analysis helps identify risks of the free-rider effect, where economically stable households may benefit from subsidies they do not necessarily need, which could undermine the program's overall impact.

Keywords: Efficiency, Energy, Subsidies

Chaotic Optimization with Different Chaos Maps for Tuning XGBoost: Application to Gas Demand Forecasting

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Accurate forecasting of gas consumption plays a crucial role in ensuring the stability and efficiency of energy systems. This paper explores the application of chaotic optimisation for tuning the hyperparameters of the XGBoost algorithm, with a particular focus on how different chaos maps influence forecasting performance. To enhance the model's predictive capabilities, several chaotic maps—including Henon, Kent, Tent, Logistic, and Random—are evaluated within a metaheuristic optimisation framework. The methodology is applied to the short-term prediction of aggregated daily gas consumption in the Czech Republic, with the Root Mean Square Error (RMSE) used as the primary evaluation metric. The study aims to assess the ability of chaos-based strategies to improve optimisation behaviour by helping the algorithm escape local optima and discover more accurate solutions.

Keywords: Chaotic Optimization, Chaos Maps, XGBoost, Hyperparameter Tuning, Gas Consumption

Lyrical Themes in Contemporary Heavy Metal Albums: A Case Study

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Heavy metal has been a leading force in the world of rock music for over five decades, and it is still going strong after all these years. Heavy metal bands are characterized by monumental sound which is supported by bass, drums and distorted guitars. Since its inception, heavy metal lyrics have been associated with a certain degree of controversy, mystery, and provocation. In this conceptual paper, we propose a method to identify the most common lyrical themes in the genre. The proposed method uses a semantic network and analytic network process to calculate the importance of individual lyrical themes, based on the lyrical themes of the leading bands in the heavy metal genre. The method provides a tool for evaluating lyrics on selected albums by a decision maker. We demonstrate the proposed concept in a case study. In the case study, we examine and evaluate the lyrics of contemporary heavy metal albums by bands that have a significant influence on the scene.

Keywords: analytic network process, case study, decision making, heavy metal, lyrical themes, semantic networks

Vehicle Routing & Simulations: Revealing Hidden Solution Qualities

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Vehicle routing problems (VRP) are among the most widely studied combinatorial optimization problems, arguably thanks to their apparent connection to omnipresent challenges in logistics. Extensive research of a broad range of VRP variants has given rise to approaches ranging from exact algorithms to metaheuristics or hybrid methods. Building on top of these decades of research experience, matured general-purpose metaheuristics such as Adaptive Large Neighborhood Search, Unified Hybrid Genetic Search, or Slack Induction by String Removals allow for addressing rich real-world industrial applications both in terms of their complexity and scale. These algorithms clearly excel at the task they were designed for such as minimizing the traveled distance, transportation costs, or the number of utilized vehicles. However, does this mean that they necessarily produce solutions possessing the qualities desirable in practice? Can the algorithmically produced solutions be executed without major disruptions when facing various types of uncertainty? If there are disruptions, is it possible to adjust the routing plan to recover from them? Would it be possible to incorporate previously unknown customers into the routing plan during its execution? Or, how inconvenient is the modification of their routes for drivers? All these questions are connected to the inherent uncertainty and dynamicity of real-world environments. Unfortunately, the aforementioned algorithms assume deterministic environments despite these questions presenting important solution qualities in practice. In order to answer these questions and reveal the otherwise hidden routing plan qualities, we simulate the executions of our routing plans. We will explore how such simulations can be used to adjust the search algorithms and to better understand routing plan qualities, covering both classical benchmark VRP variants as well as a rich VRP arising from an industrial application.

Keywords: vehicle routing problem, simulation, uncertainty, real-world problems, optimization, heuristics

Consumer Preferences and Utility in Milk Chocolate Selection: Conjoint Analysis and TOPSIS Method

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This study examines consumer preferences in the context of milk chocolate selection using a conjoint analysis based on primary data collected through a questionnaire. The analysis focusses on four key attributes of the product: brand, price, weight, and content of certified cocoa. The results of the conjoint analysis provide the relative importance (weights) of individual criteria and estimate the utility associated with brand and certified cocoa content. The resulting preference structure serves as the basis for applying the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method to rank the actual chocolate products currently available on the market. This multicriteria decision-making framework allows for a systematic comparison of alternatives with respect to an ideal product profile. In addition, a sensitivity analysis is conducted to explore the robustness of the ranking outcomes. Specifically, we investigated the extent of the change in attribute weights required to alter the final product ranking. This provides insight into which attributes have the most influence on consumer choice under varying preference scenarios.

Keywords: Conjoint Analysis, Preferences, TOPSIS

Relationship between military and social expenditures in NATO countries

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Defense can be considered an example of a public good provided by the state and financed through the state budget. The size of military expenditure as part of government expenditure is influenced by a number of factors, such as the security and the economic environment of the country. In the case of NATO countries, there is a long-standing requirement to allocate at least 2 % of gross domestic product to defense. The current security situation in Europe is driving NATO countries to reconsider this political commitment towards a future increase in military spending above the required 2 % of GDP. The increased military budget can be financed in the form of an expansion of budget revenues, an increasing of expenditures and thus an increase of the deficit and indebtedness, or in the form of a reduction of other state budget items (e.g. education expenditures) leading to a crowding-out effect of non-military expenditures and the existence of an opportunity cost. The aim of the paper is to analyze the existence of a relationship between military expenditures and social expenditures and to confirm the possible crowding-out effect of these expenditures by military expenditures. A panel data analysis between 2013 and 2021 was used to analyze the selected NATO countries. Variables characterizing military expenditure as a share of GDP, education and health expenditure as a share of GDP were obtained from the World Bank database. As control variables, (tax revenues, households consumption GDP, Gini Index and population) were used in the econometric model.

Keywords: military expenditures, crowding-out, panel data

Using Multidimensional Comparative Analysis to Assess the Health Risks of the Elderly Population

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Multidimensional comparative analysis deals with the methods and techniques of comparing objects with multiple characteristics. This analysis can be widely applied in economics. In our paper, multidimensional comparative analysis will be used after assessing the health risks of the elderly population. Recently, the relevance of this topic has increased as people in all countries of the world are living to an increasingly older age. This trend is particularly evident in developed economies, including EU countries. If we focus on health risks, the situation of older people is different from that of younger people, because older people have been exposed to various, often harmful, influences and substances over a longer time period, which have weakened the body's defences and often caused chronic diseases. These health risks also place a heavy burden on healthcare systems, especially as the proportion of older people in the population increases in developed economies. The aim of this article is to identify and quantify risk factors associated with health status, mortality and health care costs for the elderly population in the Czech Republic and selected EU countries using multidimensional comparative analysis. We also use regression and cluster analysis.

