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Contents

Indexes of Desirable Properties of a Pairwise Comparison Matrix with Fuzzy Elements

David Bartl[1], Jaroslav Ramík[2]

Abstract. In the Analytic Hierarchy Process (AHP), pairwise comparisons are used to quantify the relative importance of the elements, i.e. the criteria and/or alternatives. Fuzzy elements are appropriate whenever the decision maker is uncertain about the value of his/her evaluation of the relative importance of the elements in question. In this paper, we deal with the general case when the elements of the pairwise comparison matrix are fuzzy subsets of an Abelian linearly ordered group (alo-group). We then propose some desirable properties – consistency, intensity, and coherence – of the fuzzy pairwise comparison matrix and we also propose indexes to measure these desirable properties.

Based on these indexes, a new solution algorithm to find the priority vector satisfying these desirable properties can be formulated.

Keywords: multi-criteria optimization, Analytic Hierarchy Process (AHP), pairwise comparison matrix, fuzzy elements, consistency, intensity, coherence, priority vector, alo-group

JEL Classification: C44, C65

AMS Classification: 90C29, 90C70

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Factors Affecting the Level of Housing Expenditures in V4 Countries

Jitka Bartošová[1], Vladislav Bína[2]

Abstract. Currently, the substantial inflation growth of prices leads to the continuous increase in the expenditures of households, of which a significant proportion is caused by the increase in housing costs. This paper aims to identify relevant factors affecting the housing costs in so-called Visegrád Group or V4 countries (Czech Republic, Slovakia, Poland, and Hungary) and to quantify the intensity of their influence. To per- form this task, regression models were developed providing a possibility to explore the similarities and differences in the effect of particular factors on the housing costs in this group of post-communist countries. The analysis uses the newest available data from the broad sample survey of incomes and living conditions of households, the EU-SILC 2019 survey. The model parameters were estimated using the R software.

Keywords: EU SILC, logistic regression model, housing costs

JEL Classification: C35, I31, R21

AMS Classification: 62J12

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Application of L-Moments into Labour Market Data Analysis: Czech Sectors with the Lowest Earnings

Diana Bílková[1]

Abstract. The aim of this paper is to demonstrate the application of the L-moment method to labour market data. In the past, this method of point estimation of parameters was used mainly in the field of climatology, meteorology, or hydrology, for example in connection with the study of extreme precipitation. This paper deals with the use of the L-moment method in order to estimate the parameters of three- parameter lognormal curves used to model the distribution of monthly earnings (wages and salaries together) in the two sectors of the Czech economy with the lowest level of earnings. These are Accommodation and Food Service Activities and Administrative and Support Service Activities sectors. The level of earnings in the Administrative and Support Service Activities sector is slightly higher than the level of earnings in the Accommodation and Food Service Activities sector. This procedure succeeded in capturing the development of the distribution of earnings in these two sectors of the Czech economy during the years 2009–2020.

Keywords: three-parameter lognormal curve, L-moments of probability distribution, sample L-moments, sectors with the lowest earnings, earning distribution model

JEL Classification: E24, C51

AMS Classification: 62P20, 91B39

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DSS Capabilities Evaluation Using ANP with Methods for Consistency Improvement

Petra Bláhová[1], Helena Brožová[2]

Abstract. This paper focuses on decision-makers' preferences for Decision Support Systems. A survey questionnaire and ANP method was used for Decision support systems (DSS) capabilities evaluation. Knowledge of DSS capabilities preferences is essential for organizations using, implementing or planning to implement DSS. ANP method is based on the pairwise comparison (Saaty's method). Unfortunately, human judgement is often inconsistent and finding methods to improve inconsistency while keeping the unprecise comparisons representing the preferences of human decisions are essential. Traditionally, the Saaty's method identifies inconsistency and suggests the deduction unless revision can be made with a decision-maker which leads to changing his/her original opinion. Here, three methods for improving consistency were tested. The minimum deviation method, which highly preserves the original decision-maker's preferences while achieving the required consistency was selected for inconsistent pairwise comparisons modification. Easy application of this method shall improve ANP usage in large scale surveys.

Keywords: ANP, DSS, survey, inconsistency improvement, Saaty's matrix,

JEL Classification: C69

AMS Classification: 90B50, 90B90

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Impact of the Incoming Pandemic on Investment Decision Discussed Through a Weighted Moving Mean-absolute Negative Deviation Model

Adam Borovička[1]

Abstract. The incoming COVID-19 pandemic affected various spheres of human life. Investment decision making was no exception. Significant uncertainty triggered a wave of sell-offs on the capital market. Thus, the main aim of the article is to discuss the effects of a pandemic on investment decisions through a very broadened investment strategy. Consider a stock portfolio made before the pandemic for medium or long-term investment horizon through the weighted moving mean-absolute negative deviation model. This developed linear model can account for the dynamics of instability of the prices on the capital market. Another advantage is the possibility to ex- press preference on the importance of considered criteria – return and risk. Linear relations are application-friendly. Under the condition of a significant decline in the value of an investment in the first few weeks (February/March 2020) of a significant spread of a new disease, the investment strategy may change abruptly. A change in the attitude to the risk and turnaround in the development on the capital market with a significantly uncertain outlook encourages a change in the investment portfolio for which the flexibly adaptable model mentioned above will serve perfectly. Changing personal preferences is expressed through the weights. The dynamics of development is then included in the designed moving form of returns. The real effects of the port- folio re-optimization caused by the COVID-19 pandemic are demonstrated on the in- vestment portfolio of stocks traded on the RM-System Czech Stock Exchange. The existing and new portfolios are compared in terms of both composition and characteristics, hence their performance over real time. Based on the results, the meaningful- ness of the portfolio review decision is discussed.

Keywords: investment decision, moving, pandemic, portfolio, stock

JEL Classification: C44, C61, G11

AMS Classification: 90B50, 90C30

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Optimal Scheduling of Vehicle Loading/Unloading Operations in Depots

Martin Branda[1]

Abstract. We deal with the problem of optimal scheduling of cargo loading or un- loading for a fleet of vehicles in depots.

We show that it can lead to fixed interval scheduling where starting and finishing times of jobs are prescribed and the goal is to assign them to a set of machines. However, in real applications the finishing times can be subject to uncertainty where the random delay can be caused by unpredictable com- plications. In our case this corresponds to problems during cargo loading/unloading or even delay on arrival. We propose a two-stage stochastic programming formulation and its robust coloring reformulation leading to a large mixed-integer programming problem. In the numerical study we solve several instances of the problem.

Keywords: vehicle loading, fixed interval scheduling, random delay, stochastic optimization, robust coloring

JEL Classification: C44

AMS Classification: 90C15

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Mathematical Model for Allocation of Aircraft on Airport´s Apron

Jakub Cíleček[1], David Mičulka[2], Dušan Teichmann[3]

Abstract. The presented article deals with the allocation of handling spots on the international regional airport´s apron. In seasonal months the ground handling capacity seems to decrease and one of the possible solutions how to avoid this problem is to allocate the handling spot appropriately. With optimal handling spots, we can decrease the time of embarking and disembarking of passengers which leads to a decrease in time needed for the process of technical handling as well as increasing the airport´s handling capacity. For calculation of the solution to this problem, we created a linear mathematical model of the allocation of aircraft on the airport´s apron presented in this article. Optimizing criterium in the mentioned model was the time of embarking and disembarking of passengers. The value of optimizing criterium was minimalized. A calculation experiment was conducted in the conditions of the international regional airport Ostrava.

Keywords: Apron management, Aircraft Allocation, Mathematical Model

JEL Classification: C69, C44

AMS Classification: 90C10

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Potential Output During Great Recession and Covid-19 Crisis

Andrea Čížků[1]

Abstract. Potential output is an important economic concept representing the level of economic activity sustainable in the long run. Potential output is traditionally considered to be driven by supply-side factors such as labor supply, capital investments and new technologies. An associated concept of the output gap is usually seen as short-run deviations of actual output from its potential due to demand-side fac- tors. The great recession of 2008 slightly altered this traditional view and suggested that a demand-side factors might also play an important role on potential output. This paper proposes a modelling framework in which short-run demand-driven fluctuations of the output gap might have an important effect on the potential output and its long-run growth. Unobserved components methodology is applied and original nonlinear conditionally Gaussian state space model is formulated and econometrically estimated for the Czech Republic by maximum likelihood methodology for the time period 1996Q1-2021Q4 including great recession of 2008 and recent covid-19 crisis.

Keywords: output gap, potential output, economic crisis, unobserved components methodology, state space form, maximum likelihood.

JEL Classification: C51

AMS Classification: 90C15

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Non-Homogeneity in Data Envelopment Analysis and the Reference Set Restrictions

Martin Dlouhý[1]

Abstract. The limited comparability of production units is a practical managerial problem when conducting efficiency assessments and benchmarking. In this study, the problem of non-homogeneity is studied in the context of the data envelopment analysis, which is a well-known non-parametric method of efficiency evaluation. The original models of data envelopment analysis assume homogeneity of the production units under evaluation and homogeneity of the external environment. However, such assumptions do not often correspond to reality and may be too restrictive. The paper summarises twelve recommendations on how to deal with non-homogeneous production units and with non-homogeneous external environment. Above all, we investigate how the comparability of production units can be improved by introducing restrictions of the reference set into the model.

