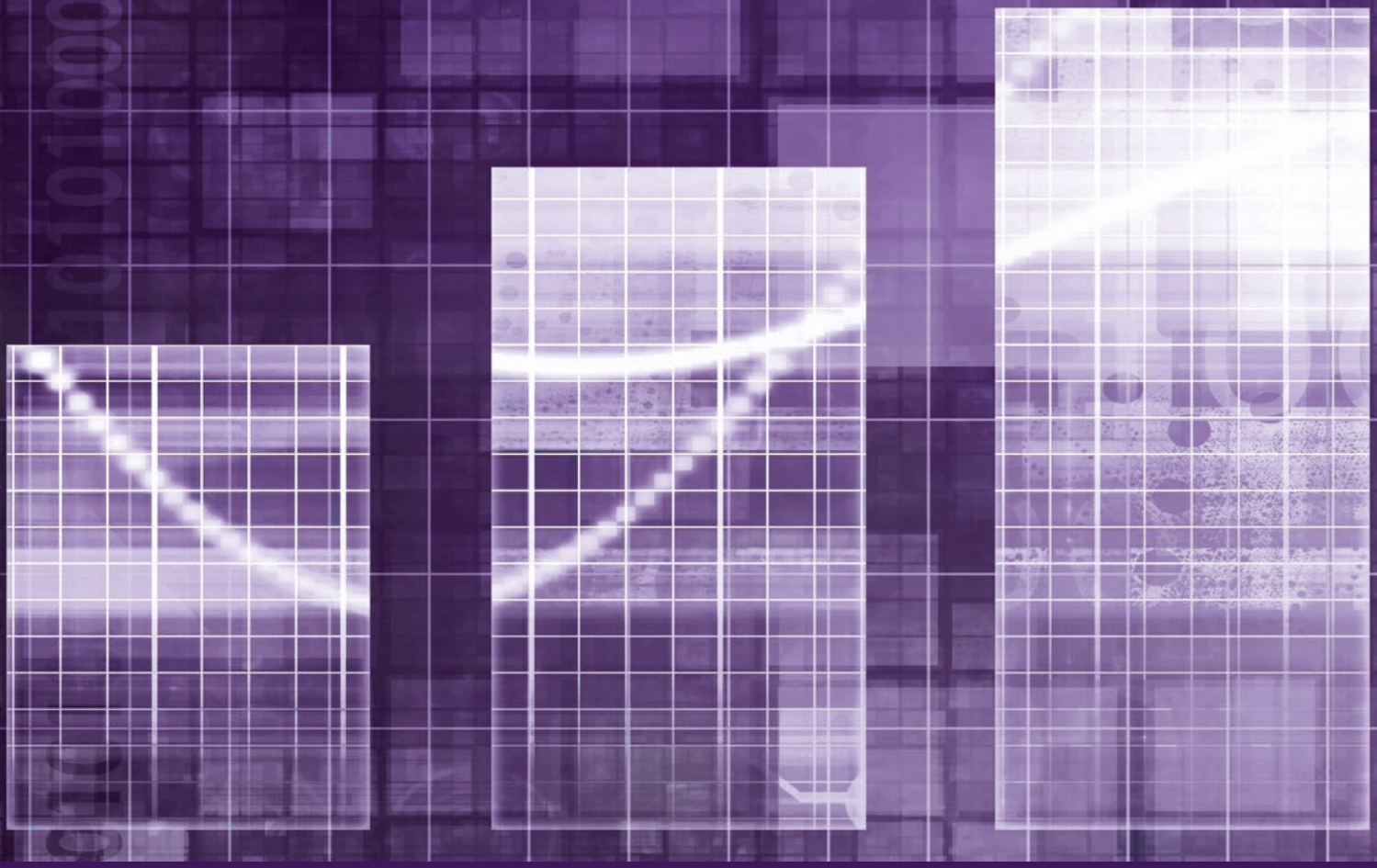
XVI EUROPEAN WORKSHOP ON EFFICIENCY AND PRODUCTIVITY ANALYSIS (EWEPA)

LONDON, JUNE 10-13 2019

CONFERENCE PROGRAMME



EWEPA LONDON 2019

Loughborough University

CONTENTS

WELCOME TO EWEPA XVI

Dear Colleagues,

The Organising Committee welcomes you to the Sixteenth European Workshop on Efficiency and Productivity Analysis (EWEPA XVI) being held at Senate House in London. This conference is hosted by Loughborough University's School of Business and Economics (SBE) and its Centre for Productivity and Performance (CPP).

This year we celebrate the 30th Anniversary of the long tradition of EWEPA conferences, which began in Louvain-la-Neuve, Belgium, in 1989 and have been organised biennially since then. From the very beginning, EWEPA has become a leading conference in the field of efficiency and productivity analysis.

For those who are interested in the history of EWEPA, our official website www.ewepa.org includes a downloadable collection of all previous EWEPA conference programmes. These materials have been carefully preserved by our colleagues organising previous EWEPA conferences in a tradition that we are proud to continue.

Following in the steps of the previous conference organised by Loughborough in 2017, EWEPA XVI brings together more than 250 participants from all six continents (except Antarctica!) presenting more than 230 papers, over four days of the conference.

Monday June 10th, the first day gives the floor to colleagues who are in the early years of their academic careers. On this day, all presenters will have more time than in the regular parallel sessions and will also receive feedback from the nominated experienced discussants.

The three main days of the conference are from Tuesday June 11th to Thursday June 13th. The highlights include the Opening session, during which a special presentation will be made to C. A. Knox Lovell for his lifetime dedication and achievements in our field.

Two Plenary sessions are scheduled on the Tuesday and Wednesday mornings. These sessions include the keynotes by Peter Bogetoft (Copenhagen Business School) and Finn Førsund (University of Oslo). The conference programme also includes a number of Special and Panel sessions devoted to different topics, and of course, all the other available slots in the seven parallel sessions are allocated to the EWEPA presenters.

The Organising Committee wishes all participants a productive and enjoyable four days of the EWEPA conference!

Warm regards,

The EWEPA XVI Organising Committee

COMMITTEES AND SPONSORS

Organising Committee, Loughborough University, UK

Victor Podinovski (Coordinator)

Anthony Glass

Karligash Glass

David Saal

Robin Sickles

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Maria Silva	Catholic University of Porto	Portugal
Léopold Simar	Université de Louvain	Belgium
Valentin Zelenyuk	University of Queensland	Australia

Jury for the best paper presented at the Early Career Research Day

Inmaculada Álvarez	Universidad Autónoma de Madrid	Spain
Gary Ferrier	University of Arkansas	USA
Anthony Glass	Loughborough University	UK
Luis Orea	Universidad de Oviedo	Spain
Antonio Peyrache	University of Queensland	Australia

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The School of Business and Economics, Loughborough University

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The Operational Research Society

The Royal Economic Society

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CONFERENCE MECHANICS

Registration

We will be open for registration every day of the conference from 8:00-17:00 in the foyer on the ground floor of the conference venue, Senate House, Malet Street, London, WC1E 7HU.

The registration desk will also be available to provide assistance each day throughout the conference.

Sessions

- All sessions, breaks, lunches and the receptions will take place at Senate House.
- Internet access is available within Senate House and the Wi-Fi code required will be provided daily.
- For most parallel sessions, each paper has been allocated 30 minutes (either 3 papers in a 1.5 hour session, or 4 papers in a 2 hour session). In some rare cases (sometimes caused by last-minute changes to the programme) it may be necessary to schedule 4 papers in a 1.5 hour session. In the latter case, there are 22.5 minutes for each paper. Please time your presentations accordingly.
- The Chair of each parallel session is the last presenting author.
- In the case of a presenter not being present in a parallel session the session will continue and finish early. In this situation more time can be given to each presentation at the discretion of the Session Chair.
- Sessions in this programme are identified using three parameters: (i) day (TU for Tuesday, WE for Wednesday and TH for Thursday); (ii) time slot (A-D), and (iii) parallel session number (1-7).
- Presenting authors are identified by the asterisk *.

Catering

The following catering items are included in the registration fee for all participants.

- Tea, coffee and Danish pastries will be served between 8:00-9:00 am.
- Lunches on all four days.
- Tea and coffee will be served during the breaks between the sessions.
- Drinks reception on Monday 10th June.
- Welcome drinks reception on Tuesday 11th June.

The Conference Dinner on Wednesday 12th June is an additional registration item and is NOT included in the standard registration fee and must be pre-booked. The Conference Dinner will be held at The Honourable Society of Gray's Inn, 8 South Square, London, WC1R 5ET. The pre-booked tickets for the dinner will be available for collection at the EWEPA registration desk at Senate House. The conference dinner will commence at 19:30 with pre-dinner drinks served from 18:45.

CONFERENCE PROGRAMME AT A GLANCE

Monday 10 June - Early Career Research Day

9:00-10:30	Session: Electricity
10:30-11:00	Break
11:00-12:30	Session: Methodology
12:30-14:00	Lunch
14:00-15:30	Session: Agriculture
15:30-16:00	Break
16:00-17:30	Session: Performance and Innovation
17:30-19:00	Drinks Reception

Tuesday 11 June

9:00-9:30	Opening Session
9:30-10:30	Plenary Session 1
10:30-11:00	Break
11:00-12:30	Parallel Sessions (B)
12:30-14:00	Lunch
14:00-15:30	Parallel Sessions (C)
15:30-16:00	Break
16:00-18:00	Parallel Sessions (D)
18:00-19:30	Welcome Drinks Reception

Wednesday 12 June

9:00-10:30	Plenary Session 2
10:30-11:00	Break
11:00-12:30	Parallel Sessions (B)
12:30-14:00	Lunch
14:00-15:30	Parallel Sessions (C)
15:30-16:00	Break
16:00-18:00	Parallel Sessions (D)
18:45	Conference Dinner (additional registration item)

Thursday 13 June

9:00-10:30	Parallel Sessions (A)
10:30-11:00	Break
11:00-12:30	Parallel Sessions (B)
12:30-14:00	Lunch
14:00-15:30	Parallel Sessions (C)
15:30-16:00	Break
16:00-17:30	Parallel Sessions (D)
17:30-18:00	Closing Session

PARALLEL SESSIONS ON 11-13 JUNE 2019

	1	2	3	4	5	6	7
Room	Beveridge Hall	Woburn Room Room 22	Montague Room Room 26	Brunswick Room Room G07	Bloomsbury Room Room G35	Gordon Room Room G34	Room G21A