Keywords: Multidimensional comparative analysis, Elderly population, Health risks

Determinants of the Herfindahl-Hirschman Index Affecting Market Power and Concentration in the Czech Insurance Sector

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This paper examines the determinants of the Herfindahl-Hirschman Index (HHI) in the Czech insurance industry, focusing on market power and concentration. The HHI values describe market concentration in the Czech insurance industry and reveal a moderately concentrated market with significant players. The 2012–2022 dataset from the Czech Association of Insurance Companies was selected for numerical analyses. Utilizing econometric methods, we assess the impact of key variables. They are divided into two categories: a) insurance sector-related indicators such as the number of insurance companies, claims settled, financial positioning, etc.; b) macroeconomic indicators such as GDP, inflation, government debt, etc. The findings suggest that factors such as the number of insurance companies and financial placement significantly affect market concentration. The paper concludes with recommendations for regulatory and strategic initiatives to increase competition and market efficiency in the Czech insurance industry.

Keywords: Herfindahl-Hirschman Index, Market Power and Concentration, Correlation Analysis, Economic Indicators

Self-Seeding in Single-Elimination Tournaments

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Seeding is crucial in ensuring the fairness and efficacy of many tournament formats. However, in many disciplines, the absence of an official ranking system complicates the seeding process. In this study, I explore a novel approach in which seeding is determined by the collective beliefs of players and teams regarding the ideal ranking order. Building on social choice theory, I examine the conditions under which this mechanism aggregates individual preferences to yield an accurate seeding and remains strategy-proof against manipulation using a simulation study focused on a standard single-elimination format. The findings provide a foundation for tournament organizers to adopt this seeding method, especially when random seeding is the only alternative.

Keywords: seeding, elimination tournaments, social choice theory, fairness, efficacy

Modeling Capital-Labor Substitution in the Era of Industry 4.0: A Sectoral Analysis of Czech Manufacturing

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The advent of Industry 4.0 is reshaping the labor, capital, and productivity landscape, posing both challenges and opportunities for economic policy and corporate strategy. A critical component of this transformation is understanding the extent to which labor is being substituted by capital—an insight essential for informed managerial decisions and the creation of innovation-driven policies. This paper employs the Cobb-Douglas production function as a robust analytical framework to quantify this dynamic within the Czech manufacturing sector. Through correlation analysis and least squares estimation, we construct production functions for the industry as a whole and for its individual subsectors. The explanatory power of each model is evaluated through determination coefficients, providing a comparative perspective on capital-labor relationships across sectors. The findings offer data-driven insights into sectoral readiness for Industry 4.0 and implications for future investments in technology and workforce development.

Keywords: Industry 4.0, Cobb-Douglas production function, manufacturing industry, labor, capital

Detecting Regime Shifts in the Taylor Curve: A Comparison of Time-Varying Parameter and Markov Switching Models

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The Taylor curve characterizes the trade-off between the variances of inflation and the output gap, offering a theory-based framework for evaluating monetary policy. This paper compares two empirical approaches to modeling the time-varying nature of this relationship: a state-space model with time-varying parameters estimated via the Kalman filter, and a Markov switching regression that allows for discrete regime changes. Using quarterly macroeconomic data from the Czech Republic, both models are applied to detect periods of policy inefficiency, focusing on key episodes such as the 2008 global financial crisis, the Czech National Bank's currency interventions, and the high-inflation period following 2021. The time-varying parameter model captures gradual shifts in the policy trade-off, whereas the Markov switching model detects abrupt structural breaks—particularly during periods of heightened macroeconomic stress. The results suggest that the choice of the model affects conclusions about the effectiveness of monetary policy in different macroeconomic periods.

Keywords: monetary policy, regime switching, Taylor curve

Extension of the WSJF method with the concept of Efficiency for Scrum team

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The paper proposes a modification of the WSJF method using the efficiency principle of the DEA method. WSJF method is used for task prioritization in the Scrum method in agile project teams. Agile project teams use prioritization when selecting tasks to tackle during sprints. Task prioritization (also known as User Stories) is a key attribute for the success of the Scrum method, i.e., meeting customer needs and expectations in the project. The authors propose an extension of the WSJF calculation using a modified Fibonacci sequence, as used in the Scrum method for user story estimates. However, the contribution of the paper is a new perspective and a new way of calculating WSJF, where the extension of the method with the efficiency principle provides new information about the nature of tasks for the team and project management. The paper responds to the increasing need for quantification of practices in agile project management, especially in teamwork according to the Scrum method. The paper includes a case study that illustrates the use of the suggestions for common practice in project management and the Scrum method. In this paper, the authors propose the use of weights for calculating Cost of Delay in the WSJF method and a correction for calculating WSJF score.

Keywords: Project management, Agile approach, Scrum, Project Team, DEA method, Efficiency

News Sentiment Aware Portfolio Optimization Strategy based on Crisis Regime Switching

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This study introduces an adaptive portfolio optimization framework that systematically integrates time-varying news sentiment signals with crisis-responsive regime switching, addressing the persistent challenge of regime shifts in financial markets. By leveraging VADER sentiment analysis augmented by news popularity decay weighting, we construct a dynamic sentiment index that captures evolving market narratives from news streams. The core technical innovation lies in a hybrid optimization architecture combining dynamic covariance estimation with sentiment momentum-adjusted return forecasting. At the same time, a self-tuning crisis module activates minimum-volatility allocation when sentiment breaches thresholds of its rolling baseline. The framework demonstrates robust performance through comprehensive backtesting on the Dow Jones component with a 1.46 Sharpe ratio and 2.27 Calmar ratio. These findings illustrate the framework's capacity to enhance return opportunities through sentiment-informed signals while maintaining controlled risk exposure during market dislocations.

Keywords: crisis regime switching, news sentiment driven, portfolio optimization, strategy comparison

Heterogeneous Region and Its Servicing by Distributed Queuing System

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Most of the location problems solved on a discrete transportation network use the model, in which both serviced demands and service centers are located at nodes of the transportation network. The nodes represent centers of gravity of the real sources of demands and also candidates of service center locations. This simplification enables determination of time or mileage distances as distances between the corresponding points on the real map of the region. On the other side, the simplification may bring severe inaccuracy in the used model, especially in the case, when the demands for service emerge randomly in the whole city district represented by the associated network node. Non-negligible size of the district area causes that the real distance between demand location and the service center located at the same city becomes zero distance and all demands in the city are neglected. If the city generates a considerable number of demands, the simplified objective function of the model is not reliable. This situation is extremely complicated a heterogeneous region, where the set of dwelling places is a mixture of small and large cities generating different numbers of demands. Within this contribution, we suggest a way to comply with the above described heterogeneity of the serviced region and publish influence of it on the suggested service system design.

Keywords: Heterogeneous region, Distributed queuing system, Emergency services

Accuracy and Complexity of the Radial Approach to Ambulance Location in Emergency Medical System

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The radial approach to location problems considerably improves solvability of the problems, where a given number of facilities should be deployed in transportation network nodes to minimize average distance between a user and a facility location. A smart solving algorithm of a location problem is especially important in situations, when an emergency medical system is designed to service a large region with hundred nodes of an associated transportation network. An excellent performance of the optimization method based on the radial approach is paid by worse accuracy. Inaccuracy of the method is caused by replacing of a real distance by a step-wise function of distance. The number and size of the steps influence conflictingly result accuracy and size of the model. This contribution is devoted to quantification of the above relations with the goal to find an acceptable balance between computational time necessary for the problem solution and accuracy of the solution.