However, no individual recommendation provides a universal solution, and it is necessary to consider the specific situation and the goal of the efficiency evaluation.

Keywords: data envelopment analysis, comparability, non-homogeneity, external environment, reference set

JEL Classification: C61 D24

AMS Classification: 91B38

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How Do Risk Appetite and Size Matter for Banking Credit Risk Management?

Xiaoshan Feng [1]

Abstract. A bank's ability to expand its business can be affected and limited to some extent by its size. In measuring the efficiency of a bank's credit risk management, it is critical to determine whether a bank's size has an impact, while the impact of a bank's risk appetite on risk management is also of concern. The objective of this paper is to examine how size and risk appetite affect the management of credit risk under the assumption of healthy efficiency scores are produced. To achieve this objective, this paper quantifies the management of credit risk, analyses the impact of bank size before and after modification of its efficiency, then includes risk appetite as one of the impact factors to investigate how size and risk appetite play out in the specific banking sector.

Keywords: Credit risk management; Size; Risk appetite; AHP; Data envelopment analysis; Logistic regression model.

JEL Classification: G21, C31, C67, C80, C61, C58

AMS Classification: 62M10**, 9**1G40, 91G70, 90C05

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Closed-Loop Supply Chain Coordination by Contracts

Petr Fiala[1], Renata Majovská[2]

Abstract. A supply chain is a decentralized system where material, financial and in- formation flows connect economic agents. There is much inefficiency in supply chain behavior. Supply chain contracts are used to provide some incentives to adjust the relationship of supply chain partners to coordinate the supply chain, i.e., the total profit of the decentralized supply chain is equal to that achieved under a centralized system. When the supply chain integrates and coordinates the backward flows of goods along with the forward flows, it takes the form of a closed-loop supply chain. The integration of forward and reverse activities into a single system pursues environ- mental goals, creates new economic opportunities and provides competitive ad- vantages. The aim of this paper is to analyze and compare contracts for supply chain and closed-loop supply chain coordination.

Keywords: supply chain, closed-loop supply chain, coordination, contracts

JEL Classification: C44

AMS Classification: 90C15

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Data Envelopment Analysis – Vehicle Routing Problem Optimization for the Inter-Municipal Cooperation in Public Security

Martin Flegl[1], Eva Selene Hernández Gress[2]

Abstract. Perception about the insecurity in Mexico remains high among its population and only 52.5% of the population identifies the performance of the State police as effective to eradicate the violence. That is why, it is of a high importance for the government to improve this situation. However, citizens consider the performance of the local governments as ineffective to solve important problems. This is mainly due to the limited resources and persistent corruption. In such situation, it is necessary to search for security strategies resulting in lower violence. In this article, we apply a combination of Data Envelopment Analysis and Vehicle Routing Problem to evaluate the technical efficiency of the public security and propose an inter-municipality cooperation. For this purpose, we use data related to the public security system in 125 municipalities in Jalisco state in Mexico. The results reveal a technical efficiency of .6944 with standard deviation of .2676. To improve the level of the technical efficiency, 78 routes between the municipalities were constructed, which lead to more efficient use of approximately 900 police units.

Keywords: Data Envelopment Analysis, Mexico, Optimization, Public Security, Vehicle Routing Problem.

JEL Classification: C44, C61, F52

AMS Classification: 90-08, 90C05, 91B32

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Pedagogical Performance Modelling at the Faculty of Economics of the University of South Bohemia – Case Study

Ludvík Friebel[1], Jan Fiala[2]

Abstract. Systemic steps that stem from a number of in-depth analyses and relations of various factors are proposed at the Faculty of Economics of the University of South Bohemia in České Budějovice following the accreditation of degree programmes to increase the efficiency of instruction and to perform op-timisation of the internal structure. The aim of the faculty management is to continuously propose and implement measures that will lead to internal restructuring of the faculty and will take into account, e.g., the constantly changing numbers of students in particular degree programmes, the pass rate, the importance (weight) of particular courses, numbers of graduation theses super-vised at particular departments, etc. The pedagogical performance of particular departments, or individual employees, can be inferred by taking all relevant factors into account, which may become a basis for making decisions concerning changes in the organisational structure of the faculty. The proposed calculation model delivers objective information concerning the performance of the faculty in relation to the curriculum of particular degree programmes.

Keywords: Probability model, Deterministic model, Operational research, Pedagogical performance of faculty, Efficiency, Optimisation.

JEL Classification: C44

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Evaluation of the Health Condition and Medical Resources in the Municipalities in the Czech Republic

Jakub Hanousek[1]

Abstract. We analyze data on the health condition of the population and medical re-sources in the 160 biggest municipalities of the Czech Republic. The method for evaluation is a data envelopment analysis. It is a method based on linear programming used to measure the efficiency of the production units. The production units in this article are the 160 biggest municipalities in the Czech Republic. The health condition of the population is considered of the most common fatal diseases per 1000 inhabitants in each municipality. Medical services are the number of several types of physicians and the number of pharmacies per 1000 inhabitants in each municipality. Municipalities that have low mortality from the most common fatal diseases and the large numbers of medical re-sources became efficient.

Keywords: Medical resources, Municipalities, Czech Republic, DEA

JEL Classification: C44

AMS Classification: 90C15

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Model Design for Team Roles in Agile IT Projects

Ondřej Havazík[1], Petra Pavlíčková[2], Jan Rydval[3]

Abstract. Scrum is one of the most widely used agile methodologies in project management, especially in the field of information technology. Due to its wide use, it also brings a large number of problems that can occur when using it. One such issue may be, for example, the filling of suitable candidates (employees) for individual roles in the team, whether they are leaders or management positions or technological, business, design, etc. It is necessary to estimate the importance of individual team roles. Therefore, it's crucial to find an appropriate mathematical model to determine the preferences of each role. The Analytic Network Process (ANP) is used to create a mathematical model. The individual clusters of the mathematical model are described. The preferences of individual Scrum roles are derived both based on the structure of the model and based on the subjective evaluation of project management students.

Keywords: Agile, Analytic Network Process (AHP), Scrum, Team Roles

JEL Classification: C44

AMS Classification: 90B50

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Is there any Dependence Between a Football Club's Financial Health and its First League Performance?

Jana Heckenbergerová[1], Irena Honková[2]

Abstract. The presented contribution aims to analyze the financial health of Czech football clubs. Financial results of selected first league football clubs are evaluated using the summary indicator IN05. Satisfactory results are achieved only by three clubs out of twelve, one club corresponds with the so-called grey zone and the remaining clubs are in the bankruptcy zone. Furthermore, the stated hypothesis verifies whether there is no correlation between club performance and its financial health. At the first sight, it seems logical that the league's performance depends on the financial situation, and one can assume that the stated hypothesis has to be rejected. Nevertheless, provided statistical analysis utilizing the Spearman's correlation coefficient proves the opposite.

Keywords: Football club, Financial health, Index IN05, Correlation coefficient

JEL Classification: C12, G32

AMS Classification: 62G10, 62P20, 91B24

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Optimisation Approach to Dealing with Saaty's Inconsistency

Robert Hlavatý[1], Helena Brožová[2]

Abstract. We revisit the issue of the AHP method, wherein it often happens that an evaluation of a matrix based on Saaty's scale is inconsistent. The inconsistency of the matrix originates from ill-defined pairwise comparisons provided by a decision- maker. The measurement of the inconsistency is very well known. The less discussed issue is fixing the original data to achieve the required consistency. It is not expected from the decision-maker to re-evaluate the comparisons because: 1) the decision- maker is not available anymore, 2) the decision-maker is not capable of making such adjustments that would lead to inconsistency improvement. We propose our own approach based on a nonlinear optimization model. We show how to adjust the matrix values to preserve the original information contained in the pairwise comparison while achieving acceptable inconsistency. We compare our approach with the earlier ones in the end.

Keywords: AHP, inconsistency, nonlinear optimization model, Saaty's matrix

JEL Classification: C61

AMS Classification: 90B50, 90C30

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Modeling the Influence of Opinion Leaders in E-commerce Networks

Jiří Homan[1], Ladislav Beránek[2], Radim Remeš[3]

Abstract. The development of Internet technologies and Web 2.0 in recent years, also in connection with the current pandemic, has stimulated the growth of e-commerce. Increased attention is also paid to business applications, strategies, and user behavior. Users in the e-commerce environment have access to share their experiences. They have access to the knowledge and understanding of other users. In this environment, opinions and decisions can profoundly affect each other.

In this paper, we examine the interaction mechanism of a group of users (autonomous agents) in an e-commerce social network. We focus mainly on the power of opinion leaders in forming the opinion of other users. Through simulations, we investigate the mechanism of influencing users' opinions by influential opinion leaders. The simulation results show that it is crucial to increase the integrity and credibility of opinion leaders. It's the only option how to improve the influence of various e-commerce ap- plications and business models,

Keywords: Opinion dynamics, e-commerce, network, simulation

JEL Classification: C63

AMS Classification: 90B10

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Mathematical Model for Air Carrier Irregularity Operation Management Under Conditions of Partial Uncertainty

Jiří Hořínka[1], Dušan Teichmann[2]. Lenka Kontriková[3]

Abstract. The business model of air transport operators (air carriers) operating scheduled passenger transport is based on periodically recurring passenger transport on selected routes. As in any real process, so-called operational irregularities occur in the case of planned operation. Some of them may affect air operations to the extent that it will not be possible to operate all scheduled flights. In such cases, the air carrier's operational control centre staff must decide which flights will be operated and which will not be served. The article aims to present a mathematical model that can help decision-making staff of the operational control department, who have the solution of these irregularities in their competence. The article will present a mathematical model for selecting flights maximizing the number of passengers carried, which will partially reflect the conditions of uncertainty. The input quantities representing the maximum time shifts of the connections will be burdened with uncertainty. Fuzzy numbers and fuzzy sets will be used to model uncertainty. Computational experiments with the proposed model will be performed on model data in the optimization software Xpress- IVE.