Tuesday 11 June

TU-A 9:00-10:30	Opening Session, Special Award to C. A. Knox Lovell Plenary Session 1: "Benchmarking – from academic studies to managerial advice", Peter Bogetoft						
TU-B 11:00-12:30	Agriculture 1	Special Session: Water regulation	SFA 1	DEA 1	Health 1	Education 1	Bad outputs
TU-C 14:00-15:30	Agriculture 2	ONS Special Session: Management & productivity	SFA 2	Special Session: Axioms	Health 2	Education 2	Electricity 1
TU-D 16:00-18:00	Agriculture 3	Special Session: Current topics in productivity analysis	SFA 3	DEA 2	Productivity change	Education 3	Electricity 2

Wednesday 12 June

WE-A 9:00-10:30	Plenary Session 2: "Environmental performance measurement: The rise and fall of Shephard-inspired approaches", Finn Førsund						
WE-B 11:00-12:30	Agriculture 4	RES Special Session: UK productivity puzzle I	Nonparametric estimation 1	DEA 3	Health 3	Agriculture 5	Electricity 3
WE-C 14:00-15:30	Panel Session: Climate	RES Special Session: UK productivity puzzle II	Indexes & decomposition	DEA 4	Banking 1	Justice	Energy 1
WE-D 16:00-18:00	Agriculture 6	Nonparametric estimation 2	SFA 4	Labour	Banking 2	Agriculture 7	Applications 1

Thursday 13 June

TH-A 9:00-10:30	Agriculture 8	Agriculture 9	SFA 5	DEA 5	Banking 3	Public Sector	Applications 2
TH-B 11:00-12:30	Agriculture 10	Markets	SFA 6	Management systems	Banking 4	Energy 2	Applications 3
TH-C 14:00-15:30	Agriculture 11	Eco-efficiency	Nonparametric estimation 3	Metafrontiers	Banking 5	Firms	Applications 4
TH-D 16:00-17:30	Agriculture 12	Applications 5	Applications 6	Education 4	Banking 6	Electricity 4	Applications 7
17:30-18:00	Closing Session						

MONDAY 10 JUNE
EARLY CAREER RESEARCH DAY

8:00-9:00 Arrival and coffee

8:00-17:00 Registration

All sessions on this day are held in Chancellor's Hall

9:00-10:30: ELECTRICITY
Session Chair: Jaap Bos

Efficiency of Indian coal-based thermal power stations: A nonradial directional distance function approach
Debarun Sengupta*

Discussant: Pablo Arocena

An updated assessment of technical efficiency and returns to scale for U.S. electric power plants
David Bernstein*

Discussant: Jaap Bos

10:30-11:00 Break

11:00-12:30: METHODOLOGY
Session Chair: William Horrace

Nonparametric three-way conditional heteroskedastic frontiers
Jun Cai*, Willian Horrace and Yoonseok Lee

Discussant: Luis Orea

Integrating spatial spillover into stochastic frontier analysis for total factor productivity in China's agriculture
Fang Yin* and Wei Huang

Discussant: William Horrace

12:30-14:00 Lunch

14:00-15:30: AGRICULTURE
Session Chair: Antonio Peyrache

Determinants of persistent and transient technical efficiency of Austrian crop farms
Felicity Addo* and Klaus Salhofer

Discussant: Gary Ferrier

The effects of the abolishment of the EU milk quota scheme on the efficiency frontiers of organic and conventional dairy farms in Denmark
Lorenz Aigner* and Mette Asmild

Discussant: Antonio Peyrache

15:30-16:00 Break

16:00-17:30: PERFORMANCE AND INNOVATION
Session Chair: Mette Asmild

Does it pay to be green? Investigating the relationship between firm economic performance and the EU ETS
Maja Zarkovic*

Discussant: Inmaculada Álvarez

Business model innovation and productivity management among small and medium-sized enterprises in the UK manufacturing sector
Fauzi Said* and Chander Velu

Discussant: Mette Asmild

TUESDAY 11 JUNE

8:00-9:00 Arrival and coffee

8:00-17:00 Registration

OPENING SESSION
9:00-9:30, Beveridge Hall

Includes: Special Award in recognition of the contribution of Professor C. A. Knox Lovell

TU-A: PLENARY SESSION 1
9:30-10:30, Beveridge Hall
Session Chair: Mette Asmild

Benchmarking – from academic studies to managerial advice
Peter Bogetoft*

Discussant: Paul Rouse

10:30-11:00 Break

TU-B-1: AGRICULTURE 1
11:00-12:30, Beveridge Hall
Session Chair: Stefan Seifert

Measuring the effects of spatial spill-overs on farm-level inefficiency: A semi-parametric approach
Kevin Schneider*, Ioannis Skevas and Alfons Oude Lansink

Evaluating agricultural productivity and policy in Russia
Nicholas Rada*, William Liefert and Olga Liefert

Price dispersion in thin farmland markets - What is the role of asymmetric information?
Stefan Seifert*, Christoph Kahle and Silke Hüttel

TU-B-2: SPECIAL SESSION: REGULATORY COST ASSESSMENT IN THE WATER INDUSTRY
11:00-12:30, Woburn Room
Session Chair: David Saal

Benchmarking the efficiency of water companies' retail businesses
Sam Williams, Christopher Pickard, Karli Glass and Anthony Glass*

Modelling wastewater costs with an average system model: A simple method to control for complex inter and intra firm heterogeneity in wastewater system design
David Saal, Maria Nieswand* and Pablo Arocena

Cost interactions and their implications for disaggregated regulatory cost assessment: Examples from Japanese and British water and wastewater regulation
David Saal*, Maria Nieswand, Takuya Urakami and Tomohiro Kitamura

TU-B-3: SFA 1
11:00-12:30, Montague Room
Session Chair: Peter Schmidt

A stochastic frontier hedonic model of a price-setting firm facing uncertain demand
Alecos Papadopoulos*

The panel stochastic frontier model with endogenous inputs and correlated random components
Hung-Pin Lai* and Subal C. Kumbhakar*

A new family of copulas, with application to estimation of a production frontier system
Peter Schmidt*, Christine Amsler and Artem Prokhorov

TU-B-4: DEA 1
11:00-12:30, Brunswick Room
Session Chair: Ole Bent Olesen

A linear programming model for generating positive weights in DEA
Paul Rouse*, Maryam Hasannasab, Dimitris Margaritis and Israfil Roshdi

Exploring the relationship between VEA and types of weight restrictions
Panagiotis Ravanos* and Giannis Karagiannis

Regularity conditions for full dimensional efficient facets in DEA
Ole Bent Olesen* and Niels Christian Petersen

TU-B-5: HEALTH 1
11:00-12:30, Bloomsbury Room
Session Chair: Gerald Granderson

Estimation of technical efficiency of Irish public hospitals using monthly panel data
Niall Devitt*, Marta Zieba* and Declan Dineen

Technical efficiency of the Chinese health care sector: The choice between market-orientation and government-orientation
Sung-Ko Li*, Xinju He and Valentin Zelenyuk

The impacts of repealing certificate of need regulation on total factor productivity growth, and its components, in U.S. Hospitals
Gerald Granderson*

TU-B-6: EDUCATION 1
11:00-12:30, Gordon Room
Session Chair: Ana Camanho

How do mergers influence universities efficiency? Empirical evidence from Russia
Aleksei Egorov*, Tommaso Agasisti and Margarita Maximova

Do work placements have an impact on university student's final grades and starting salaries? A novel way of dealing with endogeneity in educational production functions
Dimitris Giraleas*

The evaluation of performance of education systems in the light of Europe 2020 strategy: A comparison between fixed and flexible weighting systems for the construction of composite indicators
Ana Camanho*, Dovile Stumbriene and Audrone Jakaitiene

TU-B-7: BAD OUTPUTS
11:00-12:30, Room G21A
Session Chair: Robert Russell

Marginal abatement cost of CO2 in China: Application of convex quantile regression
Sheng Dai*, Timo Kuosmanen and Xun Zhou

Shadow prices and marginal abatement costs: Convex quantile regression approach
Timo Kuosmanen and Xun Zhou*

By-production approach to modeling pollution-generating technologies: Assessment of critiques and proposed extensions
Robert Russell* and Sushama Murty

12:30-14:00 Lunch

TU-C-1: AGRICULTURE 2
14:00-15:30, Beveridge Hall
Session Chair: Maria Vrachioli

The optimal size of firms with fixed equity: Microeconomic theory and an application to Danish family farms
Michael Friis Pedersen and Arne Henningsen*

Economies of scale and scope among the Norwegian dairy and crop farms
Habtamu Alem*, Gudbrand Lien, Subal Kumbhakar and J. Brian Hardaker

Impact of conservation agricultural practices on irrigation performance: The case of smallholders in India
Maria Vrachioli* and Johannes Sauer

TU-C-2: THE OFFICE FOR NATIONAL STATISTICS (ONS) SPECIAL SESSION: MANAGEMENT PRACTICES AND PRODUCTIVITY IN UK PRODUCTION AND SERVICES INDUSTRIES
14:00-15:30, Woburn Room
Session Chair: Thomas Triebs

Management practices and productivity in UK production and services industries
Gaganan Awano, Nicholas Bloom, Ted Dolby, Paul Mizen, Rebecca Riley, Tatsuro Senga, Jenny Vyas, Philip Wales
Presented by Russell Black*

Managing for a rainy day? Precautionary savings and managerial quality
Isabelle Roland*

Brexit and uncertainty: Insights from the decision maker panel
Nicholas Bloom, Philip Bunn, Scarlet Chen, Paul Mizen, Pawel Smietanka*, Greg Thwaites

TU-C-3: SFA 2
14:00-15:30, Montague Room
Session Chair: William Horrace

Heterogeneity and near-zero-inefficiency in stochastic frontier models
Kamil Makieła and Błażej Mazur*

A Bayesian estimation of panel stochastic frontier models with determinants of persistent and transient inefficiencies in both location and scale parameters
Ruei-Chi Lee and Sheng-Kai Chang*

The conditional mode in parametric frontier models
Hyunseok Jung*, William Horrace* and Yi Yang

TU-C-4: SPECIAL SESSION: THE ROLE OF AXIOMS IN EFFICIENCY AND PRODUCTIVITY ANALYSIS
14:00-15:30, Brunswick Room

Organizers: Shawna Grosskopf, Robin Sickles and Valentin Zelenyuk

Session Chair: Robin Sickles

Modeling emission-generating technologies: Reconciliation of axiomatic and by-production approaches
Sushama Murty, Robert Russell*

Axiomatic justifications for the equal-weighted averaging of indexes with respect to different references
Rolf Färe*

Axiomatic aspects of productivity indexes with fixed weights and relevance of transitivity
Valentin Zelenyuk*