Keywords: Location science, Emergency systems, Mathematical modelling, Accuracy sensitivity

Transforming Project Management through Systems Engineering Integration: A Pathway to Enhanced Efficiency and Risk Mitigation

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Abstract As project complexity continues to escalate in modern business environments, traditional project management (PM) approaches increasingly face limitations in risk control and effective coordination. This study investigates the potential of integrating project management with systems engineering (SE) as a means to enhance operational efficiency and improve project outcomes. Based on qualitative research involving in-depth interviews with ten experienced project managers from major Czech corporations, the study analyses critical areas where collaboration between project managers and systems engineers yields the greatest benefits. The findings clearly demonstrate that the active involvement of systems engineers—particularly in the early and intermediate phases of the project life cycle—significantly contributes to increased efficiency, improved cost control, and timely project completion. The integration of SE not only facilitates structured analysis and proactive risk prevention but also supports agile responses and adaptability in the face of unforeseen challenges. The study underscores the importance of early incorporation of SE into project frameworks and identifies key avenues for further research, including the development of standardized collaboration models. In conclusion, the synergy between PM and SE opens new opportunities for achieving sustainable and successful project outcomes across diverse sectors.

Keywords: systems engineering, project management, efficiency measurement, risk quantification and management, complex projects, project life cycle

Estimation of Price Elasticity of Demand for Energy in the Czech Republic

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This paper will focus on the estimation of the price elasticity of energy demand in the Czech Republic in the context of significant economic and political changes in recent years. The analysis uses a large dataset containing monthly data on electricity consumption, energy prices, meteorological conditions and socio-economic indicators. The main methodological approach is the application of ordinary least squares (OLS) regression models.

Keywords: elasticity, Czech Republic, electricity, energy consumption, OLS

Partial Least Squares Structural Equation Modeling in Energy Economics: An Empirical Assessment

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Structural Equation Modeling (SEM) is a widely used tool in multivariate analysis for examining complex relationships among observed and latent variables. While covariance-based SEM (CB-SEM) is traditionally applied for theory confirmation, Partial Least Squares SEM (PLS-SEM) has gained traction for its predictive capabilities and suitability for exploratory research. This paper presents a case study applying PLS-SEM to the energy sector, specifically to investigate the factors influencing household electricity consumption. Using publicly available monthly data on electricity consumption, prices, and climatic factors, the study constructs a PLS-SEM model to assess the direct and indirect effects of market and environmental drivers on household electricity demand. The results indicate that climatic factors exert a dominant direct influence on electricity consumption, whereas the effect of market conditions, though statistically significant, is considerably weaker. The model explains a substantial proportion of the variance in electricity demand, illustrating the value of PLS-SEM in capturing complex interrelationships among latent constructs within the energy sector. This application demonstrates the potential of PLS-SEM for exploring the nuanced determinants of energy consumption and provides new insights into the modeling of demand drivers in energy economics.

Keywords: Energy Industry, Latent Variables, PLS-SEM, Structural Equation Modeling

A Vector-Based Weight Adjustment Algorithm for Portfolio Optimization Boosting Genetic Algorithm Efficiency

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This paper presents a vector-based weight adjustment algorithm developed to enhance the efficiency of metaheuristics in portfolio optimization. The method transforms any given weight vector into a new vector with all values fitted within a desired interval. It is primarily applicable to complex portfolio optimization problems where metaheuristics are favored over exact methods due to computational challenges. In practice, investors often restrict portfolio weights to a certain range, regardless of the chosen optimization model. Typically, such constraints are enforced by introducing penalty terms in the objective function. However, the proposed algorithm overcomes this approach by directly recalculating weights at each iteration of the underlying metaheuristic. Proposed algorithm functionality is tested on a genetic algorithm proposed for second order stochastic dominance constraints model. Results are tested on S&P 500 index selected as a benchmark and its components as a stocks from which is the portfolio constructed.

Keywords: Portfolio Optimization, Second-Order Stochastic Dominance, Genetic Algorithm, Weight Adjustment, Mixed-Integer Linear Programming

An Educational Mobile Tool for Multi-criteria Decision Problems

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Many software tools support decision-making, but their commercial nature often makes them costly and inaccessible to small companies, students, and researchers. To address this, we introduce EduAHP, a novel Android mobile app succeeding the online FDA app. EduAHP enhances accessibility with a cost-free, offline solution, eliminating internet dependency and addressing privacy concerns by storing sensitive data locally. This offline capability significantly increases its appeal to users prioritizing data security. EduAHP distinguishes itself through transparency and educational value. Unlike many decision support tools that function as black boxes, EduAHP displays intermediate calculations, clarifying the decision-making process. This feature is particularly valuable for students, fostering a deeper understanding of multicriteria decision-making, including the Analytic Hierarchy Process (AHP). With an intuitive mobile interface, EduAHP ensures ease of use and supports decision-making on the go. We demonstrate its capabilities with a real-life decision problem, showcasing EduAHP as a practical and educational tool.

Keywords: Analytic hierarchy process, Multi-criteria decision making, Pair-wise comparisons, Android

The Use of Large Language Models (LLMs) in Coalition Formation in Parliamentary Systems: An Experimental Comparison With Traditional Methods

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The aim of this paper is to explore the potential of large language models (LLMs) such as chatGPT in modelling cooperative games, using the example of government coalition formation in parliamentary systems. In several selected scenarios, we give the model a description of the election results and analyze what kind of coalitions it proposes, including a justification. We compare the results with traditional game theory methods. The goal is to determine to what extent LLMs can realistically and meaningfully simulate political negotiations and whether they can be used to support decision-making processes or teaching in political modeling.

Keywords: large language models, cooperative game theory, coalition formation, parliamentary systems, political modeling

Convex Enclosures for Interval Linear Programming

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Handling inexact, imprecise, or uncertain data is a fundamental challenge in many areas of optimization and operations research. Throughout the years, several different approaches to representing uncertainty in optimization models have been proposed in the literature — one of the modern approaches being interval programming. In an interval programming model, it is assumed that only lower and upper bounds on the exact data are known in advance, and the real values can be independently perturbed within these bounds.

Interval programming, even in the linear case, often leads to non-convex solution sets, such as the set of all feasible or optimal solutions. Such non-convex sets are traditionally approximated through interval-box enclosures, which provide a simple outer approximation but often suffer from significant overestimation.

A more accurate alternative involves representing the non-convex set as a union of interval boxes, generated, for example, by a branch-and-prune procedure. While this method improves precision, it is computationally demanding and can lead to overly complex representations that are difficult to manage, especially in higher dimensions.

To balance accuracy and efficiency, we propose to investigate the use of convex polyhedral approximations beyond simple interval boxes. In particular, structures such as zonotopes offer a promising direction, as they naturally arise in interval analysis with affine arithmetic and provide tighter enclosures than standard interval methods. Additionally, convexification techniques from nonlinear programming — such as McCormick relaxations or approximations for absolute-value constraints — can be adapted to construct more general convex enclosures of the sets encountered in interval programming.

This direction aims to provide more efficient yet sufficiently accurate representations of non-convex sets, supporting better algorithms for solving key problems in interval optimization.