Keywords: Mathematical model, Optimization, Airline transport operation, Carried passengers, uncertainty

JEL Classification: C44

AMS Classification: 90C70

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Numerical Valuation of the Investment Project Flexibility Based on the PDE Approach: An Option to Contract

Jiří Hozman[1], Tomáš Tichý[2]

Abstract. The solution to the optimal investment decision, which captures the value of a flexibility embedded in a project, plays an important role in the decision-making process. In this paper we focus on a real options approach interpreting the flexibility value as the option premium and we extend our previous research to an option to contract operating scale according to market conditions.

Following a contingent claim analysis the values of both the project and the embedded flexibility, expressed as functions of time and underlying output price (following a stochastic process), can be identified as solutions of relevant PDE systems of the Black-Scholes type. More precisely, the link between project and flexibility values is realized through a payoff function, which can be enforced with respect to the flexibility type at any time prior to or at expiration date.

Due to the presence of the American constraint the real option pricing problem is not solvable analytically in general, and therefore appropriate numerical methods have to be employed. Analogously to pricing of financial options and in line with our results achieved in this field of financial engineering, the discontinuous Galerkin method is applied to solve the relevant governing equations. The capabilities of the numerical scheme resulted are illustrated on a simple contraction decision problem.

Keywords: real option pricing, project value, option to contract, Black-Scholes in- equality; American option, discontinuous Galerkin method

JEL Classification: C44, G13

AMS Classification: 65M60, 35Q91, 91G60

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Time-Dependent Vehicle Routing Problem for Waste Collection

Dušan Hrabec[1], Dominik Závada[2], Vlastimír Nevrlý[3]

Abstract. This work deals with the so-called time-dependent vehicle routing problem applied to the waste collection problem on a real traffic network. A homogeneous fleet of vehicles, where each vehicle can perform various trips, has to serve the collection points while considering one particular type of waste. However, we consider a case where travel time continuously changes according to traffic density. This empirical stochastic property can be discretized into intervals. The objective is to optimize waste collection routes when considering various time delays during various collection times. The model is tested on a case study in Zlín (Czech Republic) with a real collection network for a selected waste type. The preliminary results for a problem considering traffic flow information by the time of day, demonstrating significant savings in the total travel time, are presented. When minimizing total spending time by waste collection vehicles, the solution to such a problem also reduces costs, emissions from vehicles, and city center traffic during congested hours.

Keywords: Waste collection, Time-dependent travel time, Traffic delay, VRP, Mixed-integer programming, Congested traffic hours

JEL Classification: C44, C61, R41

AMS Classification: 90-08, 90C05

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Location of Capacity Completion Centers in Distribution Systems with Heterogeneous Vehicle Fleet

Andrea Hrníčková[1], Dušan Teichmann[2], Denisa Mocková[3]

Abstract. An important group of operations taking place in distribution parts of logistics chains is the completion of consignments. It is usually necessary to decide in which warehouse the completion of consignments will take place if distribution systems contain several warehouses. The decision of the place of completion is influenced by location of the required items in individual warehouses and by quantity of the required items in the warehouses. The presented paper deals with the problem of location of multiple completion centres with limited capacity in the conditions of a distribution system containing several warehouses, with stored items divided into several size categories. It is possible to store items of the same size in several warehouses and a vehicle fleet is heterogeneous. The problem is conceived as an optimization problem, which is solved by the methods of mathematical programming. When creating a mathematical model, the knowledge from the field of transport and location tasks is used. A computational experiment will be performed with the proposed model, and it will be performed for several numbers of warehouses to be completion.

Keywords: Mathematical Model, Optimization, Distribution, Warehouse, Completion, Location

JEL Classification: C610

AMS Classification: 90B05, 90C08

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Volatility of Corn Futures with Markov Regime Switching GARCH Model

Michaela Chocholatá[1]

Abstract. This paper deals with the analysis of the volatility of corn futures based on the daily values from January 3, 2018 to March 30, 2022. Both the univariate GARCH model and Markov switching GARCH (MS GARCH) model were estimated to illustrate the switching behaviour of analysed series during the period under consideration. The estimation results of GARCH model proved high volatility persistence of the corn market and the two-regime MS GARCH model enabled to capture various volatility switches during the analysed period.

Keywords: volatility, corn, GARCH model, regime switching, MS GARCH model

JEL Classification: C58, D53

AMS Classification: 62M05, 62M10, 91B84

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A Regression Analysis of Internationa Migration in the Czech Republic

Lucie Chytilová[1], Jiří Franek[2], Hana Štverková[3]

Abstract. We analyse the migration in the Czech Republic and the labour in the Czech Republic. There had been many papers that had been a focus on this topic but mainly on Ukrainian and Vietnamese immigrants. This paper focuses at all of them in the Czech Republic. We use the regression analysis and we use the data of data from the population register, the Census, a quantitative survey, and Publication - Foreigners in the CR by Czech statistical office. The results discuss that the size of the generosity of the welfare state is relatively low, compared to the role of labour market conditions, such as the unemployment rate and the level of wages.

Keywords: Migration; Regression Analysis; Labor

JEL Classification: C21, C31, F22

AMS Classification: 62M10

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Oil Prices Analyzed by Regression Analysis

Lucie Chytilová[1], Jana Hančlová[2]

Abstract. In this paper, we examine the relationship between real oil prices and real exchange rates using a recent panel of European Union countries (COVID-19 and the war in Ukraine). We first analyze exchange rates with real oil prices. It has been shown and confirmed that real oil prices can be the dominant source of real exchange rate movements and that there is a link between real oil prices and real exchange rates. We also examine the ability of real oil prices to predict future real exchange returns. Panel predictive regression estimates suggest that real oil prices have significant predictive power.

Keywords: Real oil prices; Real exchange rates; Panel regression

JEL Classification: C53, G10, R1

AMS Classification: 62H99, 62M20

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An Aggregation Procedure for Ranking of DMUs in DEA: A Comparison with Traditional Approaches

Josef Jablonský[1]

Abstract. Ranking of decision making units (DMUs) is one of the desirable outputs in application of data envelopment analysis (DEA) models. Especially the DMUs that are identified as efficient by a DEA model cannot be ranked due to their identical efficiency scores. The study presents an original procedure for ranking of efficient DMUs (or all DMUs) that is based on the application of the analytic hierarchy process. The procedure considers, instead of the set of inputs and outputs, the set of partial efficiency measures that are defined as the ratios an output divided by an input. Considering the set of m inputs and r outputs, the procedure works with m.r efficiency measures. They generate the same number of partial rankings. The weights of partial efficiency measures are derived using standard pairwise comparisons. Then, an original aggregation procedure that is based on goal programming methodology is applied and the final ranking is derived by minimization of the sum of weighted deviations or by minimization of the maximum weighted deviation. The results are compared with traditional DEA ranking models.

Keywords: data envelopment analysis, ranking, super-efficiency models, aggregation

JEL Classification: C44

AMS Classification: 90C08, 90B50

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Pareto Front Approximation using Restricted Neighborhood Search

Jaroslav Janáček[1], Marek Kvet[2]

Abstract. The final decision on deployment of emergency service centers includes balancing between conflicting objectives. Usually, system and fair criteria are considered. The system criterion expresses average response time of the system to randomly emerging demand for service of a system user. The fair criterion takes into account the worst situated users and it can be expressed as a number of users' demands outside a given radius from the nearest located center. To support the balancing process made by the responsible decision makers, a set of non-dominated system designs is to be determined to enable the final decisions under knowledge of consequences. The fur- ther presented research has been evoked by successfully applied "sandwich" exact method, where the neighboring members of the Pareto front were determined using a couple of exact optimization methods. Due to big computational time demanded by these methods, the whole process of Pareto front determination needed unacceptable time. We concentrate on speeding up the approach by employing an incrementing heuristic based on swap operation with respect to a given restriction. We study an impact of the heuristic usage on the method efficiency.

Keywords: location problems, conflicting criteria, Pareto front approximation, restricted neighborhood search

JEL Classification: C44, C61

AMS Classification: 90C05, 90C06, 90C10, 90C27

Acknowledgements

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Comparison of Bond Yields to Maturity Using Hawawini-Vora and IRR Methods

Petr Jiříček[1], Stanislava Dvořáková[2]

Abstract. The aim of the paper is to compare yield rates to maturity for selected bonds. Yield rates to maturity will be calculated using two methods: the classic Hawawini-Vora method and the internal rate of return (IRR) method. The IRR method is generally used to evaluate investments in the financial market. The paper will compare both methods for different types of bonds depending on the yield, maturity and market value of the bonds.