TU-C-5: HEALTH 2
14:00-15:30, Bloomsbury Room
Session Chair: Massimo Filippini

Assessing the impact of different organizational models on the performance of primary care providers
Sérgio Santos*, Carla Amado and Cristiano Teixeira

The labour management factors and nursing homes efficiency: A semi-parametric approach
Marta Zieba*, Declan Dineen and Shiovan Niluasa*

Determinants of total factor and labor productivity in the Swiss nursing home industry
Massimo Filippini*, Giuliano Masiero and Michael Santarossa*

TU-C-6: EDUCATION 2
14:00-15:30, Gordon Room
Session Chair: Jill Johnes

How do strategic choices determine universities' efficiency? A cross-country study
Tommaso Agasisti and Jasmina Berbegal-Mirabent*

Degree of autonomy and efficiency: An empirical analysis of Russian universities in 2012-2017
Ekaterina Shibanova and Tommaso Agasisti*

A network data envelopment analysis of the Teaching Excellence Framework evaluation of teaching in universities in England
Boon Lee and Jill Johnes*

TU-C-7: ELECTRICITY 1
14:00-15:30, Room G21A
Session Chair: Wadaed Uturbey

Ranking virtual networks accurately using output-oriented multiplicative DEA model with variable return to scale
Francisco Daladier Marques Júnior*, Ali Emrouznejad*, Ana Lúcia Miranda Lopes, Jorge Luiz de Castro E Silva, Kelvin Lopes Dias and Paulo Roberto Freire Cunha

Pitfalls in estimating the efficiency scores in frontier-based regulation: The case of electricity transmission in Brazil
Sara Kamali*, Mohsen Afsharian, Heinz Ahn and Ana Lopes

Modelling quality in data envelopment analysis (DEA) for the Brazilian electric power sector
Wadaed Uturbey*, Ana Lopes and Heinz Ahn

15:30-16:00 Break

TU-D-1: AGRICULTURE 3
16:00-18:00, Beveridge Hall
Session Chair: Moriah Bostian

Weather volatility and crop production
Denitsa Angelova*

Environmental efficiency of wheat production in Poland: A parametric hyperbolic distance function approach
Tomasz Gerard Czekaj*, Tomasz Żyłowski and Stelios Rozakis

Environmentally adjusted production efficiency and agricultural nitrous oxide emissions in North Africa
Wei Huang* and Assem Abu Hatab

Nitrogen use efficiency
Tihomir Ancev, Bradley Barnhart, Moriah Bostian*, Anna Michalak and Eva Sinha

TU-D-2: SPECIAL SESSION: CURRENT TOPICS IN PRODUCTIVITY ANALYSIS
16:00-18:00, Woburn Room
Session Chairs: Emili Grifell-Tatjé, Knox Lovell and Robin Sickles

Speakers: Peter Bogetoft, Finn Førsund and Sergio Perelman

TU-D-3: SFA 3
16:00-18:00, Montague Room
Session Chair: Christopher Parmeter

Skilled biased technical change and misallocation: A unified framework
Massimo Del Gatto*, Michele Battisti and Christopher Parmeter

The impact of British Columbia's carbon tax on manufacturers: A bi-production approach to estimate environmental and production efficiencies
Michael Willox*, Subal Kumbhakar and Oleg Badunenko

Stochastic frontier analysis with generalized errors: The generalized t–GB2 SF model
Kamil Makieła* and Błażej Mazur

Some skewed results on the stochastic frontier model
Christopher Parmeter* and Alecos Papadopoulos

TU-D-4: DEA 2
16:00-18:00, Brunswick Room
Session Chair: Antonio Peyrache

Competitiveness and nonparametric efficiency measurement
Philippe Vanden Eeckaut*, Anne-Laure Levet and Eliegbo Amouzou

Performance evaluation model with DEA in public sector: A Turkish university example
Ayhan Gölcükcü*, Oğuzhan Özaltın and Hasan Bal

Human capital accumulation, output growth and income distribution: DEA-based decomposition
Patrik Jankovič* and Eduard Nežinský

Variable selection in data envelopment analysis
Antonio Peyrache*, Christiern Rose and Gabriela Sicilia

TU-D-5: PRODUCTIVITY CHANGE
16:00-18:00, Bloomsbury Room
Session Chair: Luis Orea

Revisiting the efficiency-equity trade-off: A multi-objective linear problem combined with an extended Leontief input output model
Bernhard Mahlberg and Mikuláš Luptáčik*

Productivity trends in Russian industries: Firm-level evidence
Anna Tsvetkova* and Evguenia Bessonova

The relationship between technology transfer and skill-upgrading in developing countries: Evidence from plant-level data
Mahmut Yasar*

A two-level top-down decomposition of aggregate productivity growth: The role of infrastructure
Luis Orea*, Inmaculada Álvarez and Luis Serven

TU-D-6: EDUCATION 3
16:00-18:00, Gordon Room
Session Chair: Tsu-Tan Fu

Stochastic frontier analysis in higher education: A systematic review
Sabine Gralka*

Efficiency assessment of schools operating in heterogeneous contexts: A robust nonparametric analysis using PISA 2015
Jose Manuel Cordero, Cristina Polo* and Rosa Simancas

Effectiveness and efficiency in education: System level estimation for European countries
Audrone Jakaitiene*, Saule Raiziene, Dovile Stumbriene, Jogaila Vaitekaitis and Antanas Zilinskas

Performance evaluation of higher education institutions between Taiwan and China using a stochastic metafrontier approach
Tsu-Tan Fu*

TU-D-7: ELECTRICITY 2
16:00-18:00, Room G21A
Session Chair: Maria Nieswand

Productivity growth in the electricity and gas networks in Great Britain
Karim Anaya Stucchi*, Victor Ajayi and Michael Pollitt

The profitability change and its drivers: An empirical analysis of the Spanish power companies before and after industry reforms
Leticia Blazquez*, Emili Grifell-Tajé and Pablo Arocena

Network utilities performance and institutional quality: Evidence from the Italian electricity sector
Golnoush Soroush*, Tooraj Jamasb, Carlo Cambini and Manuel Llorca

German distribution grids in the context of the Energiewende – New evidence from efficiency analysis
Julia Rechlitz, Astrid Cullmann and Maria Nieswand*

WEDNESDAY 12 JUNE

8:00-9:00 Arrival and coffee

8:00-17:00 Registration

WE-A: PLENARY SESSION 2
9:00-10:30, Beveridge Hall
Session Chair: Robert Chambers

Environmental performance measurement: The rise and fall of Shephard-inspired approaches
Finn Førsund*

Discussant: Robert Russell

10:30-11:00 Break

WE-B-1: AGRICULTURE 4
11:00-12:30, Beveridge Hall
Session Chair: Ruth Pincinato

Frontier analysis providing a Copernican view to flat-earth economics issues in smart farming
Ludwig Lauwers* and Jef Van Meensel

Productivity, price and profit change in a common pool industry
John Walden* and Min-Yang Lee

The economics of escaped farmed salmon
Ruth Pincinato*, Frank Asche and Kristin Roll

WE-B-2: THE ROYAL ECONOMIC SOCIETY (RES) SPECIAL SESSION: UK PRODUCTIVITY PUZZLE I
11:00-12:30, Woburn Room
Session Chair: Karligash Glass

WE-B-3: NONPARAMETRIC ESTIMATION 1
11:00-12:30, Montague Room
Session Chair: Cinzia Daraio

Improving finite sample approximation by central limit theorems for DEA and FDH efficiency scores
Léopold Simar* and Valentin Zelenyuk*

Estimation and Inference for Malmquist productivity indices: The case of non-convex technologies
Alois Kneip, Léopold Simar and Paul W. Wilson*

Testing restrictions in nonparametric frontier models: New insights
Cinzia Daraio*, Léopold Simar* and Paul W. Wilson*

WE-B-4: DEA 3
11:00-12:30, Brunswick Room
Session Chair: Maria Silva

Combining a Markov process model with the DEA framework. A hybrid model in measuring the efficiency of alternative Markov manpower policies
Andreas Georgiou*, Emmanuel Thanassoulis and Alexandra Papadopoulou

Returns to scale in polyhedral production technologies: Theory and examples
Victor Podinovski*

The whole and its parts: Inefficiency of production systems and its decomposition
Maria Silva* and Antonio Peyrache*

WE-B-5: HEALTH 3
11:00-12:30, Bloomsbury Room
Session Chair: Fanny Goude

Pay for performance in health care: A new best practice tariff-based tool using a log-linear piecewise frontier function and a dual-primal approach for unique solutions
Diogo Ferreira*, Rui Marques and Alexandre Morais Nunes

Factor-analysis-based directional distance function: The case of New Zealand hospitals
Zhongqi Deng, Nan Jiang* and Ruizhi Pang

Productivity growth in total hip arthroplasty in Sweden – An application of Malmquist productivity index
Fanny Goude*, Göran Garellick, Sverre A.C. Kittelsen, Szilárd Nemes and Clas Rehnberg

WE-B-6: AGRICULTURE 5
11:00-12:30, Gordon Room
Session Chair: Wirat Krasachat

Gender and agricultural productivity: Econometric evidence from Malawi, Tanzania, and Uganda
Jacques Julien* and Boris Bravo-Ureta*

Factors determining differences in organic agricultural production across Spanish regions: A stochastic frontier approach
Alan Wall* and Luis Orea

Stochastic cost frontier for chili production in Thailand
Wirat Krasachat* and Suthathip Yaisawarng

WE-B-7: ELECTRICITY 3
11:00-12:30, Room G21A
Session Chair: Heike Wetzel

A novel approach to measure energy systems integration
Tooraj Jamasb, Manuel Llorca* and Ana Rodríguez-Álvarez

Including determinants of allocative and technical inefficiency in a stochastic frontier analysis framework
Ørjan Mydland*, Subal Kumbhakar, Andrew Musau and Gudbrand Lien

Scale and scope economies of German electricity and gas distribution networks
Heike Wetzel*

12:30-14:00 Lunch

WE-C-1: PANEL SESSION: WEATHER, CLIMATE AND AGRICULTURAL PRODUCTIVITY GROWTH
14:00-15:30, Beveridge Hall
Session Chair: Boris E. Bravo-Ureta

Estimating the effects of weather and climate change on agricultural productivity
Christopher O'Donnell*

Accounting for climatic effects in measuring U.S. field crop farm productivity
Sun Ling Wang and Nicholas Rada*

Will the real weather/climate specification please stand up?
Eric Njuki*

The effect of weather and climate extremes on agriculture: Empirical evidence and methodological issues
Emanuele Massetti*

Modelling the effects of weather on extensive dairy farming
David Roibas* and Alan Wall