Keywords: optimization under uncertainty, interval data, convex enclosures

On Discrete Dynamical System of New Keynesian Model

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The paper analyses a simplified version of the New Keynesian macroeconomic model. The model comprises three fundamental equations: the IS curve, the forward-looking Phillips curve and the Taylor rule. The focus of this study is the dynamic properties of the system, which can be expressed in the form of a linear difference equation of the second order or a linear system of difference equations. The analytical derivation of the matrix of the given discrete dynamical system is undertaken, and the characteristic polynomial and eigenvalues of the system are investigated. The results obtained demonstrate that the response rate of the central bank to inflation exerts a pivotal influence on the stability of the equilibrium. It has been observed that for higher values of the parameter, the roots of the characteristic polynomial may be complex, resulting in different dynamic properties of the model. The paper provides an overview of the conditions for possible solutions.

Keywords: New Keynesian model, Inflation, Interest rate, Difference equation, Stability, Eigenvalue analysis

Portfolio Selecting Under Vague Preferences

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The capital market is a dynamic, volatile space where a diverse range of investment opportunities meet a mix of different strategic approaches, emotional outcomes, temperaments. In such a varied environment, decision-making is potentially extremely complex. Not only the less experienced investor can be naturally hesitant, or shy about expressing the preferences or requirements for investment. Preferences about the shape of the portfolio, or its characteristics, are then expressed tentatively, with a certain amount of uncertainty, tolerance or reserve. Recent mathematical optimization models supporting investment decision-making do not allow preferences to be expressed in an imprecise form. To eliminate this deficiency, their integration into model structures via so-called one-sided triangular fuzzy numbers is proposed. The fuzzy model is convertible into a strict form due to the piecewise linear preference. The methodology is designed in an interactive form of STEM method so that an investor in an already difficult situation can form preferences gradually. The step-by-step optimization process allows to achieve a portfolio composition reflecting the investor's preferences, which enhances its credibility. The applicative power of the proposed methodological approach is demonstrated in the selecting an investment portfolio of sustainable mutual funds.

Keywords: mutual fund, portfolio, preference, vague

Entropy-Based Investing Strategies to Hedge Systemic Risk

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This contribution proposes a set of semi-passive investment strategies to hedge systemic risk using entropy-based trading rules. In particular, our strategies are based on investments in funds that replicate equity indices, but in case of financial distress signalled by a sudden increase of entropy in the return of an index, the investment is moved to a riskless asset. In the empirical analysis, we consider two specifications of the trading entropy-rules using seven equity markets and nine indices to compute systemic risk. The ex-post empirical analysis shows that the strategies proposed are effective in increasing the risk-adjusted performance of the portfolios, even when realistic transaction costs are included. We find that entropy rules based on the VIX are effective in increasing the risk-adjusted performance across several markets, and we interpret this result as a hint of risk spillovers from the US market to the rest of the world.

Keywords: Early-warning system, Entropy, Portfolio selection, Systemic risk

Preventive Maintenance in Fixed Interval Scheduling Problems Under Endogenous Uncertainty

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Fixed interval scheduling addresses the challenge of assigning jobs—each with predetermined processing times—to available machines. In this work, we focus on scenarios where job completion times are affected by random delays. We study the problem under an objective that minimizes the expected number of overlaps, which represent instances where additional machines are required due to delayed jobs not fitting their originally assigned schedules. To mitigate these effects, we incorporate preventive maintenance operations aimed at enhancing machine reliability and improving the delay distributions of jobs assigned to the same machine. This framework results in a two-stage stochastic optimization problem with endogenous uncertainty. To address it, we propose an extended robust coloring reformulation. Furthermore, we develop a decomposition algorithm to optimally solve larger instances and conduct a numerical analysis on simulated data.

Keywords: Fixed interval scheduling, Preventive maintenance, Endogenous uncertainty

A Copula-Based Scenario Generation Method for Discrete Data

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Stochastic optimization relies heavily on scenario generation, which has a large impact on the tractability of optimization methods and the quality of obtained solutions. Despite its importance, scenario generation for discrete data is rarely studied and even when it is, it often involves a problem-oriented method. However, the development of these methods is resource-intensive, resulting in a situation where viable easy-to-use alternatives to sampling are missing. In this article, we attempt to remedy the situation by proposing a new copula-based scenario generation method for discrete data. The method is based on extending discrete random variables and subsequent use of the so-called extension copula. We demonstrate the effectiveness of this method on the stochastic knapsack problem by using several metrics like in-sample stability, out-of-sample evaluation gap, and optimality gap. The results show that our method outperforms sampling and can serve as a more challenging benchmark for problem-oriented methods.

Keywords: stochastic optimization, scenario generation, discrete data, copula

Minimizing Elevation Difference in Route Construction: A Geospatial and Computational Analysis

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Our study examines a class of routing problems involving minimizing of differences in terrain altitude; a class of problems encountered in traffic use cases, such as railroad construction. We present a graph-based approach to this problem, leveraging a square grid derived using a real world altimetry. We discuss two classes of undesirable behavior of a grid based approach on synthetic data, and a workable solution of the problem using a real world dataset.

Keywords: routing, spatial analysis, graph networks, computational complexity

Towards Evaluation of the Czech Primary Education and Its Effect on Civic Engagement and Governance

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The Czech primary education faces several challenges mainly linked to socioeconomic inequalities, which affect students' outcomes, low literacy levels, and outdated teaching methods. As significant differences in educational quality can be observed across the country, it is necessary to develop instruments to enhance quality in education and eliminate inefficient resource allocations. Furthermore, the Czech Republic has historically faced challenges in fostering widespread political engagement, with many citizens showing limited participation in formal democratic processes. To analyze the role of education in civic engagement, a two-stage DEA cross-efficiency model was constructed, where Stage 1 evaluates primary education quality and Stage 2 evaluates the impact of primary education quality on civic engagement and governance. The analysis used information about education and social conditions in the Czech Republic and information related to civic engagement and governance in regions published by DataPAQ and the System for evaluating and comparing the quality of life of the population of the Czech Republic, respectively. As socioeconomic disparities exist between different regions and within individual regions as well, the analysis is presented for 206 Czech municipalities with extended jurisdiction. Results of such micro-level analysis enable the creation of precise decision-making policies.

Keywords: Czech Republic, Data Envelopment Analysis, Primary education, Cross-efficiency analysis, Political and community activities

Efficiency Dynamics in the Czech Brewing Industry: A Post-Pandemic Comparison of Small, Medium, and Large Breweries

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This paper builds on previous analyses of efficiency in the Czech brewing industry using Data Envelopment Analysis (DEA) models. It focuses on differences in technical efficiency among micro, small, and medium-to-large breweries in the post-COVID-19 period (2021–2022). The study applies input-oriented DEA models with both constant and variable returns to scale (CCR and BCC) to evaluate how effectively breweries convert economic inputs (labour costs, debt, equity) into financial outputs (sales, profit). While the results suggest a trend of increasing efficiency with firm size, statistical tests indicate that these differences are not significant. The findings provide practical insights for managers and policymakers and high-light opportunities for performance improvement across different types of breweries.