Keywords: bond yield, internal rate of return, Hawawini-Vora method

JEL Classification: C6, G23

AMS Classification: 65H04, 68R10

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Performance Evaluation of Lithuanian II Pillar Pension Funds Using Rolling Window Technique

Audrius Kabašinskas[1], Miloš Kopa[2], Kristina Šutienė[3], Aušrinė Lakštutienė[4], Aidas Malakauskas[5]

Abstract. This paper presents results of performance evaluation of Lithuanian II pillar pension funds using rolling window technique. The Lithuanian pension system has three pillars: mandatory (Ist, social insurance system), quasi-optional (IInd, life-cycle pension funds) and optional (IIIrd, any kind of pension funds or insurance). Investments in II pillar from standard funds were changed to life-cycle funds in 2019. To reveal different behavior of market risk and performance of funds, we used 120 days windows (rolled by 1 day). Risk-adjusted performance of funds was measured by employing mean return, average recovery and Sharpe-based ratios such Calmar ratio, Sortino ratio, adjusted Sharpe ratio, VaR Sharpe ratio. However, to describe market risk we only focused on 5 special time windows related to COVID-19.

Keywords: pension funds, rolling window, performance measurement, risk assess- ment

JEL Classification: C44, D81, G32, G11, H55, J32

AMS Classification: 62P05, 62P20, 91G15, 91G70

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A Bootstrap Comparison of Robust Regression Estimators

Jan Kalina[1], Patrik Janaáček[2]

Abstract. The ordinary least squares estimator in linear regression is well known to be highly vulnerable to the presence of outliers in the data and available robust statistical estimators represent more preferable alternatives. It has been repeatedly recommended to use the least squares together with a robust estimator, where the latter is understood as a diagnostic tool for the former. In other words, only if the robust estimator yields a very different result, the user should investigate the dataset closer and search for explanations. For this purpose, a hypothesis test of equality of the means of two alternative linear regression estimators is proposed here based on nonparametric bootstrap. The performance of the test is presented on three real economic datasets with small samples. Robust estimates turn out not to be significantly different from non-robust estimates in the selected datasets. Still, robust estimation is beneficial in these datasets and the experiments illustrate one of possible ways of exploiting the bootstrap methodology in regression modeling. The bootstrap test could be easily extended to nonlinear regression models.

Keywords: linear regression, robust estimation, nonparametric bootstrap, bootstrap hypothesis testing

JEL classification: C14

AMS classification: 62F40

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Single Sampling LTPD Plans for Inspection by Variables with Known Standard Deviation

Nikola Kaspříková[1]

Abstract. The paper addresses the Lot Tolerance Proportion Defective plans. The Lot Tolerance Proportion Defective plans which minimize the mean inspection cost per lot of the average process quality were originally designed by Dodge and Romig for sampling by attributes. The plans for the inspection by variables have been then proposed for a quality characteristic which follows normal distribution. The variables sampling plans generally allow to achieve significant savings in the mean inspection cost.

The variables inspection plans available so far include single sampling plans for the case that the standard deviation of the quality characteristic is not known. This paper addresses the case of the known standard deviation.

The tables of plans for single sampling by variables when the standard deviation is known are provided in this paper for several values of the input parameters. The software implementation of the calculation of plans which may be useful for the situations not covered in the tables is discussed.

Keywords: acceptance sampling, single sampling plans, inspection by variables, LTPD

JEL Classification: C44

AMS Classification: 90C15

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A Comparison of MCDM and DEA Models

Jana Klicnarová[1], Michaela Brabcová[2]

Abstract. The MCDM and DEA models are widely used in many, not only economical, studies. The main aim of the MCDM models undoubtedly differs from the aim of the DEA ones; on the other hand, somewhere, it could be reasonable to use both methods and compare the results; in some cases, it is not possible.

The aim of the paper is to summarize and discuss the differences between these two approaches and show the possible differences between results of these methods.

Keywords: Multiple Criteria Decision Making, Data Envelopment Analysis, criteria preferences

JEL Classification: C830

AMS Classification: 90B50

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Facility Layout Problem with Logistic Constraints

František Koblasa[1], Miroslav Vavroušek[2]

Abstract. The great pressure to maximise productivity and minimise logistics costs in manufacturing systems leads to the problem of efficient layout arrangement and logistics path planning. An efficient layout not only minimises product cost but also leads to greater customer satisfaction in the form of earlier delivery dates.
This article aims to develop a constructive algorithm for the Facility Layout Problem of Flexible Manufacturing Systems with material handling. The model of this system consists of cells with unequal sizes oriented in an open field layout and connected with paths. Paths that use facility space create a logistic system between facility entrance and exit and production cells pick-up and drop-off points.
Solution construction mainly consists of selecting a cell to be placed and a suitable free space where the cell can be oriented to fit area limitations and, at the same time to be connected to logistics paths.
There are proposed dispatching rules to make decisions in the before-mentioned steps and tested on developed model instances. The key objective is to minimise material handling costs. However, an additional optimisation objective of potential free space for new cells is also discussed.

Keywords: Facility Layout Problem, Flexible Manufacturing System, Material handling, Constructive Algorithm.

JEL Classification: C60, C63

AMS Classification: 90C27

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Stochastic Dominance Constrained Portfolio Optimization with Distortion Risk Measures

Miloš Kopa[1]

Abstract. The paper deals with risk-minimizing, stochastic dominance constrained portfolio optimization problems where the risk is modeled by distortion measures. These measures could be seen as a generalization of Value at Risk, Conditional Value- at-Risk or Expected shortfall. If the associated distortion function is concave the measure is coherent. We analyze several such portfolio selection problems for different choices of a concave distortion function. First, assuming a discrete distribution of returns, we identify in-sample optimal portfolios with and without second order stochastic dominance constraints. Then we compute the out-of-sample characteristics. Finally, we compare the in sample and out-of-sample results of all considered models among each other.

Keywords: portfolio optimization, distortion risk measure, stochastic dominance

JEL Classification: D81, G11

AMS Classification: 91B16, 91B30

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The Position of the Czech Republic within the Metallurgical Sector

Michal Krejčí[1], Michaela Staňková[2]

Abstract. This article deals with the evaluation of technical efficiency in the metallurgical sector in selected EU countries. The data envelopment analysis method was chosen to calculate the efficiency. The efficiency evaluation is performed on the basis of data from 2000 to 2015 with an emphasis on the position in the Czech Republic. Radial input-oriented models are constructed separately for individual years. In addition to calculating the efficiency itself, the article also focuses on changes in efficiency and changes in the production possibility frontier through the Malmquist index.

The results of this article show that the Czech Republic lags far behind other countries in terms of efficiency for the entire period under review. In the case of the Czech Republic the largest increase in efficiency was recorded in 2003–2004, when the government decided to transfer several companies into private ownership.

Keywords: data envelopment analysis, efficiency, linear programming, metallurgical sector

JEL Classification: C44, D24

AMS Classification: 90B50, 90C08

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Comparison of the Relationship Between CPI and PPI in the Czech Republic and Slovakia

Radmila Krkošková[1]

Abstract. The goal of this article is to investigate the existence and character of the relationship between the Consumer Price Index (CPI) and the Producer Price Index (PPI) for the Czech Republic and Slovakia. Is there a relationship between the CPI and PPI? The CPI-PPI indicator also has a strong correlation with the overall growth rate of the economy. The smaller the difference of CPI-PPI, the higher the operating cost of the enterprise, the lower the profit of the enterprise, the slower growth of the profit of the enterprise, and the slower economic growth.

The existence of long-run equilibrium relationship between CPI and PPI has been tested with the Johansen cointegration. The existence of long-run equilibrium relationship between CPI and PPI was confirmed in the case of Slovakia. The short- run dynamics were confirmed through statistical methods such as VEC model, Granger causality, and impulse-response function. Granger causality *CPI→PPI* was confirmed in Slovakia, the causality *PPI→CPI* was confirmed in the Czech Republic. The EViews 12 was used for data evaluation. The results are based on the analysis of the data from Eurostat from January 2005 to June 2021 for the Czech Republic and Slovakia.

Keywords: ADF test, CPI, Granger causality, impulse-response function, PPI, VEC model

JEL Classification: C51, F63

AMS Classification: 62P20, 91B02

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Analysis of the Efficiency of the Czech Companies in the NACE Sector "Accommodation and Food Service Activities"

Martina Kuncová[1], Petra Zýková[2], Petra Kozáková[3], Lenka Lízalová [4]

Abstract. The 2019-2020 COVID pandemic has affected many organisations and companies. One of the most affected sectors is accommodation and food service activities. The aim of this paper is to assess technical efficiency of Czech companies in this sector. The research sample included thousands of enterprises (Group I according to the Statistical Classification of Economic Activities in the European Community - NACE). These enterprises were evaluated for the years 2019 and 2020 in order to track changes in pre-pandemic and pandemic years. The data was exported from the Albertina CZ Gold Edition database. DEA models are used for analysis and comparison. Efficiency scores were calculated based on the CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes, Cooper) models with 6 and 4 inputs and 3 and 2 outputs. The results show that there were already many inefficient companies in the given sector in 2019 and this was also observed for 2020, however, there was a significant reduction in the number of subjects in the database, which may also be due to the impact of the COVID-19 pandemic.