Discussant: Madhur Gautam

WE-C-2: THE ROYAL ECONOMIC SOCIETY (RES) SPECIAL SESSION: UK PRODUCTIVITY PUZZLE II
14:00-15:30, Woburn Room
Session Chair: Anthony Glass

WE-C-3: INDEXES & DECOMPOSITION
14:00-15:30, Montague Room
Session Chair: Bert Balk

The local circularity test and a new local Hicks neutrality condition
Jesus T. Pastor* and Knox Lovell*

Financial inclusion, financial technology, and economic development: A composite index approach
Barnabe Walheer*

The decompositions of cost variation
Bert M. Balk* and José L. Zofío

WE-C-4: DEA 4
14:00-15:30, Brunswick Room
Session Chair: Giovanni Cesaroni

Stock performance measurement based on data envelopment analysis approach with bounded variables
Patcharaporn Yanpirat* and Sajika Thammanukitcharoen

Performance evaluation in education under uncertainty: A robust optimisation approach
Adel Hatamimarbini* and Aliasghar Arabmaldar

Centralized allocations in free disposal hull technologies
Giovanni Cesaroni*

WE-C-5: BANKING 1
14:00-15:30, Bloomsbury Room
Session Chair: Camilla Mastromarco

Assessing the performance of Spanish banks: An application of conditional efficiency measures with unobserved heterogeneity
Jose Manuel Cordero*, Carlos Díaz-Caro and Nickolaos Tzeremes

Assessing and explaining the impact of stock volatility on the efficiency of listed commercial banks
Anamaria Aldea and Luiza Badin*

Empirical evidence on the transmission of monetary policy through the banking system
Camilla Mastromarco* and Paul W. Wilson

WE-C-6: JUSTICE
14:00-15:30, Gordon Room
Session Chair: Osman Zaim

Explaining differences in efficiency. A meta-study on judicial literature
Francesco Aiello, Graziella Bonanno and Francesco Foglia*

Who got it right? Comparing the efficiency of justice across countries: Italy vs. Sweden
Jonas Månsson, Antonio Peyrache and Angelo Zago*

Judicial efficiency in EU countries: A dynamic network model approach
Osman Zaim*

WE-C-7: ENERGY 1
14:00-15:30, Room G21A
Session Chair: Tom Weyman-Jones

Sustainability and energy efficiency in Indian manufacturing
Kankana Mukherjee*

Empirical estimation of the level of energy efficiency in the European household sector: Evidence from Italy, the Netherlands and Switzerland
Nina Boogen, Cristina Cattaneo, Massimo Filippini and Adrian Obrist*

Measuring efficiency in residential electrical energy: A microdata case study
Tom Weyman-Jones*, Júlia Mendonça Boucinha* and Catarina Feteira Inácio*

15:30-16:00 Break

WE-D-1: AGRICULTURE 6
16:00-18:00, Beveridge Hall
Session Chair: Simone Pieralli

Adjusting for greenhouse gas emissions in agricultural productivity analysis: A global perspective
Frederic Ang* and K. Hervé Dakpo*

The millennium droughts and Australian agricultural productivity performance: A nonparametric analysis
Robert Chambers, Yu Sheng* and Simone Pieralli

Modelling state-contingent technology: The case of production and price uncertainty
Raushan Bokusheva* and Lajos Barath*

Estimating the impacts of soil on the climate sensitivity of European agricultural productivity
Simone Pieralli*

WE-D-2: NONPARAMETRIC ESTIMATION 2
16:00-18:00, Woburn Room
Session Chair: Paul W. Wilson

Estimating technical efficiency from sample designs using robust nonparametric models
Gabriela Sicilia*, Daniel Santín and Juan Aparicio

Testing productivity change, frontier shift, and efficiency change
Mette Asmild*, Dorte Kronborg* and Anders Rønn-Nielsen*

Shape constrained kernel weighted least squares: Extensions and computational issues
Andrew Johnson*, Daisuke Yagi and Hiroshi Morita

Nonparametric stochastic frontier models with multiple inputs and outputs
Léopold Simar* and Paul W. Wilson*

WE-D-3: SFA 4
16:00-18:00, Montague Room
Session Chair: Ioannis Skevas

Dependence of the technical efficiency on the uncertainty of the inefficiency error
Anatoly Peresetsky, Yevhenii Shchetynin*, Alexey Zaytsev* and Subal C. Kumbhakar

Estimation of a four component semiparametric stochastic production frontier model with endogenous regressors and determinants of inefficiency
Subal Kumbhakar, Kai Sun* and Ragnar Tveteras

Evaluating the CDF of the distribution of the stochastic frontier composed error
Christine Amsler*, Peter Schmidt* and Wen-Jen Tsay

Drawing inference in the context of spatial stochastic frontier analysis
Ioannis Skevas*

WE-D-4: LABOUR
16:00-18:00, Brunswick Room
Session Chair: Thomas Triebs

Impact of automation on labour use: Decomposition approach
Eduard Nežinský* and Mikuláš Luptáčik

Mind the gap: A global Phillips curve and the effects of labor market frictions
Ming Li*, Jaap Bos and Matteo Millone

The complementary effect of organizational practices and workers' type of education
Filippo Pusterla*

The shadow price of management
Thomas Triebs*, Kai Sun and Robin Sickles

WE-D-5: BANKING 2
16:00-18:00, Bloomsbury Room
Session Chair: Takayoshi Nakaoka

Directional slack-based decomposition of profit performance: An application in Chinese banks
Xiang Chen*, Tsu-Tan Fu and Emili Grifell-Tatjé

Are capital structure, fragility and efficiency drivers of bank market value?
Ana Lozano-Vivas* and Claudia Curi

Malmquist-Luenberger productivity indexes for dynamic network DEA models
Pooja Bansal* and Aparna Mehra*

An analysis of the bank merger gains using the directional distance function model with undesirable outputs
David Saal, Pablo Arocena and Takayoshi Nakaoka*

WE-D-6: AGRICULTURE 7
16:00-18:00, Gordon Room
Session Chair: Suthathip Yaisawarng

Assessing the effect of different agricultural subsidies on beef production efficiency in the EU. A stochastic metafrontier approach
Maria Martinez-Cillero*, Fiona Thorne and Michael Wallace

Jevons vs. Borlaug – Is efficiency a driver or damper of area expansion of oil palm production?
Bernhard Dalheimer* and Bernhard Brümmer

Does inefficiency affect firm crisis? Evidence from Italian agri-food industry
Pierluigi Toma*

Does environmental safety production technique reduce farmers' profit efficiency? Evidence from small chili farms in Thailand
Suthathip Yaisawarng* and Wirat Krasachat

WE-D-7: APPLICATIONS 1
16:00-18:00, Room G21A
Session Chair: Nicky Rogge

The efficiency implications of political donations
Vitezslav Titl*, Kristof De Witte and Benny Geys

Impact of power outages on firms efficiency in Asian emerging and developing countries
Anam Shehzadi* and Heike Wetzel

Efficiency of manufacturers in a developing country
Chau Chu*

Fifty states of human development? Measuring human development in the US using a 'Benefit-of-the-Doubt' human development index
Nicky Rogge*

THURSDAY 13 JUNE

8:00-9:00 Arrival and coffee

8:00-17:00 Registration

TH-A-1: AGRICULTURE 8
9:00-10:30, Beveridge Hall
Session Chair: Timo Sipiläinen

The measurement of transient and persistent technical efficiency of Polish crop farms
Andrzej Pisulewski* and Jerzy Marzec

Transient and persistent rice farming efficiency in Vietnam: A generalized true random effect model approach
Trong Phuc Ho*, Atakelty Hailu and Michael Burton

A dynamic stochastic frontier approach with unobserved heterogeneity, persistent and transient inefficiency
Jean Joseph Minviel and Timo Sipiläinen*

TH-A-2: AGRICULTURE 9
9:00-10:30, Woburn Room
Session Chair: Daniel Higgins

Specialized agricultural services and technical efficiency – Evidence from crop planting in China
Qian Liu* and Wei Huang

Technical efficiency of coffee production in the Colombian Coffee Cultural Landscape: The role of payments for environmental services
Orlando Rodriguez*, Maria Vrachioli* and Johannes Sauer

Irrigation infrastructure and farm productivity in the Philippines: A stochastic meta-frontier analysis
Daniel Higgins*, Boris Bravo-Ureta and Aslihan Arslan

TH-A-3: SFA 5
9:00-10:30, Montague Room
Session Chair: William Greene

Robust estimation of the stochastic frontier model
David Bernstein, Christopher Parmeter and Ian Wright*

A semiparametric smooth coefficient approach to estimate effects of farmers risk attitudes on productivity: Analysis of rice production in India
Ashok K. Mishra, Subal C. Kumbhakar and Gudbrand Lien*

On hypothesis testing in latent class and finite mixture stochastic frontier models
Alexander D. Stead*, Phill Wheat and William Greene*

TH-A-4: DEA 5
9:00-10:30, Brunswick Room
Session Chair: Philippe Vanden Eeckaut

A stepwise benchmarking approach to DEA with interval scale data
Akram Dehnokhalaji*, Nasim Nasrabadi, Pekka Korhonen and Jyrki Wallenius

Using a Choquet integral-based approach for incorporating decision-maker's preference judgements in a data envelopment analysis model
Miguel Pereira*, José Figueira and Rui Marques

Computing nonparametric measures with R. A critical surveys and future recommendation
Philippe Vanden Eeckaut*, Eliegbo Amouzou and Mohamed Charhbili

TH-A-5: BANKING 3
9:00-10:30, Bloomsbury Room
Session Chair: Karligash Glass

European bank loan loss provisioning cost efficiency and bank innovations
Aristeidis Dadoukis*

Cost efficiency, economies of scale and determinants of economies of scale: Evidence from regional commercial banking sector in China
Yuzhu Li* and Richard Simper

Spatial scale and product mix economies in U.S. banking with simultaneous spillover regimes
Anthony Glass*, Karligash Glass* and Amangeldi Kenjegaliev

TH-A-6: PUBLIC SECTOR
9:00-10:30, Gordon Room
Session Chair: Shawna Grosskopf

Searching for the optimal territorial structure: The case of Spanish provincial councils
Isabel Narbón-Perpiñá*, María Teresa Balaguer-Coll, Diego Prior and Emili Tortosa-Ausina

Technology, efficiency, and productivity: Evidence from U.S. local governments
Caitlin O'Loughlin* and Paul W. Wilson

Estimation and application of Lerner type indexes for the public sector
Rolf Färe, Shawna Grosskopf*, Kathy Hayes, William Weber and Heike Wetzel*