Keywords: DEA models, brewing industry, efficiency, small breweries, medium-sized enterprises, large breweries, post-pandemic analysis

ATS as a Modern Tool in Citizen Investing

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In an era of growing interest in investing and the automation of financial processes, automated trading systems (ATS) are gaining increasing importance. These systems enable investors to apply algorithmic strategies without the need for constant market supervision. The aim of this work was to design and implement an open ATS that allows users to create, configure, and backtest trading strategies on historical data. The developed system is built on modern technologies — the backend is implemented in Python, the frontend in React, and the solution also integrates an AI-based model for predicting market movements. In the practical part, the application is tested on AI strategies and compared with other types of asset investment. The results confirm that combining traditional rule-based approaches with predictive models can significantly improve the decision-making process in algorithmic trading.

Keywords: automated trading system, algorithmic trading, artificial intelligence, backtesting, investing

Assessing Violations of the Independence of Irrelevant Alternatives in the Plackett-Luce Model

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A commonly used probability distribution for ranking data is the Plackett-Luce distribution. It relies on the assumption of independence of irrelevant alternatives, which is rooted in Luce's choice axiom and implies that the internal ranking of a set of items remains unaffected by the presence or absence of other items in the set. However, this assumption may not hold in many real-world contexts. This study investigates the extent to which this assumption is violated in practical applications, such as the ranking of decision-making units in efficiency analysis and the ranking of sports teams in tournaments. The limitations of the Plackett-Luce model under such violations are highlighted, and potential implications for the analysis of ranking data are discussed.

Keywords: ranking data, Plackett-Luce distribution, independence of irrelevant alternatives

The Solving of Optimal Routes for Multi-Warehouses Distribution by Returning Vehicles

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This article proposes a solution to the vehicle routing problem for multi-store distribution of ordered goods when each vehicle returns to the point of departure. A wholesale company that offers food products to retail customers has multiple warehouses. It is assumed that each warehouse can distribute the entire range of products offered. The wholesale company solves the problem of distributing ordered goods from s warehouses to n customers as efficiently as possible. The goods ordered by each customer are placed in a certain number of transported containers. All stores and customer points are determined by GPS coordinates and all distances between warehouses and customer locations are known from truck navigation systems. The target of the solution is to heuristically select customers to the warehouses and plan the number of vehicles used and their routes between the distribution warehouses and the customer locations so that the total distance or travel time is as short as possible. The full procedure of solution is developed and implemented in Matlab code.

Keywords: customer, goods, location, Matlab, optimization, point of departure, vehicle routing problem, warehouse, wholesale

Forecasting of Electricity Prices With Trading Applications

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This study extends recently introduced neural networks approach, based on a regularized distributional multilayer perceptron (DMLP) technique for a multivariate case electricity price forecasting. The performance of a fully connected architecture and a LSTM architecture of neural networks are tested. Different from previous studies we incorporate dependence between multiple exchanges (EPEX and Nord Pool). The empirical data application analyzes two auctions in the day-ahead electricity market for the United Kingdom market. Along with statistical evaluation of probabilistic forecasts we develop a flexible bidding strategy based on risk-adjusted investor utility function. The trading application leverages the differences of the two exchanges by having long/short positions in both. Our findings demonstrate while DMLP shows similar performance compared to the benchmarks, the algorithm is considerably less computationally costly. LASSO Quantile Regression is better in terms if statistical evaluation of distributional fit, while DMLP outperforms in terms of Sharpe ratio (by 18%) in the trading application.

Keywords: Electricity prices, trading strategy, multivariate probabilistic forecasting

Real Waste Collection Problem: Review and Model

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Efficient waste collection and transportation are critical components of municipal waste management, significantly influencing both operational costs and environmental outcomes. This paper addresses the challenge of optimizing inter-municipal waste collection through a comprehensive problem formulation rooted in real-world operations. Unlike many existing studies that rely on simplified or artificially generated instances, our research draws on detailed data from four Czech waste collection companies serving over 180,000 inhabitants and collecting more than 109 kilotonnes of waste annually. We present a multi-faceted problem description that reflects actual planning practices, operational constraints, and optimization goals, including route efficiency, workload balancing, schedule flexibility, and compliance with service regulations. Key features of the problem include a heterogeneous vehicle fleet, multi-depot assignment, seasonal and waste-type-specific collection frequencies, time window constraints, and multi-disposal site management with legal and logistical limitations. Special attention is paid to the complexity introduced by container-specific handling technologies, waste stream separation requirements, and the strategic design of standardized service intervals. The study aims to bridge the gap between theoretical optimization approaches and practical applicability by providing a structured analysis of real constraints and objectives. A critical literature review is conducted to assess how current academic solutions align with or diverge from operational needs. Our findings emphasize the importance of integrating flexible, context-aware optimization models to support long-term planning and daily operations in inter-municipal waste logistics.

Keywords: Inter-municipal Waste Collection, Routing Problem, Annual Planning, Heuristic Optimization

Modeling CO_2 Emissions and Economic Growth: A Spatial Panel Approach to the N-Shaped EKC

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This paper examines the relationship between economic growth and environmental degradation in the context of the Environmental Kuznets Curve (EKC) hypothesis, paying particular attention to its N-shaped variant. Using annual panel data for 29 European countries from 2017 to 2022, the study employs spatial panel econometric techniques to address spatial dependence and temporal dynamics. The empirical analysis is based on a spatial panel data model (a fixed effects spatial lag model) estimated via maximum likelihood, which incorporates spatial lags of the dependent variable in order to capture both direct and indirect effects. The results support the existence of an N-shaped EKC, suggesting that, after an initial decline in CO_2 emissions associated with economic growth, emissions may rise again at higher in-come levels. This development may indicate that efforts to reduce CO_2 emissions have been exhausted. This paper's key contribution lies in its application of a spatial panel data model, which captures spatial dependencies and spillover effects and enhances the EKC's empirical analysis.

Keywords: Environmental Kuznets Curve (EKC), Spatial Econometrics, CO_2 Emissions, Gross domestic product (GDP), Spatial Panel Data Analysis

The Weak Evidence Effect Revisited: A Mixed-Effects Approach

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The Weak Evidence Effect (WEE) is a cognitive bias in which people assign lower probability to a claim when weak supporting evidence is presented than when no evidence is given—contradicting the law of total probability. In this study, we examine the WEE using a hierarchical mixed-effects regression model, a statistically grounded approach that accounts for variability across participants and topics in the experiment. We replicate the original study by Fernbach et al. (2011), "When Good Evidence Goes Bad: The Weak Evidence Effect in Judgment and Decision-Making", employing larger samples, a broader set of topics, and a regression-based analysis. We further explore the underlying mechanisms of the WEE and test whether it is driven by neglect of alternative causes through a revised experimental design. We also examine whether individual differences in need for cognition (NFC) moderate sensitivity to weak evidence. This modeling framework enables a more rigorous analysis of how people incorporate weak information into probabilistic reasoning.