Keywords: efficiency, DEA models, accommodation and food service activities

JEL Classification: C44, L83

AMS Classification: 90C15

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Directed Search for Pareto Front Approximation with Path-relinking Method

Marek Kvet[1], Jaroslav Janáček[2]

Abstract. This paper is focused on determination of good approximation of the Pareto front of public service system designs. Generally, an approximation of Pareto front seems to be a very useful tool for a negotiation between the system founder and public representatives, when the system utility is evaluated from two different points of view. The core of presented research consists in generalization of the directed search, which originally inspects solutions in a given direction from a starting solution. The original approach determines the direction in a cone determined by directions derived from two succeeding members of non-dominated solution set. Our generalization replaces the directed search by inspection of the shortest path connecting the two succeeding members. To perform the inspection, the path-relinking method is applied.

Keywords: public service system design problem, bi-criteria optimization, Pareto front, directed search, path-relinking method

JEL Classification: C44, C61

AMS Classification: 90C05, 90C06, 90C10, 90C27

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Significance of Web Search Data in Research of Sales in Auto-motive Industry

Radoslav Lacko[1]

Abstract. Massive development of the internet resulted in many new various types of data. Some of them are indirectly created by users. Almost each of our step on the internet is tracked and written somewhere in the databases. We are able to get the data of users' searches and implement it into econometric research or modelling. Many marketing departments are already doing research of success of their marketing campaigns based on this data. Web search data can relatively fast reflect the changes in customer behavior. We examine how reliable the data are in the long term and evaluate its reliability in this research. Therefore, we have chosen the product that is not fast reversible. Automotive industry, namely passenger cars, would be a great example to test the reliability of web search data in longer period. Industry has gone through de- mand and supply shocks during over past years, such as green economy transformation, pandemic, or global chip shortage. Finally, we discuss the possible utilization of web search data in macroeconomics, or microeconomics.

Keywords: web search data, automotive industry, google trends

JEL Classification: C51

AMS Classification: 91B74

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The Impact of COVID19 Lockdown on Imprecision Measure of TrOFNs Portfolio Analysis

Anna Łyczkowska-Hańćkowiak[1], Aleksandra Wójcicka-Wójtowicz[2]

Abstract. Oriented fuzzy numbers (OFNs) can be used in managing an investment portfolio – they include information uncertainty and imprecision related to financial market. A portfolio analysis bases on an expected fuzzy discount factor and an imprecise present value (PV). The main purpose of the paper is to compare a portfolio analysis including stocks identified by PV assessed by trapezoidal oriented fuzzy number (TrOFNs) in times of regular stock exchange session and during unexpected events (COVID19 lockdown). All considerations are illustrated by an empirical case study. The imprecision risk of the investment portfolio is estimated by energy and entropy measures, comparison of which proves that extreme events, had a tremendous impact on both measures. The analysis also shows that the aggregated portfolio measures of energy and entropy in case of regular situation are lower than in case of a crisis and also lower than measures of individual elements of portfolio.

Keywords: OFN; imprecision; PV; discount factor; portfolio analysis

JEL Classification: C44, G11, G24

AMS Classification: 03E72

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Grouping Genetic Algorithm Application While Minimizing the Risk of Connection Delays

Tomáš Majer[1], Dalibor Gonda[2]

Abstract. The problem of planning in public bus transport is to arrange a given set of connections on a minimum number of tours that meet several additional restrictions. The number of tours has been optimized in several optimization cycles. First, the number of buses was minimized, then the number of empty tours, and in the final phase, the risk of connection delays must be minimized. The planning of the arrival of the connection at a time of increasing traffic density is influenced by many factors, which can be classified into the category of random events. Random phenomena bring with them a degree of uncertainty that can be quantified using fuzzy numbers. In this paper, we focus on the use of the Grouping Genetic Algorithm (GGA) in optimizing the number of tours. In particular, the GGA used the crossing method, which crossed a tour with a high risk of delay with a tour with a low risk of delay. The risk of delay was assigned to each connection in the form of a fuzzy number.

Keywords: fuzzy number, connections crossing, optimization

JEL Classification: C610

AMS Classification: 0C850, 65K05, 90C05

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MILP Model of Crew Scheduling in Public Bus Transport

Tomáš Majer[1], Dalibor Gonda[2]

Abstract. Mathematical models for optimizing bus routes in public bus transport are known. The goal is usually to minimize the number of buses and the number of empty kilometers. Designing shifts suitable for bus drivers is a much more complex problem, because the working time of drivers in transport must meet various legislative requirements for safety breaks, maximum driving time, minimum rest time, etc. Nowadays, there is a great shortage of bus drivers and therefore the criterion of minimizing the required number of drivers rather than buses is much more important. In this paper, we propose a MILP model to solve the above optimization problem with the fulfilled legislative requirements for working time of drivers in transport.

Keywords: MILP model, public transport, crew scheduling

JEL Classification: C61, R40

AMS Classification: 90C11

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Robust Efficiency Analysis of Czech and Slovak Universities

Markéta Matulová[1], Hana Fitzová[2]

Abstract. As the number of universities, study programs, and their capacities has rapidly grown during the last twenty years, the availability of tertiary education in society has increased highly. Thus, a question about the performance of individual institutions in the university education market arises. Activities of universities are usually subsidized using public funds, typically based on the number of students. However, the efficiency in providing educational services is not automatically guaranteed. So, it is helpful to measure, evaluate, and benchmark the performance of educational institutions. Higher efficiency in this area can lead to the more appropriate use of public money. The aim of this study was to evaluate the efficiency of Czech and Slovak universities and identify the factors influencing efficiency. The analysis was carried out on a sample comprising the data of nearly 50 universities in the Czech Republic and Slovakia during the years 2011–2016. The data were analyzed through a two-stage procedure, where the Data Envelopment Analysis (DEA) was used in the first stage to evaluate the efficiency. The input variables included total academic staff and personnel expenditures; outputs comprised the total number of students and graduates, international mobilities, and research and development performance indicators. The efficiency scores were computed for all the examined institutions each year using several DEA models, including the robust approach. In the second stage of the analysis, DEA scores were explained by a set of operational, socio-economic, and demographic explanatory variables to find determinants of efficiency. The results of our analysis help to identify the operating conditions that are the most important to achieving good performance and can be used as a guide for public policy.

Keywords: DEA, education, efficiency

JEL Classification: C67, I23

AMS Classification: 90C90

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Dynamics of the Economic-Ecological System of Aral Sea

Mira Mauleshova[1], Igor Krejčí[2]

Abstract. Paper deals with the implementation of the system dynamics model of the Aral Sea. The proposed model focuses on the impact of the agricultural use of the water and its influence on the environment in the Republic of Uzbekistan. The model explains the causality of agroeconomic activity in the examined area and the enormous decrease of the water in the lake known as the Aral Sea but also the significant deterioration of water's quality in it, namely its salinity.

The paper presents the stock and flow diagram, which describes the basic demographical structure, its connection to the agricultural subsystem and the impact of agriculture on the flow of the river Amu Darya. The construction of the simulation model is described, estimation of the parameters and model validation are discussed. The last part of the paper shows the baseline scenario behaviour of the core variables, such as the volume of water flowing to the Aral Sea, the volume of the lake and salinity. The text is closed with the discussion and model limitations.

Keywords: Aral Sea, Computer simulation, System dynamics

JEL Classification: C44, C63, Q15

AMS Classification: 90B90, 93C15

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On the Ordering of Cycles in the Threshold Digraphs of Concave Monge Matrices in Max-min Algebra with Respect to Robustness

Monika Molnárová[1]

Abstract. Threshold digraphs with respect to strongly connected components identification and robustness of concave Monge matrices over max-min algebra are studied. Properties of matrices in max-min such as periodicity and robustness are investigated using the corresponding so-called threshold digraphs. Therefore, characterization of their structure is crucial for further research. The nodes of two cycles from different non-trivial strongly connected components satisfy an ordering. Consequently, the nodes of a strongly connected component are numbered by a sequence of consecutive natural numbers and the threshold digraph of a concave Monge max- min matrix has a block form for each threshold. A more efficient algorithm for finding the strongly connected components of the threshold digraphs of a concave max-min Monge matrix is presented. The robustness of considered class of matrices with fixed data is proved.

Keywords: max-min algebra, concave Monge matrix, robustness, threshold digraph

JEL Classification: C02

AMS Classification: 08A72, 90B35, 90C47

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Weak Solvability of Interval Max-min Matrix Equations

Helena Myšková[1]

Abstract. Behavior of discrete event systems, in which the individual components move from event to event rather than varying continuously through time, is often described by systems of linear equations or by matrix equations in max-min algebra, in which classical addition and multiplication are replaced by maximum and minimum, respectively. Max-min equations have found a broad area of applications in causal models which emphasize relationships be- tween input and output variables. Many practical situations can be described using max-min matrix equations.

It often happens that a max-min matrix equation with exact data is unsolvable. If we replace matrix elements with intervals of possible values, we obtain an interval matrix equation. Several types of solvability of interval max-min matrix equation have been studied yet. In this paper, we shall deal with the weak solvability of interval max-min matrix equations. We provide a procedure for checking the weak solvability.