TH-A-7: APPLICATIONS 2
9:00-10:30, Room G21A
Session Chair: Gary Ferrier

Assessing firm market power non parametrically: An example of the GB residential mortgage market
Minyan Zhu* and Antonio Peyrache*

Relationship between credit conditions and efficiency in real sector: Firm-level evidence
Viktor Khanzhyn*

The transient and persistent inefficiency of hedge funds
Gary Ferrier* and Albane Tarnaud

10:30-11:00 Break

TH-B-1: AGRICULTURE 10
11:00-12:30, Beveridge Hall
Session Chair: K. Hervé Dakpo

Do farm advisory services affect total factor productivity growth?
Iordanis Parikoglou*

Uruguay's dairy farms efficiency: management or environment?
Federico Garcia-Suarez*

Polluting-input-based production technologies and efficiency in French dairy farming: A latent class stochastic frontier with class dependency pattern
K. Hervé Dakpo*, Laure Latruffe and Luis Orea Sanchez*

TH-B-2: MARKETS
11:00-12:30, Woburn Room
Session Chair: Jaap Bos

Estimating informational effectiveness of markets based on the BoD model
Giannis Karagiannis*

Evaluating the efficiency of structural funds application in the competitiveness of SMEs across different EU beneficiary regions
Maria Gouveia*, Carla Henriques and Pedro Costa

Trick or treat: Latent class modeling of average treatment effects
Jaap Bos* and Lu Zhang

TH-B-3: SFA 6
11:00-12:30, Montague Room
Session Chair: Robin Sickles

A count data stochastic frontier model for panel data
Richard Hofler* and Eduardo Fe

Robust stochastic frontier analysis: A panel data model with Student's t errors
Phill Wheat*, Alex Stead* and William Greene*

The term structure of sovereign CDS and currency carry trades
Giovanni Calice, Kerda Varaku, Robin Sickles* and Yukun Shi

TH-B-4: MANAGEMENT SYSTEMS
11:00-12:30, Brunswick Room
Session Chair: Kostas Triantis

The values change management cycle: Ethical efficiency
Dinah Payne*, Rajni Soharu and Pamela Kennett-Hensel

Estimation of the workload boundary in socio-technical infrastructure management systems
Taylan Topcu, Kostas Triantis* and Bart Roets

Workload quantification and distribution in socio-technical infrastructure management systems: Human vs. autonomous systems
Taylan Topcu, Kostas Triantis* and Bart Roets

TH-B-5: BANKING 4
11:00-12:30, Bloomsbury Room
Session Chair: David Tripe

Efficiency contribution patterns in Chinese commercial banks
Ning Zhu*, Jens Leth Hougaard, Zhiqian Yu and Qian Niu

Performance of Chinese banks over 2007–2015
Shirong Zhao* and Paul Wilson

The effect of merger to Vietnamese bank efficiency: A two-step DEA window analysis approach
David Tripe*, Trang Tran and Jing Liao

TH-B-6: ENERGY 2
11:00-12:30, Gordon Room
Session Chair: Pablo Arocena

Dynamic energy demand and the rebound effect: A two-stage approach
Golnaz Amjadi*, Tommy Lundgren and Wenchao Zhou

Revenue decoupling and energy consumption: Empirical evidence form the U.S. electric utilities sector
Victor von Loessl* and Heike Wetzel

A model for the competitive benchmarking of energy costs
Pablo Arocena*, Antonio Gómez and Sofía Peña

TH-B-7: APPLICATIONS 3
11:00-12:30, Room G21A
Session Chair: Harold Fried

Efficiency, technological advancement, and spillovers of hotels in China
Barnabé Walheer, Linjia Zhang* and Yingchan Luo

Effect of environmental regulations on efficiency of Kanpur leather industry: A DEA and directional distance function approach
Aparajita Singh* and Haripriya Gundimeda

Leaning to win on the PGA Tour
Harold Fried*, Juan Aparicio, Jesus Pastor and Loren Tauer*

12:30-14:00 Lunch

TH-C-1: AGRICULTURE 11
14:00-15:30, Beveridge Hall
Session Chair: Inmaculada Alvarez

Estimation of technical inefficiency and TFP growth via an input distance frontier with application to Lithuanian dairy farms
Tomas Balezentis* and Kai Sun

The competitiveness of Danish dairy farm
Mette Asmild*, Dorte Kronborg and Anders Rønn-Nielsen

Rural and agricultural development by land consolidation: A spatial production analysis of Asturias' parishes
Inmaculada Alvarez*, Luis Orea and Jose Antonio Perez

TH-C-2: ECO-EFFICIENCY
14:00-15:30, Woburn Room
Session Chair: Oleg Badunenko

Identifying best practices and potentials for performance improvement in EcoDriving: An efficiency analysis approach
Kenneth Løvold Rødseth*

Industrial eco-efficiency performance and dynamics in Europe. The existence of technological spillovers within a metafrontier framework
Eirini Stergiou* and Konstantinos Kounetas

Modeling inefficiency in a framework characterized by the two-tier behavior within stochastic frontier analysis: With application to the environmental Kuznets curve
Oleg Badunenko*, Marzio Galeotti and Lester C. Hunt

TH-C-3: NONPARAMETRIC ESTIMATION 3
14:00-15:30, Montague Room
Session Chair: Ørjan Mydland

Efficiency aggregation in stochastic frontier analysis with hierarchical data
Yashree Mehta* and Bernhard Bruemmer

A novel approach for measuring conditional efficiency in non-parametric models: An application to European banking
Panagiotis Tziogkidis*, Mike Tsionas and Dionisis Philippas

Estimating parameter uncertainty in the StoNED model
Ørjan Mydland*, Jonas Andersson and Endre Bjørndal*

TH-C-4: METAFRONTIERS
14:00-15:30, Brunswick Room
Session Chair: Kristiaan Kerstens

Strategic management and technical efficiency in local governments: A stochastic meta-frontier analysis
Joanna Kamiche-Zegarra* and Boris Bravo-Ureta*

Metafrontier Malmquist productivity index and the price of a convexification strategy
Qianying Jin*, Kristiaan Kerstens* and Ignace Van de Woestyne

The cost metafrontier is nonconvex in the outputs since the metafrontier is nonconvex: The price of a convexification strategy
Kristiaan Kerstens*, Christopher O'Donnell and Ignace Van de Woestyne

TH-C-5: BANKING 5
14:00-15:30, Bloomsbury Room
Session Chair: Charles-Henri DiMaria

Dynamics of total factor productivity change: An empirical analysis of Indian commercial banks
Mohammad Shahid Zaman* and Anup Kumar Bhandari

Measuring bank performance using production trade-offs: A network DEA approach
Stavros Kourtzidis* and Nickolaos Tzeremes

Banks' efficiency: A National Accounts micro-perspective
Charles-Henri DiMaria*

TH-C-6: FIRMS
14:00-15:30, Gordon Room
Session Chair: Marijn Verschelde

Cookie-cutter competition? Non-price strategies of multiproduct firms under uniform pricing
Gianluca Antonecchia* and Ajay Bhaskarabhatla

The comparative advantage of firms
Johannes Boehma, Swati Dhingrab, John Morrow*

Nonparametric analysis of multiproduct pricing behaviour
Laurens Cherchye, Thomas Demuynck, Bram De Rock, Catherine Fuss and Marijn Verschelde*

TH-C-7: APPLICATIONS 4
14:00-15:30, Room G21A
Session Chair: Loren Tauer

Productivity and firm sizes: Evidence from Vietnam
Hien Pham, Nhan Phan* and Shino Takayama

Output attributes and hedonic prices: An analysis of airfares
Charles Howell* and Emili Grifell-Tatjé

Wine hedonic pricing using the two-tier stochastic model
Loren Tauer* and Harold Fried

15:30-16:00 Break

TH-D-1: AGRICULTURE 12
16:00-17:30, Beveridge Hall
Session Chair: Magdalena Kapelko

Know what you sow: The cost of seed type misidentification in Tanzania
Federico Trindade*, Ayala Wineman, C. Leigh Anderson and Timothy Njagi

An efficiency analysis of small maize farms: A case of South Punjab region in Pakistan
Muhammad Omer Chaudhry* and Abdul Rehman Muhammad

Modelling environmental inefficiency under a quota system
Juan Aparicio, Magdalena Kapelko* and Lidia Ortiz

TH-D-2: APPLICATIONS 5
16:00-17:30, Woburn Room
Session Chair: David Roibas

Estimating airport efficiency of Peru airports
Julio Aguirre*, Enzo Defilippi, Jacques Julien and Paulo Quequezana

What does drive efficiency of urban railway operators in Japan? Focusing on time-invariant and time-varying effect
Yeon-Jung Song*

The effect of weather conditions on port technical efficiency
Lorena Garcia-Alonso, Ticiana Grecco Zanon Moura and David Roibas*

TH-D-3: APPLICATIONS 6
16:00-17:30, Montague Room
Session Chair: Abid Burki

Productivity dynamics in French woodworking industries
Enrico De Monte* and Anne-Laure Levet

User cost of capital and factor demand modelling: Implications on energy demand and technical change analysis
Sourour Baccar*

Trade liberalization and firm productivity in the manufacturing sector of Pakistan
Umer Khalid, Mazhar Iqbal and Abid Burki*

TH-D-4: EDUCATION 4
16:00-17:30, Brunswick Room
Session Chair: Giovanna D'Inverno

Dealing with imperfect compliance in frontier evaluation: A probabilistic efficiency model approach
Anna Mergoni*, Giovanna D'Inverno* and Kristof De Witte

Impact evaluation in a multi-input multi-output setting: Evidence on the effect of additional resources for schools
Giovanna D'Inverno*, Mike Smet and Kristof De Witte

TH-D-5: BANKING 6
16:00-17:30, Bloomsbury Room
Session Chair: Panagiotis Zervopoulos

Stochastic nonparametric estimation of productivity growth
Yu Zhao* and Hiroshi Morita*

Measuring the employee productivity in a retail bank – An axiomatic non-parametric approach
Juha Eskelinen* and Markku Kuula

A Bayesian data envelopment analysis approach for correcting bias of efficiency estimators: Evidence from the EU banking sector
Panagiotis Zervopoulos* and Konstantinos Triantis*

TH-D-6: ELECTRICITY 4
16:00-17:30, Gordon Room
Session Chair: Hilde Marit Kvile

Evaluation of DEA models with multiple environmental variables for cost regulation of transmission service operators
Aline Veronese da Silva*, Marcelo Azevedo Costa, Mohsen Afsharian and Ana Lúcia Miranda Lopes