Keywords: Cognitive Bias, Mixed-Effects Model, Weak Evidence Effect

When Does Reoptimization Pay Off? A Hierarchical Approach to Vehicle Route Planning*

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In today's fast-paced economic environment, minimizing costs and time is a central concern for operational efficiency and financial sustainability. With the rapid advancement of technology, we now have greater capabilities to optimize and solve increasingly complex logistical problems. This paper focuses on the solution of the Vehicle Routing Problem (VRP) with geographical partitioning, where the goal is to determine multiple delivery routes to ensure optimal delivery routes. Modern computational tools enable us to solve complex routing problems and dynamically update delivery paths in real time. Reoptimization is a common strategy in VRP to adapt to changes in customer demand or network structure. However, the conditions under which reoptimization provides substantial benefit remain underexplored. In this study, we present a critical evaluation of reoptimization within a hierarchical VRP framework, where routes are planned on two levels: (i) a fixed backbone infrastructure dividing the customer base, and (ii) weekly local tours serving dynamically selected customers based on demand. *The work of Jana Klicnarová was partly supported by the Czech Science Foundation project GA24-10078S.

Keywords: Vehicle Routing Planning, VRP with geographical partitioning, Reoptimization, Financial Sustainability

New Negotiation Mechanism in Solving Double Auctions

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Auctions are important market mechanisms for the allocation of goods and services. In forward auctions, a single seller sells resources to multiple buyers. In reverse auctions, a single buyer attempts to source resources from multiple suppliers, as is common in procurement. Auctions with multiple buyers and sellers are called double auctions and are becoming increasing popular in electronic commerce. It is well known that double auctions in which both sides submit demand or supply bids are much more efficient than several one-sided auctions combined. The paper presents new models and solutions for negotiation mechanism in double auctions.

Keywords: double auction, negotiation, models, methods

Dynamic Stochastic General Equilibrium Model With Heterogeneous Expectations for Small Open Economy

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We propose a small open economy model which deviates from traditional DSGE frameworks by allowing agents to form expectations using both rational and subjective mechanisms, reflecting real-world deviations from full rationality. By incorporating heterogeneous expectation formation, the model should better represent observed macroeconomic fluctuations, particularly in response to external shocks. In the empirical section, we perform impulse response simulations, comparing the newly developed model with a standard DSGE model to assess the impact of usage of heterogeneous expectations. The findings suggest that incorporating heterogeneous expectations leads to prolonged adjustment dynamics with observable oscillations during adaptation period. This underscores the importance of expectation heterogeneity in macroeconomic modeling and policy design.

Keywords: DSGE models, heterogeneous expectations, small open economy, rational expectations

Integrating Market Attention into Portfolio Optimization

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Behavioral finance research has increasingly examined how market attention influences financial market dynamics. In recent years, the development of big data technology has facilitated the use of search engine data, particularly Google Trends, to measure market attention. However, existing studies mostly focus on verifying the statistical correlation between Google Trends and market variables (e.g., returns, trading volume, or volatility). Few investigations examine the systematic embedding of attention indicators, like Google Trends data, in portfolio construction and asset allocation strategies. Building on the existing literature, this paper applies Google Trends search data as a proxy variable for investor attention and explores its practical application in stock investment strategies. This research concentrates on integrating Google Trends search data as an attention factor into an actionable portfolio optimization framework. The study also compares the performances with a traditional optimization model that does not incorporate attention factors. The results indicate that market attention has significant practical value in portfolio optimization.

Keywords: Market attention, Google Trends, Portfolio optimization, Behavioural finance

General Equilibrium Modeling of Monetary Policy in Resource-Rich Economies: A Systematic Review (2000–2024)

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Since the global financial crisis of 2008, there has been a significant increase in studies applying General Equilibrium Models (GEMs) in the context of resource-rich economies. This systematic review synthesizes 96 studies published between 2000 and 2024 that apply GEMs to examine optimal monetary policy in oil- and commodity-exporting economies, covering both developing and developed countries. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, studies were selected from a pool of 1,254 sources, including journal articles, dissertation essays, book chapters, and institutional working papers. These were retrieved from Google Scholar, Scopus, and Web of Science based on predefined criteria, with data manually extracted using a structured framework. Due to heterogeneity in models, contexts, and methods, a narrative synthesis was adopted. The study employs a comparative ranking of DSGE models—adapted from Wieland (2012) and adjusted to resource-rich settings—prioritizing sectoral complexity to capture oil sector dominance and Dutch disease effects. This is followed by shock variety, fiscal policy integration, monetary policy rule design, and estimation technique. Based on these criteria, the study identifies the best-suited models for each economy, discusses monetary policy insights, and evaluates optimal strategies. Inflation targeting emerges as a widely recommended framework for large, oil-dependent economies, while fixed exchange rate regimes are favored for smaller or highly open economies. The review highlights the importance of monetary–fiscal policy coordination and shows how models reflect institutional, structural, and policy features in both developed and developing economies. Appendix tables summarize calibration methods, sectoral complexity, shocks, and policy representation.

Keywords: General Equilibrium models, Monetary policy, Oil exporting economies

A Two-Stage DEA Model for Assessing SME Efficiency Using Multi-Year Accounting Data

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This paper presents an extension of the two-stage Data Envelopment Analysis (DEA) model tailored to evaluate the efficiency of small and medium-sized enterprises (SMEs) based on multi-year accounting data. The model incorporates a temporal dimension and decomposes the production process into two logically connected stages. The first stage assesses human capital efficiency using inputs such as number of employees and labour costs, while the second stage evaluates business efficiency based on indicators such as economic results and added value. Intermediate variables—including investments and stock levels—serve as connecting factors across stages and years.

Empirical analysis is conducted on a sample of 20 Czech hospitality-sector SMEs using data from 2020 to 2022. Three model variants are compared: standard DEA, multiplicative decomposition, and multiplicative DEA, with the multiplicative model demonstrating the strongest interpretability for managers. The results highlight which firms efficiently transform human capital into business performance and identify consistent inefficiencies in early-stage processes. Based on these findings, the study formulates practical recommendations aimed at optimising staff structure, investment decisions, and financial sustainability. The research also outlines opportunities for future model extensions, including a potential transition to three-stage or network DEA models.

Keywords: SMEs, efficiency measurement, two-stage DEA, accounting data

Coordination of Expectations: A Case Study in Multi-Asset Markets

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We present the results of a multi-asset Learning-to-Forecast experiment. Participants were asked to predict the prices of three risky assets, with their key information being the initial price history of these assets. Our research investigates how participants coordinate their expectations in a multi-asset market environment. To analyze this coordination, we decompose individual forecast errors into two components: dispersion error (DE) and common error (CE). The results reveal two key insights. First, in stable markets, a relatively small CE suggests that individual forecast errors tend to cancel out in the aggregate, consistent with the notion of rational expectations with error. Second, in markets characterized by moderately large bubbles, there is a clear dominance of smaller DE, indicating a high degree of coordination among participants, reflecting a spontaneous alignment of beliefs – possibly driven by similar interpretations of price trends, despite the absence of direct communication. This study is classified as a case study due to the limited number of sessions. While exploratory, the findings offer valuable insights into how initial conditions shape expectation coordination.