Keywords: max-plus algebra, interval matrix, matrix equation, weak solvability

JEL classification: C02

AMS classification: 15A18; 15A80; 65G30

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Application of ARMA–GARCH Returns Generation in Portfolio Selection Process

David Neděla[1]

Abstract. In this paper, we examine the application of a return scenario generation procedure in the portfolio optimization strategy based on an ARMA–GARCH model. We assume that residuals follow a stable distribution and the dependency structure of residuals is determined by Student *t*a nd skewed *t*c opula. Moreover, we analyse the modification in dependency estimation of residuals obtained from the ARMA– GARCH model in order to find an appropriate setting. Then, we compare the effect of selected return approximation methods on the ex-post portfolio wealth and statistics determined using a portfolio model maximizing selected widely used reward-risk measures. Additionally, the strategy consists of monthly re-optimization and trans- action costs expressed proportionally. The following empirical analysis on the U.S. market data allows us to evaluate the impact of return approximation in the portfolio optimization process. Results obtained using analysed approaches generate lower risk with affecting portfolio performance for certain models compared to the benchmark.

Keywords: ARMA–GARCH model, Copula, Performance measures, Portfolio selection

JEL Classification: C53, C61

AMS Classification: 62M10, 90C05, 90C06

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Impact of Financial Development and Trade Openness on the GDP of CR

Václava Pánková[1]

Abstract. Economic development, always conditioned by economic growth, is one of the most important indicators of a healthy economy. The main factors of economic growth could be supported directly or indirectly by financial development and international trade. The financial development and the trade openness are defined, measured, and related to the GDP per capita of the Cze1ch Republic.

Econometric techniques are applied comprising data generating process allowing for break points. The break indicated in 2008 is treated as a difference between financial crisis 2008 – 09 and other years using multiplicative dummies. Relevant econometric model is formulated and estimated.

From the results a conclusion follows that both financial development and trade open- ness show their positive role just during the period of a crisis.

Keywords: economic growth, structural break, model ECM

JEL Classification: C40, F13, G01

AMS Classification: 60H30, 62G05

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Identification of Investment Strategies for Portfolio Selection Utilizing the Markov Switching Model and Optimization Model of Portfolio Selection with Conditional Value-at-Risk

Juraj Pekár[1], Ivan Brezina[2], Marian Reiff[3]

Abstract. The investor decides which products or securities to invest in and chooses the time of investment. The investor is faced with the question of the possible return investment, taking into account the investment risk. The possible return and risk are different in bull and bear markets. The paper presents a method to determine the bear and bull markets using the Markov switching model and then determine investment strategies for these markets using a portfolio selection model using the CVaR risk measure. The proposed method of investment strategy selection was realized based on the historical data of the Dow Jones Industrial Average (DJIA) stock index components from January 1, 2007, to February 22, 2022.

Keywords: Markov switching model, portfolio selection, CVaR, bear market, bull market

JEL Classification: G11, C60

AMS Classification: 91B30, 90C90

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Measuring the Performance of Czech Cluster Organizations: Malmquist Index Approach

Natalie Pelloneová[1]

Abstract. The main aim of this research is to use the Malmquist Index to evaluate the influence of Czech cluster organizations on the financial performance of member companies. Due to the considerable diversity of individual clusters in terms of their date of establishment and due to the availability of financial statements, the research was focused on the period 2012–2017. All cluster organizations operating in the Czech Republic were selected for this research. There were a total of 30 cluster organizations. The input variables selected for the model are total assets and long-term invested capital. The output was the economic value added. The research found that in the Czech Republic, out of the total number of 30 examined clusters, only 12 clusters increased their financial performance in the period 2012–2017. On the other hand, the remaining 18 clusters saw a decline in financial performance during the period under review. The possible causes of this finding are discussed at the end of the paper.

Keywords: Malmquist index, economic value added, cluster organization, performance

JEL Classification: C10, C67, L25

AMS Classification: 90B90, 90C90

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Measuring the Efficiency of Football Players by DEA Model

Natalie Pelloneová[1], Michal Tomíček[2]

Abstract. Football is a very popular subdivision of sports not only in our country, but also all around the world. This article expands the ideas from the economic literature on efficiency to develop method for evaluating the performance of football players that take into account many dimensions of football performance. The evaluation of football players has always been an important input for strategic decisions in the football industry. The aim of this paper is to apply an input-oriented Data Envelopment Analysis (DEA) model in order to measure football players' efficiency and to identify the technically efficient players with regard to their position on the field. Efficient players will be further ranked using the Andersen-Petersen super efficiency model. The model is empirically applied to players of the first and second Slovak football leagues in the 2020/21 season. The model proposed in this paper seeks to incorporate more objectivity into decision-making and can thus be an important step in developing a systematic methodology for evaluating football players.

Keywords: football player, DEA, efficiency, super-efficiency, sport

JEL Classification: C10, L83, C67, C44

AMS Classification: 90B90, 90C90

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Transport Infrastructure Investment Project Portfolio Optimization Using a Cascade Approach to Solving the Min-max Problem

Daniel Pilát[1], Karel Ječmen[2], Dušan Teichmann[3], Olga Mertlová[4]

Abstract. Transport infrastructure investment projects are usually very costly and time consuming. The limited capacity of resources does not allow the implementation of all prepared projects at the same time; therefore it is necessary to select a portfolio of projects for implementation. The selection must be made in such a way that not only the requirements of transport policy are met, but also the rules of the investment funds from which the projects are financed. The quality of the selected project port- folio is crucial due to their significant socio-economic impacts represented by indicators representing the usefulness of the buildings in the effective use of available funds. The aim of optimization is to minimize the maximal negative deviations from the minimum values of indicators representing the degree of non-fulfilment.

The article presents one of the possible approaches to solving this problem based on linear programming with the addition of a cascade approach providing improved results.

Keywords: linear programming, min-max problem, cascade approach

JEL Classification: C610

AMS Classification: 90C47

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Interval Versions of Eigenspaces in Idempotent Semirings

Ján Plavka[1]

Abstract. Idempotent semiring is a bounded linearly ordered set S equipped with two binary operations addition and multiplication, where addition is idempotent, S with additionisacommutativemonoid, S with multiplicationis-amonoidandmultiplication left and right distributes over addition. A vector x is said to be an eigenvector of a square matrix A if $Ax = \lambda x$ for some $\lambda \in S$. This paper investigates the properties of eigenspace for matrices and vectors with interval coefficients in idempotent semirings. An interval vector X is said to be a strong eigenvector of a square matrix A if $Ax = \lambda x$ holds for each x in $\mathbf{X}$ and for some $\lambda \in S$. We suppose that an interval vector $\mathbf{X}$ and an interval matrix A can be split into two subsets according to forall–exists quantification of its interval entries. The properties of various versions of eigenspaces in idempotent semirings are studied and characterizations of equivalent conditions are presented.

Keywords: eigenspace, interval, eigenvector

JEL Classification: C60

AMS Classification: 08A72, 90B35, 90C47

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Reverse Channel Competition in a Dual Sustainable Closed-Loop Supply Chain

Petr Pokorny[1]

Abstract. In this paper we present a closed-loop supply chain (CLSC) model with a retailer selling products produced by a manufacturer. Products can be returned like a returnable packaging used in beverage industry. The products are returned through a 3rd party collector who makes effort to acquire them and sells them to a manufacturer who can recycle them and reuse the recycled raw material to produce a new product at a lower marginal cost. The customer is stimulated to buy sustainable products at a guaranteed buy-back price received at the point of collection. First, we model the case where only the 3rd party collects and we compare this model with the case where the 3rd party collector competes with the retailer who also enters the market to collect. We derive the CLSC's stability conditions of the solution with respect to the intensity level of the competition between the retailer and the 3rd party collector. We show that the customer benefits from the competition in the reverse chain boosting the whole market size and increasing the profit of the total supply chain. We also discuss the competition impact on the 3rd party collector who is impacted adversely by the market power of the retailer and the manufacturer.

Keywords: Closed-Loop Supply Chain, Reverse Chain, Game Theory, Nash Equilibrium, Reverse Channel Competition

JEL Classification: C72

AMS Classification: 91A06 91A10

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Shooting Method for Boundary Value Problems of Ordinary Differential Equations in Economics

Pavel Pražák[1]

Abstract. Optimal control problems over the finite time horizon often lead to the solution of nonlinear ordinary differential equations with given boundary conditions. These problems are known as boundary value problems. There are several numerical methods for solving such problems. This paper mainly deals with the shooting method. Then, a variant of bisection method for solving nonlinear equations is introduced to find a suitable initial condition. The given procedure is also applied to a particular nonlinear dynamics economic model dealing with optimal consumption. All calculations are realized using MATLAB.

Keywords: bisection method, boundary value problems, optimal control, shooting method, life-cycle model

JEL Classification: C44, C61

AMS Classification: 34H05, 49K15, 34B05

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Is the Czech Capital Market Weak Form Efficient?

Pavla Říhová[1], Milan Svoboda[2]

Abstract. This study deals with the short-term prediction of share prices in the Czech stock market. A stochastic model based on the analysis of simple Markov chains was used for the short-term prediction of share prices. Buy and sell signals were generated on the basis of this prediction. The prediction model is considered to be successful if trading with the use of this model outperforms the market; in other words, it yields higher returns than the passive "Buy and Hold" investment strategy. The study was performed using daily data from the Czech stock market for the 14-year period, from the beginning of 2006 until the end of 2019, i.e., approximately 3,500 trading days. The study results have shown that stocks that are traded in higher turnovers outper- formed the Buy and Hold strategy over the period under review. Conversely, stocks that are traded daily in low turnovers do not outperform the Buy and Hold strategy. Thus, it seems that stocks traded in large turnovers do not behave efficiently. Stocks traded in small turnovers tend to behave as weak form efficient.