Impact of weights limits in the efficiency analysis of the power distribution segment in Brazil
Lorena Santos, Jairo Eduardo Alvares, Rafael Gomes*, Maria Angelica Barbosa, Giulia Medeiros, Luana Lima, Anderson Rodrigo Queiroz and José Wanderley Lima

Seemingly homogenous outputs – Improving the output variables capturing the task of electricity distribution companies
Hilde Marit Kvile*, Tore Langset and Ole-Petter Kordahl

TH-D-7: APPLICATIONS 7
16:00-17:30, Room G21A
Session Chair: Tomohiro Kitamura

The impact of heterogeneous terrorism risks on trade efficiency – Evidence from countries surrounding the China-Pakistan economic corridor
Zhirui Li*

Immigrant wage gaps and determinants: A stochastic wage frontier approach using linked employer-employee data
Ragnar Tveteras* and Subal C. Kumbhakar

Difference in productivity between water-sewerage integrated systems and separated systems: Evidence from Japan
Tomohiro Kitamura*

CLOSING SESSION
17:30-18:00, Beveridge Hall

ABSTRACTS

Ordered lexicographically by the author (family) names

Asterisk * denotes presenting authors

Determinants of persistent and transient technical efficiency of Austrian crop farms
Felicity Addo* and Klaus Salhofer

Over the last two decades, the Common Agricultural Policy of the European Union (EU) has experienced significant changes creating a highly competitive market in which farmers nowadays operate. This is particularly challenging for countries with small-scaled agriculture like Austria, requiring farms to significantly improve technical efficiency in order to be competitive. In this paper, we follow Kumbhakar, Lien, & Hardaker (2014) and apply a four error component model to decompose technical efficiency into persistent inefficiency, which captures long run effects of farm management, and transient inefficiency, which accounts for how farms adjust to random shocks, while also controlling for farm heterogeneity and a random error. We extend Kumbhakar et al. (2014) to include exogenous determinants for both types of technical inefficiency. To do so, we estimate a trans-log stochastic production function for a panel of 231 crop farms in Austria for the period 2003-2016. We observe that both transient and persistent efficiency are equally important in counting for overall technical efficiency, which is 88% on average. In regard to persistent technical efficiency we find that full time farms and medium to large scale farms are more efficient. However, we observe that older farmers and farms that employ a high proportion of family labour are less persistently efficient. Regarding transient technical efficiency, we find that farms that cultivate more on their own land are less transiently efficient compared to farms on rented land. Lastly, we observe that farm subsidies in general negatively affects both types of efficiency.

How do strategic choices determine universities' efficiency? A cross-country study
Tommaso Agasisti and Jasmina Berbegal-Mirabent*

In an increasingly global and competitive landscape, universities are adopting different strategies to address their objective function, allocate resources and remain attractive to prospective students and researchers. This study tackles this issue by exploring the extent to which strategic choices regarding international positioning and scope determine how efficient universities are in the allocation of their internal resources. This work is particularly innovative because it assumes an international perspective, analysing how strategies vary within and between countries in Europe.

Data come from the European Tertiary Education Register (ETER) and the European Patent Office's Worldwide Patent Statistical Database (PATSTAT). Our sample is an unbalanced panel covering a 3-year period (2011-2013) with 761 observations coming from 307 universities located in 8 European countries.

First of all, a cluster analysis to characterise European universities is performed. Three main groups emerge: world-class, flagship and regional universities. Second, we model universities' objective function as a mix of teaching, research and third mission endeavours, and efficiency scores are calculated. In so doing, a meta-frontier analysis based on data envelopment analysis is used to consider potential structural differences across the three groups of institutions. This approach allows comparing efficiency frontiers across groups and relative to a common frontier. Bootstrap techniques on the efficiency scores obtained are applied to correct the estimated efficiencies from the sampling bias. Lastly, a truncated regression analysis is performed in order to determine the external factors shaping inefficiency. Implications for policy and practice within and between groups are discussed.

Estimating airport efficiency of Peru airports
Julio Aguirre*, Enzo Defilippi, Jacques Julien and Paulo Quequezana

Airports in developing countries have historically been owned and managed by government agencies. However, the number of airports managed by private operators has increased significantly during the last decades due to the rise of public-private partnerships (PPP) (Oliveira and Cunha, 2011). Our hypothesis is that PPPs tend to generate better results because they allow allocating inputs more efficiently, which generates benefits for the local and regional economy (Aguirre et al., 2019; Sheard, 2014; Green 2007; Benell and Prentice, 1993; Button et al., 2010). In this paper, we analyze the drivers of productivity and efficiency of Peruvian regional airports in order to generate useful information for the public sector; in particular, the regulatory agencies in charge of setting rates and monitoring airport operations.

Using yearly panel data for 2001-2017, we compare the efficiency of 12 regional airports before and after their concession to the private sector. We consider medium and long-term effects and also provide insight analysis of technological change. We provide a robust approach by performing both DEA techniques and Random and Fixed effect Stochastic Production Frontier model, which account for time-varying regional socio-economic covariates in addition to the ones available in the literature. Since climate and geographic characteristics are different among Peruvian regions, we also control for unobserved heterogeneity between regions.

Explaining differences in efficiency. A meta-study on judicial literature
Francesco Aiello, Graziella Bonanno and Francesco Foglia*

One learns two main lessons from the efficiency literature on judicial systems. The first lesson regards the heterogeneity in the efficiency scores reported in primary papers. The second lesson is that there is no quantitative evidence on the role played by the features of each paper (i.e. estimation method, functional form, sample size, number of inputs and outputs, returns to scale) in explaining the differences in results. In order to fill this gap, we review the related empirical literature and perform a Meta-Regression-Analysis (MRA) by examining 340 efficiency scores retrieved from 45 papers published from 1992 to 2018. The empirical setting is based on a random effect model estimated with the Random Effects Maximum Likelihood (REML) technique, because it controls for within- and between-study heterogeneity. We also run fixed-effect unrestricted Weighted Least Squares (WLS) regressions.

Due to its main research focus, that is measuring the impact of potential sources of heterogeneity on judicial efficiency, the paper contributes to the debate in two ways. One of this concerns the role of methodological choices made by researchers when performing an efficiency study. The second regards the role of reforms in judicial systems, which is a policy-issue in a number of countries.

Results show that efficiency scores are highly heterogeneous. To be precise, significant differences in means are found when grouping efficiency on the basis of different criteria. The meta-regression estimates indicate that. using panel data in primary studies allows researchers to obtain higher efficiency of district courts than papers using cross-section data. Interestingly, FDH studies yield, on average, higher efficiency scores than DEA papers, thereby suggesting that in this literature the convexity hypothesis of the production set is a matter. We also provide evidence that the estimated efficiency scores in primary papers increase with the number of inputs and outputs when estimating the frontier. Furthermore, we find that primary papers evaluating the efficiency of European courts provide higher efficiency scores than studies focusing on Africa, Asia and Latina America. Importantly, MRA results are robust to the potential outliers in efficiency and sample size distributions.

The effects of the abolishment of the EU milk quota scheme on the efficiency frontiers of organic and conventional dairy farms in Denmark

Lorenz Aigner* and Mette Asmild*

The present study analyzes the consequences of the abolishment of the EU milk quota scheme in 2015 on the dairy sector in Denmark using a comprehensive data set comprising organic and conventional dairy farms from 2011 to 2017. Initially, we calculate productivity changes over time using the Malmquist index and its components based on efficiency frontier estimates obtained from DEA. Permutation tests are performed to test for statistical significance of these changes in productivity over time. Next, we calculate the differences between the organic and the conventional frontiers in each year, for observations from each of the two groups. Jackknifing is applied to correct for estimation bias. Subsequently, the intersections of the group frontiers can be identified in order to determine the circumstances under which each technology is superior to the other. Our analysis shows that the drop in the milk prices following the abolishment of the quotas is likely what led to worsened (economic) production possibilities in 2015 and 2016, followed by an improvement in 2017, for both groups, but where the effect experienced by the organic farms was less pronounced. Furthermore, under certain conditions, the organic technology offers better production possibilities even for conventional farms after 2015, which becomes especially clear when correcting for estimation biases.

Assessing and explaining the impact of stock volatility on the efficiency of listed commercial banks

Anamaria Aldea and Luiza Badin*

The financial soundness of the banking system, especially after the crisis, represents one of the main focuses of investors, as the banks' roles in the economic development of a country are significant. The influence that listed commercial banks have upon the region they activate in depends on their efficiency, as well as on their reaction to the magnitude of an important event, such as a financial crisis.

In this paper we use conditional efficiency analysis to assess and explain the impact of stock volatility on the efficiency of listed commercial banks. The approach is fully nonparametric and allows an insightful understanding of the compound impact of external factors (impact on the shape of the frontier and/or impact on the distribution of inefficiency). To estimate the conditional efficiencies, we apply the most recent bootstrap-based method proposed by Badin, Daraio and Simar (2018) for bandwidth selection in conditional frontier models. In our empirical study, we consider listed commercial banks from FactSet database, as their activity represents the primary function of banks, namely lending and borrowing financial resources and their usually associated lower risk makes them easier to handle.

Economies of scale and scope among the Norwegian dairy and crop farms

Habtamu Alem*, Gudbrand Lien, Subal Kumbhakar and J. Brian Hardaker

The aim of this paper was to investigate the existence of economies of scope and scale among the Norwegian dairy and crop-producing farms using a flexible technology approach, accounting for a regional difference. In the literature on economies of scope, it is usual to make the strong assumption of a common technology for diversified and specialized farms. To avoid this shortcoming, we estimated economies of scope and scale accounting for different technologies for specialized and mixed farms. We fitted translog cost functions to farm-level panel data for the period 1991-2014. We found that both economies of scope and scale exist on Norwegian dairy and crop-producing farms. We also found that dairy farms have an economic incentive to integrate dairy farming with crop production in all regions of Norway and vice versa. Thus, policymakers need to understand that interventions that inhibit diversification or structural change in farming can push up the costs of food production.

Rural and agricultural development by land consolidation: A spatial production analysis of Asturias' parishes
Inmaculada Alvarez*, Luis Orea and Jose Antonio Perez

This paper evaluates the impact of the land consolidation processes that have taken place in Asturias during the period 2001-2017. These processes have been received European funds because of their potential to improve the economic activity in rural areas and stabilize their population. In particular, land consolidation aims to increase farms' productivity as these processes involve public investment in infrastructures that favour accessibility and development in these and adjacent areas. To evaluate the effect of land consolidation processes on milk and meat production we treat the parishes in Asturias as production units and estimate a set of distance functions. Our preliminary results indicate that land consolidation contributes to increase farms production, although those processes not always are accompanied by an increase in the number of farms. Finally, it worth highlighting that the investment made in infrastructures is the most relevant feature of the land consolidation processes.