Keywords: experimental economics, expectations, asset pricing

Scenario Generation for Stochastic Vehicle Routing Problem

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We consider a stochastic Vehicle Routing Problem (SVRP) with penalization, where decisions must be made before the realization of uncertain demand, assumed to follow a known distribution. Our focus is on the scenario generation phase, with the goal of constructing a minimal yet representative set of scenarios that support high-quality decision-making. We propose a problem-oriented scenario generation method, where the structure of the underlying optimization problem directly drives the scenario selection process. Central to our approach is a loss function that measures the discrepancy between in-sample and out-of-sample performance over a pool of heuristically generated candidate solutions. This formulation enables us to capture complex dependencies between random variables — a feature often overlooked in existing SVRP literature — and ensures that the selected scenarios are tailored to the problem's decision-making needs.

Keywords: Stochastic optimization, Scenario generation, Vehicle routing problem

Optimizing Fleet Deployment under the Contract of Affreightment

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We propose a stochastic optimization algorithm for a fleet deployment problem arising in maritime transportation. The problem features two distinct types of demand. Primary demand arises from long-term Contract of Affreightment (COA) obligations, which require fixed port calls to fulfill a relatively stable and periodic shipment schedule. Secondary demand consists of spot cargo opportunities that can be served opportunistically using the spare capacity of vessels already deployed for COA commitments. The objective is to maximize risk-adjusted profit over a planning horizon, while satisfying constraints related to fleet capacity, fixed port schedules, and shipment volumes. Our approach captures the trade-off between contractual reliability and opportunistic revenue generation under uncertainty, offering a flexible and robust framework for real-world maritime logistics planning.

Keywords: stochastic optimization, maritime transportation, logistics

How Good Is FGKLA Algorithm on Random Data Coming From Ugly Distributions? A Computational Study.

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Consider the following problem motivated by robust statistics: given a list of intervals, what is the maximal sample variance if a data point is selected from each of the intervals? From the optimization viewpoint, the problem can be stated as maximization of (a special) convex quadratic function over a hypercube. It is know to be NP-hard. Despite the theoretical hardness, there are efficient algorithms for certain classes of instances. Recently, the average-case behaviour of so-called FGKLA algorithm was studied. It was shown that if the input list of intervals comes from a suitable probabilistic setup, the algorithm runs in almost linear time, since the hard instances (that force the algorithm to exponential behaviour) occur very rarely. The probabilistic setup was indeed general and natural: only mild assumptions were laid on the centers and radii of the intervals. Aside from indepedence of centers and radii, only Lipschitz continuity of distribution of centers and finiteness of the first moment of distribution of radii were assumed. This paper perform computational experiments showing the behaviour of the algorithm on (in some sense exotic) distributions that violate the assumptions on the probabilistic setup. Namely, distributions with no finite mean are considered. Also, the tradeoff between existence of finite moments of higher order and violation of the independence assumption is discussed and shown.

Keywords: interval data, sample variance, nonconvex optimization, NP-hard problem

An ALNS Heuristic for Heterogeneous Fleet Routing With Continuity and Compatibility Constraints

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This work presents an Adaptive Large Neighborhood Search (ALNS) algorithm tailored to address complex variants of the vehicle routing problem, with a particular focus on municipal solid waste (MSW) collection operations. The underlying problem considers a heterogeneous fleet of single-compartment vehicles, multiple waste types with varying compatibility, and operational constraints such as trip chaining and daily working time limits. A key feature of the model is the continuity constraint: depending on the waste types, vehicles may continue collecting without intermediate cleaning, while in other cases, a cleaning process (entailing time and cost) is required before proceeding. The decision problem integrates routing, scheduling, and fleet sizing, with the overall objective of minimizing operational costs, including routing expenses, vehicle acquisition, and cleaning operations. The proposed ALNS framework builds upon established methods by incorporating a wide range of destroy and repair heuristics, such as random, Shaw, and worst-case removal, as well as greedy, GRASP-based, and regret-k insertion methods. These heuristics are adaptively selected based on a performance-driven weight adjustment mechanism. The algorithm's effectiveness is assessed through computational experiments on three distinct types of problem instances: (i) a set of artificial benchmarks designed to evaluate algorithmic components under controlled conditions; (ii) a real-world olive oil collection problem featuring multiple product grades and collection compatibility constraints; and (iii) a benchmark periodic vehicle routing problem (PVRP) sourced from the literature. These scenarios represent varying levels of complexity and operational realism, allowing a comprehensive evaluation of the algorithm's robustness, flexibility, and applicability to environmental and agri-food logistics contexts.

Keywords: Periodic Vehicle Routing Problem (PVRP), Adaptive Large Neighborhood Search (ALNS), Municipal Solid Waste Collection, Multi-trip Routing

The Impact of Social Media on Consumer Behaviour and Its Effect on GDP Growth in India

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This study explores the relationship between social media-driven consumer behaviour and its impact on GDP growth in India. With the increasing penetration of digital platforms, social media has become a significant driver of consumer preferences, spending habits, and overall economic growth. By analyzing secondary data, this research aims to understand the influence of social media on consumer spending, the role of social media platforms in shaping purchasing decisions, and the correlation between social media engagement and GDP growth in India. From small businesses to large corporations, the influence of social media is substantial. This Paper delves into how social media is playing a essential role in contributing to India's Gross Domestic Product (GDP) and ushering in a new era of economic engagement. The rise of social media has been instrumental in the digital transformation of the Indian economy. With platforms like Facebook, Instagram, and WhatsApp, businesses can establish an online presence, showcase their products, and directly connect with consumers. This has fuelled the e-commerce boom in India, contributing significantly to the GDP.

Keywords: GDP, Social Media Usage, Consumer Behaviour, Social Media

Data Envelopment Analysis: How Input Choices Undermine Policy Conclusions

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Data envelopment analysis (DEA) is widely used to assess technical efficiency, often in two-stage analyses where policy variables are used to explain estimated DEA scores. This study shows that such analyses are highly sensitive to how input variables are measured – even when alternatives are strongly correlated. This sensitivity leads to inconsistent and potentially misleading policy conclusions. We argue that methodological tweaks to DEA cannot resolve this issue; instead, robustness must be explicitly tested across different input specifications.

Keywords: Data envelopment analysis, Technical efficiency, Specification issues, Measurement impact

The Impact of Healthcare Expenditures on Pharmaceutical Sales and GDP in Czech Republic

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This paper investigates the correlation between healthcare expenditure, pharmaceutical sales, and gross domestic product (GDP) in the Czech Republic from 2010 to 2020. Using correlation and regression analyses, the study examines the inter-annual variation in these variables to assess the dynamic relationship between public health funding and economic indicators. The findings reveal a positive correlation between health expenditures and GDP, and a moderate yet significant correlation between health expenditures and pharmaceutical sales. These results underscore the dual role of healthcare investment as both a social necessity and a stimulus for economic development. This work builds upon a growing body of literature that frames healthcare spending as a driver of economic performance and public health improvements.