Keywords: Markov chain analysis, Efficient Market Hypothesis, share price prediction

JEL Classification: C22, G17

AMS Classification: 90C40, 91G15

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Robust Optimization Approach in Travelling Salesman Problem with Service Time

Tereza Sedlářová Nehézová[1], Robert Hlavatý[2]

Abstract. The travelling salesman problem has been addressed by researchers over again in the past decades. The main focus of the problem is computing a Hamiltonian path over a given set of vertices with respect to edge costs, while other criteria and aspects are considered concerning the needs of practitioners. In our contribution, we consider a travelling salesman problem with a service time needed when each vertex is visited. The expected service time may vary depending on the time of the day. We propose an optimisation model for minimising the total journey length, including the service time. Consequently, we consider that both service time on vertices and travelling time between vertices may be uncertain. The Gamma-robustness approach is used in order to deal with the uncertainty issues and propose an optimal travelling strategy.

Keywords: robust optimization, travelling salesman problem, uncertainty

JEL Classification: C61

AMS Classification: 90C05, 90C08, 90C11

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Influence of the Inclusion of the Dominated Alternative on the Final Arrangement of Alternatives in Selected MCDA Methods

Jana Sekničková[1], Martina Kuncová[2]

Abstract. Multi-criteria decision making (MCDM) usually covers the multi-criteria evaluation of alternative methods, sometimes called multi-criteria decision analysis (MCDA) and multi-criteria programming. MCDA methods have been developed to help the decision-maker to find a solution among a lot of different alternatives on the basis of several selected criteria. The goal may lie in sorting alternatives into acceptable and unacceptable, alternatives' ranking, or in the choice of the best alternative. An alternative that is dominated, meaning there is another alternative better or equally evaluated in all criteria, cannot be the best in the best choice problem, however, it can be at the forefront when the aim is alternatives' ranking, and it can also influence the final arrangement. The aim of this article is to analyze the effect of the inclusion of dominated alternatives on the results. WSA and TOPSIS methods using criteria weights were selected for the analysis in this paper.

Keywords: multi-criteria evaluation of alternatives, ranking problems, dominated alternatives

JEL Classification: C44, C61

AMS Classification: 90B50, 90C29

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Application of a System Dynamics Model of Recovery

Anna Selivanova[1, 2]

Abstract. This work focuses on the application of a recovery model to inhabited areas around a selected nuclear power plant (NPP). The mathematical model includes dosimetry calculations and allows to perform economic analyses for cases of decontamination of urban/agricultural objects after deposition of radionuclides. Costs of items required for the decontamination process were set up in accordance with actual conditions in the Czech Republic. The model was designed using the System Dynamics approach and consists of dynamic sequences of selected countermeasures. In order to estimate possible deposition patterns, transport of an atmospheric radionuclide release was simulated using the JRODOS tool. Within the modelling, historical meteodata provided by the Czech Hydrometeorological Institute were used. The release composition and its duration (source term) were selected according to the JRODOS library. Results of simulations in JRODOS were used as input data (affected areas and corresponding surface activities) for the System Dynamics model of recovery. Applying the decontamination model to the NPP of interest, proposed scenarios were simulated in the Vensim software and mutually compared. Based on the simulation results, the cost-benefit analysis of each scenario was carried out.

Keywords: System Dynamics, simulation, Nuclear Power Plant, recovery, decontamination, countermeasure, radiation, atmospheric release

JEL Classification: C63, Q51

AMS Classification: 90B99

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A Sightseeing Tour That Maximizes Efficiency

Ondřej Sokol[1], Vladimír Holý[2], Jan Pelikán[3]

Abstract. A modification of the traveling salesman problem that finds the optimal route by maximizing the ratio between the time spent at places of interest and the time spent moving (denoted as the time efficiency), under constraints of a set of mandatory places, a minimum number of visited optional places, and a maximum total time, is proposed. The model can be linearized using the Charnes–Cooper transformation, transforming the model to linear integer programming problem.

Keywords: vehicle routing problem with profits, orienteering problem, integer programming

JEL Classification: C44

AMS Classification: 90C15

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Secondary Education Efficiency in Selected Countries

Barbora Staňková[1], Hana Stojanová[2]

Abstract. At present, it is assumed that the skills of employees depend, among other things, on having a completed education. The major part of the population over the age of 15 consists of people with at least a secondary education. This article focuses on evaluating the efficiency of secondary education, which then affects the skills of the majority of employees in selected countries. The data envelopment analysis method was used to evaluate this efficiency. The compiled model is based on three input and two output variables. Inputs include public funding of secondary education, the number of teachers and the average wage. The output variables are represented by the number of young people employed and the number of students in secondary education. The radial model with variable returns to scale has been selected to calculate the efficiency score in 2018 and 2019. The empirical results show that countries such as Austria, Germany, Belgium, Portugal, Norway and Italy generally achieve the lowest efficiency values. In contrast, some economically weaker countries are achieving 100% efficiency. These countries included, for example, the Slovak Republic and Israel.

Keywords: data envelopment analysis, efficiency, linear programming, secondary education

JEL Classification: C44, H52, I21

AMS Classification: 90B50**,** 90C08

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Modelling the Process of Selecting Satisfactory Methods for Controlling System Tasks

Petr Suchánek[1], Robert Bucki[2]

Abstract. The paper highlights the problem of the selection of the most appropriate methods for process control in the logistics system. Representative methods most of- ten implemented to improve the functioning of such systems were selected for the analysis. It was assumed that for input data selected randomly, manually or taken from a ready file, it is possible to carry out a simulation process whose task is to find the best method to improve the previously programmed process flow. Due to the fact that each method optimizing the process has both advantages and disadvantages, they had to be taken into account when looking for a satisfactory solution. For the problem formulated in this way, the mathematical model containing the necessary specification assumptions was presented, and then a system design equipped with a pseudocode enabling the creation of the adequate process simulator was presented. The simulation process was carried out for real input data. The resulting data was thoroughly analyzed and adequate conclusions were drawn.

Keywords: process control, mathematical model, simulation, optimization, satisfac- tory solution

JEL Classification: C61, C63

AMS Classification: 00A72, 68U01, 90B06

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EU Artificial Intelligence Act in Banking Sector: Impact and Implementation

Pavel Šálek[1]

Abstract. The European Union Commission's regulatory proposal on Artificial Intelligence will enter into force within the next two years. The focus of the Act is the introduction of regulatory and legal frameworks for the application of the artificial intelligence across European Union. The Act divides the implementation of AI into four main categories by the risk involved with their possible applications. The risks assessed are mainly opacity, complexity, unpredictability, autonomy, and data. The systems in the low risk category are permitted to use without any restrictions. The next category is AI systems with specific transparency obligations (i.e., chatbots, deep fakes). The high risk category involves systems that are products of other safety regulations (i.e., machinery, toys, and medical care) and systems listed by the European Commission as high risk. The AI systems in this category must be sufficiently transparent to enable users to understand and control how the high-risk AI system produces its output. The last category is systems with unacceptable risk where the application of AI is prohibited. Systems that can cause physical or emotional harm (i.e., social scoring) fall into this category. This article aims to assess the impact of the obligations in different risk categories on the AI systems and discuss the potential explainability and interpretability techniques that can be used to ensure the successful implementation of the Act.

Keywords: AI, artificial intelligence act, explainability, interpretability, regulation, machine learning

JEL Classification: C44

AMS Classification: 90C15

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Stakeholders' Support by Agricultural Holdings: Analysis of Determinants by Logit Model

Marie Šimpachová Pechrová[1], Ondřej Šimpach[2]

Abstract. It is acknowledged by many firms that their survival depends not only on its competitiveness, but also the relation towards various stakeholders that can affect the firm, is important. Therefore, we held a primary survey that analysed the social responsibility in agricultural firms. The aim of the paper is to assess what factors affect how important is for an agricultural holding the supports of the stakeholders.

We used ordered logistic regression model. As explanatory variables were included characteristics of the agricultural holding and of its manager. However, we found out that only legal form of a firm and business target of improving existing products and developing new products were statistically significant determinant of to what extent is the support of stakeholders important.

Despite that we assumed that representants of cooperatives would see the support of stakeholders as more important, our results show that when the company is a cooper- ative, the odd that the support of stakeholders is very important (over other categories) is lower 0.48 times. When the business target is improving and developing the product the odds that support is "very important" (over other categories) is 25.4 times higher. The importance of stakeholders' support was not statistically significantly determined nor by the sex, education or age of the manager, nor by the size (number of employees) and other business targets of the agricultural holding.