Dynamic energy demand and the rebound effect: A two-stage approach
Golnaz Amjadi*, Tommy Lundgren and Wenchao Zhou

Energy efficiency improvement (EEI) is generally considered as a cost-effective tool to reduce energy use, combat climate change and improve energy security. However, behavioral responses to EEI, referred to as the energy rebound effect, may mitigate, increase, or even reverse the emission and energy savings expected from EEI. Despite the consensus on the existence of energy rebound effect, as well as the importance of taking it into account when energy and climate policies are set, there is a lack of consensus regarding how to measure this effect. In this study, we propose a new two-stage approach to measure the rebound effect in both short and long run, applied to a firm-level data set from the Swedish manufacturing industry for 1997–2008. In the first stage, data envelopment analysis is applied to obtain energy efficiency scores. In the second stage, a dynamic panel data regression is used to estimate the rebound effect. In contrast to previous studies, our two-stage approach allows us control for the production of bad outputs while measuring energy efficiency, and is also able to capture the full range of possible responses to EEI. We find that in the short-run, partial rebound effects exist within all sectors, meaning that the rebound effect does not totally offset the potential energy and emission savings expected from EEI. In the long-run, results show that substantially smaller rebound effects remain within most of sectors. Furthermore, our firm-level estimates show that rebound effects tend to be lower among firms with relatively higher energy costs.

Evaluating the CDF of the distribution of the stochastic frontier composed error
Christine Amsler*, Peter Schmidt* and Wen-Jen Tsay

In the stochastic frontier model, the composed error is the sum (or difference) of a normal and a half normal random variable. Often the composed error is linked to other errors using a copula, and evaluation of the copula requires evaluation of the cdf of the composed error. There is no analytical expression for this cdf, though there are several approximations. We propose a computationally efficient simulation based method of evaluation and use it to evaluate the accuracy of these approximations. We also derive the exact cdf of the composed error for the special case that the stochastic frontier relative variance parameter λ equals one, and we use this expression to investigate the accuracy of our evaluations and the existing approximations.

Productivity growth in the electricity and gas networks in Great Britain
Karim Anaya Stucchi*, Victor Ajayi and Michael Pollitt

This paper evaluates the productivity growth of the electricity and gas networks in Great Britain (GB) since privatisation and the introduction of incentive regulation (around 1990). The paper uses the Malmquist data envelopment analysis (DEA) method with the variable return to scale (VRS) input

oriented approach. We perform separate analyses for four network sectors: electricity and gas distribution and electricity and gas transmission. Different models are proposed for each sector with a combination of inputs/outputs and non-quality/quality variables. Results suggest that electricity distribution has performed better than gas distribution, and in both cases their performance increase when quality variables are taken into account. At transmission, gas performs better than electricity. Electricity transmission productivity has contracted for the period that was analysed, which may be explained by the higher replacement capital expenditure in this sector (in comparison with gas transmission). In general the energy sector has performed better than the reported performance for the whole market economy in the UK. This performance is hardly surprising given that the productivity growth for the whole economy has also been slow and the headline real revenue reductions from the energy network price controls are to some extent consistent with this. The GB energy sector has been exposed to challenging conditions in which to improve productivity since 2005, that may also contribute to low productivity growth. These include falling demand, increased pressure to improve quality of service and the rise of small scale distributed generation.

Nitrogen use efficiency

Tihomir Ancev, Bradley Barnhart, Moriah Bostian*, Anna Michalak and Eva Sinha

Nitrogen (N) fertilizer plays an important role in agricultural production, contributing to higher crop yields and the intensification of lower soil quality land. However, excess application leads to N runoff from the crop field into surrounding water systems. In practice, N pollution remains a leading contributor to water quality impairment around the world. This has led to increased scrutiny by researchers and policy makers of N use efficiency (NUE), which generally refers both to the effectiveness of N use in increasing crop yields and to the environmental from any associated runoff. This increased interest has also led to a number of different NUE measures, so that no universal indicator currently exists, and existing measures generally ignore concepts of economic efficiency and productivity. We bridge this gap here, by developing a Luenberger index for NUE that is grounded in production and index theory, and can be used to assess relative performance across both space and time. We apply this framework to the US Mississippi-Atchefelaya River Basin (MARB), one of the most productive agricultural regions in the world, and also the source of N runoff fuelling the annual Gulf of Mexico 'Dead Zone.' To do this, we use geographic information systems (GIS) to connect agricultural production data to biophysical hydrology estimates of N runoff at the sub-basin scale, for agricultural census years 2002-2012. We use the Luenberger NUE index to consider the spatial distribution of NUE over the basin, and to assess changes in NUE and the production technology over time. We also compare our results to existing measures in the literature. We find considerable spatial variation in our results, which could be used to better target policy incentives for environmental management practices and lower the overall cost of water quality improvements.

Adjusting for greenhouse gas emissions in agricultural productivity analysis: A global perspective

Frederic Ang* and K. Hervé Dakpo*

9.8 billion people will inhabit this Earth by 2050 according to the most recent projections by the UN (2017). A growing population leads to rising food demand, which requires a substantial increase in food supply. However, agricultural production is often an important driver of environmental problems. Most notably, almost one quarter of the global greenhouse gas (GHG) emission originates from the agricultural sector (FAO, 2014). The “Sustainable Intensification” (SI) paradigm envisions the process of increasing production from existing farmland while minimizing pressure on the environment (Garnett et al., 2013). There is a growing consensus among policy makers and researchers that SI is an important part of the solution to the challenges presented to the food system. Here, we quantitatively assess the global progress towards SI for the period 1961 – 2014, using an environmental Total Factor Productivity (TFP) index that incorporates GHG emission. We augment O’Donnell (2014)’s Färe-Primont TFP index with Murty et al. (2012)’s by-production approach to model pollutants. We use non-parametric Data Envelopment Analysis (DEA) to compute the environmental TFP indexes. When using inputs, farms have only limited information on the

future realization of output production and GHG emission, due to random weather fluctuations. Therefore, we remove these annual fluctuations using the Hodrick-Prescott filter following Fuglie et al. (2012). Although the environmental TFP index increases in this period, there is substantial heterogeneity.

Weather volatility and crop production
Denitsa Angelova*

European conditions for crop production are characterized by significant regional heterogeneity in terms of geography and weather. This contribution, in particular, investigates the production of winter wheat and maize in a primal fashion by utilizing a multi-input, multi-output framework, which was modified to accommodate regional heterogeneity and stochastic elements. The empirical analysis relies on a dataset based on aggregated accounting records from the FADN database and weather data in a compatible spatial granularity obtained through the newly established Copernicus Climate Change Service. This hypothesis on weather variability is examined by framing weather as a combination of temperature and rainfall and calculating yearly values for the second moment of their respective distributions based on daily observations. The empirical findings confirm that regional weather fluctuations, and not only regional weather averages, are a significant determinant in the crop production process and constitute an important feature of the production environment.

Cookie-cutter competition? Non-price strategies of multiproduct firms under uniform pricing
Gianluca Antonecchia* and Ajay Bhaskarabhatla

In this paper, we study how multiproduct firms compete using non-price strategies in an industry where all firms charge the same price. Using Nielsen data on biscuit manufacturers in India, we find that products with one standard deviation higher productivity offer, on average, 1.5% more quantity for the same price. Firms also compete by offering volume promotions and price discounts for more productive products. Using non-price strategies more productive products appear to gain market share, indicating competition thrives under the veil of uniform pricing. We find greater levels of product availability and productivity-induced competition in urban areas compared to rural areas, implying uneven welfare effects. We show that deviating from uniform pricing can improve welfare of rural consumers. In the paper we propose a quantity-based measure of product-level productivity that controls for the biases related to input measurement, simultaneity and product scope of the firm. Our results are robust to alternative methods of estimating product-level productivity.

Modelling environmental inefficiency under a quota system
Juan Aparicio, Magdalena Kapelko* and Lidia Ortiz

This paper introduces the methodology necessary to evaluate inefficiency of regulated decision making units that operate under quotas accounting for both quotas' restrictions and negative environmental externalities of production. Three technical inefficiency measures are proposed: inefficiency in the production of marketed output, environmental inefficiency, and inefficiency with quotas. It is then shown how to aggregate these measures in order to obtain indicators of overall performance. The new approach is illustrated through an empirical application that uses data available for the European Union dairy sector. The analysis suggests more inefficiency regarding marketed outputs than undesirable outputs. Also, considerably smaller inefficiencies are found when quotas restrictions are accounted for in the model than in the model without quota imposition, indicating that not accounting explicitly for quotas when measuring performance in regulated sectors may lead to serious overestimation of firms' technical inefficiency.

A model for the competitive benchmarking of energy costs
Pablo Arocena*, Antonio Gómez and Sofía Peña

The increasing relevance of energy as a factor of competitiveness has brought the need of managing energy costs to the forefront. Hence, benchmarking appears as an essential tool for companies to quantify how their energy costs compare against competitors and understand the sources of their

cost differences, with the ultimate goal of using that insight to identify strengths and opportunities for the improvement of performance. This paper develops an analytical framework for benchmarking the energy cost variance across firms. Specifically, we formulate a cost frontier based decomposition of the observed energy cost gap between two firms, the gap being the difference between the unit energy cost of a benchmarking producer and the unit energy cost of a target firm. The unit energy cost gap is decomposed into six constituents that quantify how much of the gap between two firms is due to differences in (i) energy prices; (ii) non-energy prices; (iii) energy efficiency; (iv) capital intensity; (v) outsourcing level; and (vi) production scale. We illustrate the implementation and usefulness of the proposed model by means of an empirical application of energy cost benchmarking on a sample of manufacturers of cement products.

Testing productivity change, frontier shift, and efficiency change
Mette Asmild*, Dorte Kronborg* and Anders Rønn-Nielsen*

In this talk a novel set of significance tests for DEA-based productivity change measures will be discussed. The tests are based on permutations and accounts for the inherent correlations when panel data are observed. They are easily implementable and give exact significance probabilities as they are not based on asymptotic properties. Tests are formulated both for the geometric means of the Malmquist index, and also of its components, i.e. the frontier shift index and the efficiency change index, which together enable analysis of not only the presence of differences, but also gives an indication of whether productivity change is due to shifts in the frontiers and/or changes in the efficiency distributions. Simulation results show the power of, and suggest how to interpret the results of, the proposed tests. Permutation-based test methods testing for differences between different production plans will also be discussed.