Keywords: healthcare expenditure, GDP, Pharmaceutical sales, correlation analysis

Predictive Modelling of Dairy Herd Health Using Markov Chains and Neural Networks

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Accurately predicting disease progression in dairy herds promotes effective health management and economic sustainability. In this context, Long Short-Term Memory (LSTM) networks outperform statistical models, such as Markov chains and naive prediction. However, advanced deep learning technologies requires major investments in infrastructure, which many smallholder dairy farms simply cannot afford. To assess the performance and suitability of these models for farms with varying technological and financial resources, we compared three predictive models for disease development, namely two statistical approaches and a machine learning model based on an LSTM neural network. For this purpose, we analyzed data from 36 diseases recorded in a dairy herd over a five-year period. The LSTM model showed the highest prediction accuracy, whereas the statistical models showed no difference in many scenarios. Nevertheless, the statistical models achieved satisfactory accuracy for diseases with low prevalence. As such, statistical models are suitable for less-equipped dairy farms seeking simpler and more cost-effective solutions. These findings support the adoption of tailored predictive approaches based on farm resources and disease profiles.

Keywords: prediction time series, neural network, Markov chains, naive prediction, machine learning, dairy farms, herd health

Threshold Effects with Exogeneity and Endogeneity in Stochastic Frontier Models: An Application for Public Finance

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This paper investigates the impact of simultaneous heterogeneity-exogeneity and heterogeneity- endogeneity of input on the (in)efficiency of tax administration units of OECD and emerging economies in a short-panel 2018–2022 period. We select the tax audit as a potential variable holding features of simultaneous threshold and exogeneous/endogenous effects. The outcome of an efficient two-step least squares estimator (for heterogeneity-exogeneity) is compared with the result of a developed GMM estimator (for heterogeneity-endogeneity) in terms of capturing true efficacy and dynamism of the targeting input.

Keywords: Dynamic SFA Threshold Models, Endogenous Threshold Effects, D_GMM, 2SLS, Linearity and Exogeneity, Tax Administration, Tax Audit

A Note on Characterization of Comonotonicity

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The contribution is devoted to providing a full characterization of functions φ and ψ, where $\varphi, \psi\colon [0, \bar{y}] \to [0, \bar{y}]$, satisfying the inequality $\varphi(a \triangle b) \leq \varphi(a) + \varphi(b) - \psi(a \circ b)$ for any a, b, under fixed couple of operations $(\triangle, \circ)$, where $\triangle, \circ\colon [0, \bar{y}]^2 \to [0, \bar{y}]$, while providing another view on the class of comonotone functions. As it has been shown, convexity of the considered functions play a key role.

Keywords: comonotone functions, convexity, duality, monotone measure

The Industry-Level Heterogeneous Impacts of Investor Sentiment on Return, Volume, and Volatility: Evidence From The S&P500

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This paper investigates the heterogeneous effects of investor sentiment across industries within the S&P500 constituents. Using extended Fama-French 3-factor and 5-factor models augmented by sentiment spread variables, combined with trading volume and return volatility as additional response variables, we estimate firm-level sensitivities via OLS regressions. The sample is classified by GICS sectors. A multi-stage statistical procedure, including Welch ANOVA and Games-Howell post-hoc tests, is applied to identify significant cross-industry differences in sentiment sensitivity. The empirical results reveal that certain industries, such as Health Care, Financials, and Information Technology, demonstrate stronger return or volatility reactions to sentiment changes, while others remain relatively insensitive. This research contributes to understanding the behavioral aspect of asset pricing and provides new industry-specific evidence on the role of investor sentiment.

Keywords: investment sentiment, S&P500, behavioral finance

Two-Stage Stochastic Program for University Campus EV Charging

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The presented paper discusses the stochastic programming approach to the electric vehicles charging problem at a particular university campus in the Czech Republic. A significant challenge is the implementation of electric vehicle chargers within parking facilities, necessitating an efficient and user-friendly approach to ensure smooth integration and optimal functionality. In the subsequent discussion, a number of modelling concepts pertaining to the optimal decision-making process concerning charging capacities and their distribution across the university campus will be presented. The fundamental model draws inspiration from the newsvendor problem, combining an expected value-based objective function, a two-stage decision structure, and scenarios that embody uncertainties pertaining to the diverse requirements of car owners. Subsequently, the real-world data and expert-based updates prompted a further refinement of the initial model. The present study will examine two extensions. The primary issue under consideration is that of the allocation of charging places within the campus. This is accompanied by the introduction of indicator variables and associated constraints. Subsequent model enhancements are set to deal with systematic development of charging infrastructure within the campus network. The optimal results obtained from simulated and real-world data sets can be compared with the development of charging networks and their utilization by electric vehicles, as determined by common sense. The prospect of charging electric vehicles could also serve as a catalyst for the augmentation of building-integrated photovoltaics on the university campus. A significant correlation has been observed between the hours during which employees park their vehicles on campus and the electricity generation by the photovoltaic panels. Consequently, the subsequent refinement of the presented models will be deliberated.

Keywords: charging of electric vehicles, allocation of electric vehicle chargers, two-stage stochastic programming, scenario-based model, indicator variables

Solving Engineering Design Problems with Probabilistic and Differential Equations Based Constraints

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Optimization problems in engineering practice often involve constraints that can be described by ordinary or partial differential equations. In the construction of models for such problems, numerical methods are frequently employed due to their convenience. A further element of engineering practice that has been identified as a potential catalyst for the emergence of problems is the necessity for high design reliability. Probabilistic constraints are useful for this purpose as they capture the essence of practical situations in the best way. Specifically, it is not important how much the safety constraint is exceeded, but only with what probability it is exceeded. So, one of the issues that must be addressed is that of optimization of the design of a reliable structure. The present paper addresses various issues associated with such a design. The primary focus of this study is to identify the most effective dimensions for the design of the cranked member. Such problems can differ in several ways. For instance, the case of a static load with a probabilistic constraint on the maximum stress in the structure can be studied. Subsequently, the dynamic load can be modelled, incorporating a probabilistic constraint on the minimum number of load cycles to fatigue fracture. In addressing these issues, contemporary penalty concepts, drawing inspiration from other domains such as logistics and finance, are refined and integrated into the original algorithms. The variants selected for comparison are evaluated through the execution of computational experiments. The proposed procedures have the potential to develop models for the other analogous engineering problems.

Keywords: design of reliable construction, differential equations in constraints, stochastic programming, FME reformulations, probability constraints, penalty approaches

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

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This study investigates the benefits of stochastic programming in vehicle routing problems with stochastic demands (VRPSD) through a systematic review and meta-analysis. Using structured searches in academic databases and predefined keywords, we identify and synthesize existing research quantifying the value of stochastic solution (VSS) in routing applications. The meta-analysis provides aggregated evidence on the performance gap between stochastic and deterministic approaches, including confidence intervals of expected savings or improvements when uncertainty is explicitly modeled. Our findings contribute to a better understanding of when and to what extent stochastic programming offers significant advantages in logistics planning, and they provide guidelines for both researchers and practitioners on the relevance of VSS in real-world routing scenarios.

Keywords: VSS, Vehicle routing problem, Stochastic demand, Stochastic programming, Systematic review, Meta-analysis

MME 2025

The 43rd International Conference on Mathematical Methods in Economics

3–5/9/2025

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