Keywords: agricultural holding, determinant, logistic regression, social responsibility

JEL Classification: C25, Q13

AMS Classification: 62J05

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The Effect of Business Clustering on Scale Efficiency

Eva Štichhauerová[1], Miroslav Žižka[2]

Abstract. This paper examines the impact of an organised and natural cluster on the scale efficiency of firms in the engineering industry. Three groups of firms were included in the research. The first group consisted of member firms of the Czech Machinery Cluster, representing one of the oldest organised clusters in the Czech Republic. In the second group, firms of the natural cluster were represented. These companies operate in the same industry and the same region as the Czech Machinery Cluster but are not members of it. The third control group represents machinery firms from other regions of the Czech Republic. Scale efficiency was examined using CRS and VRS DEA models for the period 2009 to 2019. The results showed that firms achieved the best scale efficiency in the cluster organisation. Member firms of this organised cluster operate under constant or increasing returns to scale. On the contrary, there was no significant difference in scale efficiency between firms in the natural cluster and other firms. Firms in these two clusters predominantly operate under conditions of decreasing returns to scale, i.e. they do not use their inputs efficiently enough.

Keywords: Data envelopment analysis, returns to scale, scale efficiency, technical efficiency, cluster organisation, natural cluster.

JEL Classification: C61, L25, L64**.**

AMS Classification: 90B90, 90C90

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Design of Optimization Model for Network Coordination of Public Transport Connections with Periodically Alternating Headway

Dušan Teichmann[1], Denisa Mocková[2], Michal Dorda[3], Pavel Edvard Vančura[4], Ivana Olivková[5], Vojtěch Graf[6]

Abstract. The basic aspect of public transport in terms of its use must be its attractiveness for passengers. If it is not possible to provide a direct connection for each passenger, discomfort must be minimized for passengers who will have to change during the transport process. Their discomfort can be reduced by shortening the time they must wait for the consequent connection. Reducing the waiting time during transfers can be achieved mainly by a higher level of network coordination of connections. The given problem can be solved as an optimization task. The motivation for the article is the specific nature of the timing of connections in the Prague public transport system, where coordination between subway and bus lines is required on weekends. For the bus lines, the so-called periodically alternating headway is applied on weekends. The connections are run at 7- and 8-minute headways, and this sequence is repeated regularly throughout the weekend. The optimization criterion is the total time loss of transferring passengers in all transfer nodes. The value of the total time loss is minimized. The computational experiment was realized in the Xpress-IVE optimization software.

Keywords: Public transport, network coordination, periodically alternating headway, optimization.

JEL Classification: C44

AMS Classification: 90C11

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Forecasting Cryptocurrency Price Dynamics Using Reinforcement Learning

Jan Thiele[1], Quang Van Tran[2]

Abstract. Reinforcement learning is a machine learning division as well as a part of artificial intelligence which can deal with problems requiring human decision making intelligence. It can work in a fashion resembling human brain which is to take actions through trial and error towards the results so that it can reward itself. Hence, this feature of reinforcement learning makes it distinct from others. We propose a trading strategy with cryptocurrencies resulted from reinforcement learning algorithms which utilize the patterns in predictors of cryptocurrencies prices to create state and reward signals to generate the corresponding trading signals. This algorithm is then tested on a basket of several cryptocurrenices with encouraging initial results.

Keywords: Forecasting, cryptocurrencies, machine learning, reinforcement algorithm

JEL Classification: C45, C53

AMS Classification: 68T07

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Measuring the Efficiency of English Football Clubs: Empirical Evidence from Professional Football

Michal Tomíček[1]

Abstract. The aim of the paper is to propose a method for evaluating the performance of football clubs based on the method of Data Envelopment Analysis. The article also deals with the impact of the reprisals caused by the Covid-19 pandemic, which limited fans' access to the stadiums as well as the football competitions themselves. Professional English football clubs playing in the English Premier League were selected for empirical analysis. The performance evaluation of English football clubs is an important reference for team managers, the management of individual clubs and the selected competition as a whole. One of the two most frequently used DEA models, the CCR model, was used to analyze the relative efficiency of football clubs. The study focuses on clubs operating in the highest English football competition during the seasons 2017/18 to 2020/21.

Keywords: Data Envelopment Analysis, European Football, Efficiency, English Premier League

JEL Classification: C10, L83, C67, C44

AMS Classification: 90B90, 90C90

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VaR and CVaR of Czech Financial Assets Returns Using GARCH Models with Heavy Tails Distributions

Quang Van Tran[1], Jiří Málek[2]

Abstract. Value at Risk (VaR) and Conditional Value at Risk (CVaR) are popular measures used to estimate the risk exposure of investments of risky financial assets. Their accurate evaluation is important as they affect the further actions in risk management. As volatility of returns of financial assets exhibit heteroskedastic behavior, GARCH models are often used to capture this property. Further, it is also known that returns of financial assets are often distributed with heavy tails. So far this character is modeled with heavy-tailed distributions. We investigate the ability of the most often used heavy tailed distributions in GARCH and GJR-GARCH models to evaluate how well they can help to properly compute VaR and CVaR on several types of Czech financial time series as index PX, CEZ stock price and exchange rate EURCZK. In the conclusion we offer some inferences for practical implications for the use of heavy-tailed distributions in GARCH models for the stated purpose.

Keywords: VaR and CVaR, GARCH model, Returns of Czech Financial Assets, Comparison

JEL Classification: C13, C46

AMS Classification: 62P05, 91G15

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Determinants of International Tourism Inbound Receipts: The Quantile Regression Approach

Petra Vašaničová[1], Sylvia Jenčová[2]

Abstract. Challenges in tourism arising from the COVID-19 pandemic, e.g., a decline in domestic and international travel, are forcing destinations to focus on improving tourism performance. Therefore, it is important for stakeholders to know the key determinants affecting tourism performance. This paper aims to find out whether a country's international tourism inbound receipts are determined by GDP, the number of international arrivals, and travel and tourism competitiveness. The proposed model for 125 countries is specific because we consider conditional quantiles of the dependent variable. The advantage of quantile regression is that it can determine whether individual percentiles of a dependent variable are more affected by independent variables than other percentiles of a dependent variable, which is then reflected in the change in regression coefficients. This study contributes to the existing literature that includes TTCI as an independent variable in tourism performance models.

Keywords: tourism, receipts, arrivals, GDP, competitiveness, quantile regression

JEL Classification: L83, Z33, Z31

AMS Classification: 62G08

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The Optimal Settings of a Genetic Algorithm for Variable Selection in a Non-linear Time Series Model

Lukáš Veverka[1]

Abstract. Common methods for a variable selection in linear regression do not work in models including non-linearity because of the different ranges of the values of the estimated parameters for a single variable. The binary version of a genetic algorithm comes in handy for this purpose. Since the performance of both genetic algorithm and non-linear optimization is sensitive to the setting, it is convenient to look for an optimal setting reaching the best result. However, in the early stages of the model definition, it is practical to limit the estimation time to reveal some misspecifications of the model (e.g. forgotten seasonality). Therefore, the optimal settings are found with repeated cross-validation selecting various combinations of settings for different time categories.

Keywords: Genetic algorithm, Variable selection, Non-linear optimization

JEL Classification: C22

AMS Classification: 68W50

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Analysis of Impact of Covariates Entering Stochastic Optimization Problem

Petr Volf[1]

Abstract. In the contribution we study consequences of imperfect information to precision of stochastic optimization solution. In particular, it is assumed that the characteristics of optimization problem are influenced by a set of covariates. This dependence is described via a regression model. Hence, the uncertainty is then caused by statistical estimation of regression parameters. The contribution will analyze several regression model cases, together with their application. Precision of results will be explored, both theoretically as well as with the aid of simulations.

Keywords: stochastic optimization, empirical distribution, regression model, statistical estimation, optimal maintenance

JEL classification: C41, J64

AMS classification: 62N02, 62P25

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The Exact Solution of Travelling Salesman by Mixed Integer Programming in Matlab

Jaromír Zahrádka[1]

Abstract. This contribution comes up with a specific solution of the travelling sales- man problem. The driver of hauler has to deliver, using his truck, goods from the depot to n customers. Each customer point of delivery is given by GPS coordinates. The objective of the solution is to select the sequence of delivery points so that firstly the travel distance and subsequently the total travel time are minimal. The driver visits all delivery points and returns to the depot. In this contribution, one general solution is presented using the bound-and-branche method and by using mixed integer linear programming implemented in M-function. The created algorithm can be used in general for any number n of customers.

Keywords: branch-and-bound, linear programming, Matlab, travelling salesman

JEL classification: C64

AMS classification: 68W04; 90C11, 05C20

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Waste Collection Vehicle Routing Using Smart Re-Ports on the Utilization of Bin capacities

František Zapletal[1], Petr Kozel[2], Lucie Chytilová[3]

Abstract. Vehicle routing is a common optimization problem applicable for various kinds of companies and institutions in general. One of its typical applications is a waste collection, which can help not only a company managing the waste logistics but also citizens and other stakeholder groups in cities and villages. Many studies have been devoted to the optimization of the waste collection in the past under different special conditions like time windows, different types of waste and vehicles, etc. In this paper, we focus on the frequency with which bins are serviced. Usually, the frequency is fixed and the bins are serviced on a given day weekly or every second week. This setting, however, does not distinguish to what ex-tent a bin is full, thus its efficiency is disputable. Our aim is to explore whether some kind of direct smart re- ports from citizens on the utilization of bin capacities can potentially re-duce the total costs of waste collection. The proposed model is verified using numerical examples and different scenarios.

Keywords: PROMETHEE, conditional evaluation, multi-criteria decision-making, dependence.

JEL classification: C44

AMS classification: 90C08

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