The competitiveness of Danish dairy farm
Mette Asmild*, Dorte Kronborg and Anders Rønn-Nielsen

In this paper we analyze the relative competitiveness of the Danish dairy farms, compared to similar farms across Europe, based on a large dataset of farm level data collected by FADN. We utilize two new bilateral indicators that make it possible to distinguish between differences in production conditions (indicated by DEA estimated frontiers for the different countries) and differences in the utilization of those conditions (indicated by efficiencies relative to the national frontiers). We also investigate the development of the production conditions in the different countries over time and use novel permutation tests to determine the significances of the frontier shifts.

The results are interesting since they reveal that the Danish dairy farmers generally have a better utilization of worse (economic) production conditions than the comparable farms in all the other European countries. Furthermore, the development of the production possibilities for the Danish farms over time is worrying since it seems to be falling short of the development in several other countries in the latter part of the study period.

User cost of capital and factor demand modelling: Implications on energy demand and technical change analysis
Sourour Baccar*

In this paper we report results of a rather successful attempt to provide evidence on the substitution possibilities between capital, labour, and energy in the three branches of manufacturing industry. In order to assess the sensitivity of results to the choice of the functional form and to data construction procedures, alternative specifications of the cost function are estimated, based on three flexible functional forms (i) the Translog, (ii) the Generalized Leontief, and (iii) the Symmetric Generalized McFadden - while two different series of the user cost of capital are constructed (i) the implicit ex ante price (including fiscality parameters), obtained by extending the theoretical model of Jorgenson and (ii) the ex post price computed as the residual rate of return to capital, when zero profits are imposed at full equilibrium position. We show that the choice of the regressors is even important in

the context of the choice of the functional form. We also consider the validity of the ex post approximation of the user cost of capital, frequently used in studies of production and investment behavior, and find that our data do not support it.

Our most important innovation is then in confronting results and interpretations yielded by three flexible approximations of the cost function when the two measures of the user cost of capital are alternatively used. In cases where we can precisely estimate an elasticity, our results seems robust to the choice of the functional form and the method of calculating the user cost of capital. Nevertheless, inconsistencies are enough frequent since this circumstance is scarce with the ex post approximation. This explain the fact that regressions with the ex post price of capital yield elasticities that can diverge from theirs true values and discrepancies between the estimates suggests that care should be taken during the interpretation of the econometric results. The issues analysed in the present paper are therefore not merely of theoretical interest, but also of practical concern.

Modeling inefficiency in a framework characterized by the two-tier behavior within stochastic frontier analysis: With application to the environmental Kuznets curve
Oleg Badunenko*, Marzio Galeotti and Lester C. Hunt

The empirical analysis of the Environmental Kuznets Curve (EKC) is typically performed to identify the turning point in economic development where the emissions are at a maximum. Irrespective which methods is used for such identification, cross-sectional or panel data approach, cointegration analysis etc, it is assumed that nations do not strive to be environmentally conscious. Stochastic frontier (SF) analysis lends itself as a convenient tool to measure the ability (or efficiency) of nation to reduce its environmental impact jointly with the above mentioned turning point. The standard SF approach would measure the vertical distance from observation to the frontier. This is appropriate in the EKC framework only for nations above the turning point. Assuming that countries below the turning point would only be interested in reducing emissions without targeting economic development would overestimate their inability to achieve desired combination of emissions and economic development. We model this two-tier behavior within SF framework and well as devise a trick to estimate the turning point and inefficiency for nations in different stages of their economic development. Preliminary results show that the turning point seems to be overestimated if approached of previous studies is used.

Estimation of technical inefficiency and TFP growth via an input distance frontier with application to Lithuanian dairy farms
Tomas Balezentis* and Kai Sun

This paper presents a smooth coefficient model for analysis of the total factor productivity (TFP) change in a multiple-input–multiple-output setting. The novelty of the proposed framework lies in that we directly estimate the dynamic input distance frontier rather than derive it from the static setting. What is more, the error term is decomposed into inefficiency and noise with the former following truncated normal distribution where both mean and variance are explained in terms of contextual variables. The empirical example focuses on Lithuanian dairy sector which has seen serious transformations following accession to the European Union and introduction of the Common Agricultural Policy (CAP). The results indicate slightly decreasing technical efficiency. Lithuanian dairy farms maintained TFP growth of 1.1 per cent p.a. on average during 2004-2016. Much of it was attributed to the technical change and mark-up component.

The decompositions of cost variation
Bert M. Balk* and José L. Zofío

In this paper a number of meaningful and empirically implementable decompositions of the cost variation (in ratio and difference form) are developed. Given data from a (balanced) panel of firms, all the necessary ingredients for the computation of the various decompositions can be obtained by using linear programming techniques. A real-life application will be provided.

Malmquist-Luenberger productivity indexes for dynamic network DEA models
Pooja Bansal* and Aparna Mehra*

The data envelopment analysis (DEA) model for computing the Malmquist-Luenberger productivity index (MLPI) has been proved useful in measuring the productivity change in the decision making units (DMUs) over two consecutive periods. In our findings, in this paper, we detect the infeasibility of directional distance function (DDF) based DEA model of MLPI in the presence of negative data values. We address this issue and formulate a new DDF based DEA model to compute an improved MLPI. We extend the DDF approach to the dynamic network structure to introduce the dynamic MLPI for analyzing the efficiency performance of DMUs over the horizon of study. We also introduce the dynamic sequential MLPI (DSMLPI) to capture the shifts in the efficient frontiers induced by random shocks or innovations in technology over the period. The dynamic network structure involved in both the indexes is composed of multiple divisions of DMUs vertically connected by intermediate productivity links and horizontally attached over time by the carryover activities. The proposed models are shown to be feasible and bounded in the presence of undesirable features and negative and non-negative data values. The viability of the proposed models is demonstrated using a real data of 20 Indian nationalized banks from 2008-09 to 2012-13. The results present the productivity change, technical change, and efficiency change in these banking units.

Empirical estimation of the level of energy efficiency in the European household sector: Evidence from Italy, the Netherlands and Switzerland
Nina Boogen, Cristina Cattaneo, Massimo Filippini and Adrian Obrist*

We analyse the level of efficiency in the use of electricity in the European residential sector using a cross-sectional dataset comprised of 1381 observations from Italian, Dutch and Swiss households observed in 2016. To do this, we estimate an electricity demand frontier function using a stochastic frontier approach. The demand frontier function reflects the minimum electricity needed to produce a predefined level of energy services. This benchmarking analysis estimates an efficiency index for each household.

The empirical results show that the residential sector in these three European countries could save approximately 20-25% of its total electricity consumption on average if it improves the level of efficiency in the use of electricity. These figures are in line with recent studies for Switzerland and for the US residential sector.

An updated assessment of technical efficiency and returns to scale for U.S. electric power plants
David Bernstein*

This paper utilizes cutting-edge panel stochastic frontier models to study electricity production of natural gas fired power plants in the United States. Using an expansive dataset collected for the period 1994 to 2016 I simultaneously account for plant specific heterogeneity as well as time varying and time constant inefficiency. Previous studies of electricity generation in the U.S. have ignored at least one of these components. The ability to control for unobserved heterogeneity is import in assessing long-term managerial effectiveness. Deploying a translog function form I am also able to extract firm specific information on scale economies. Results indicate that mean persistent technical efficiency for natural gas fired power plants is 81 percent, transient technical efficiency is 73 percent, and returns to scale are 1.04. These results have important implications for regulation and policy making for the energy sector in the U.S.

Robust estimation of the stochastic frontier model
David Bernstein, Christopher Parmeter and Ian Wright*

While data envelopment analysis has seen sustained success developing methods to mitigate the impact of outliers, the same cannot be said for stochastic frontier analysis. Methods to explicitly account for outliers in the stochastic frontier setting have only recently been proposed and entailed various distributional assumptions that allowed for a thicker tail of the two-sided noise distribution

(Tancredi, 2002; Horrace and Parmeter, 2018; Greene, Wheat, and Stead, 2019). However, changing the assumed distribution of the two-sided error may not be prudent in this setting. Rather than propose a distributional pair for the composed error term to allow for thick tails, we instead use a general estimation methodology to ensure maximum likelihood analysis is robust, known as psi-divergence. With psi-divergence any likelihood function can be wrapped in an increasing, convex and differentiable function that controls for contamination. We demonstrate that in the presence of contamination the robust MLE is relatively more efficient than the standard SFA estimators. Simulations also reveal that our robust MLE can outperform existing methods when those distributional assumptions fail.

The profitability change and its drivers: An empirical analysis of the Spanish power companies before and after industry reforms

Leticia Blazquez*, Emili Grifell-Tajé and Pablo Arocena

The electricity industries of many countries have experience fundamental changes since the nineties. In Spain these changes have been especially profound, as long as, simultaneously, the power sector was progressively liberalized and opened up to competition, although a relevant segment of residential consumers still pays a regulated (and controversial) tariff; a series of mergers and acquisitions consolidated the industry substantially; and the only public-owned utility, Endesa, (the largest player in the industry) was privatized and diversified. Together with these regulatory, business and market organization changes, the irruption and sustained increase of renewable energies in the energy production mix (especially wind and solar) has meant a significant technological alteration for all electricity companies. In this paper we jointly evaluate the impact that these reforms and transformations have had on the profitability of the companies and its components. Thus, we decompose the profitability change into productivity changes, price recovery changes and quantity mix index in order to assess the main effects of the three changes. Our results show that (i) the liberalization of the Spanish electricity sector contributed to improve the productivity and to pass the efficiency gains on to the customers; (ii) the privatization promoted the cost reduction and the increase in productivity and profitability for Endesa; and (iii) the consolidation of the industry entailed a change in the business mix of the companies that undermined their profitability.

The comparative advantage of firms

Johannes Boehma, Swati Dhingrab and John Morrow*

Multiproduct firms dominate production, and their product turnover contributes substantially to aggregate growth. Theories propose that multiproduct firms grow by diversifying into products which need the same know-how or capabilities, but are less clear on what these capabilities are. Input-output tables show firms co-produce in industries that share intermediate inputs, suggesting input capabilities drive multiproduct production patterns. We find evidence for this in Indian manufacturing: the similarity of a firm's input mix to an industry's input mix predicts entry into that industry. We identify the direction of causality from the removal of size based entry barriers in input markets which made firms more likely to enter industries that were similar in input use to their initial input mix. We rationalize this finding with a model of industry entry to estimate the importance of input capabilities in determining comparative advantage through economies of scope. Complementarities driven by input capabilities make a firm on average 5% (and up to 15%) more likely to move into an industry. Entry barriers in input markets constrained the comparative advantage of firms and were equivalent to a 10.5 percentage point tariff on inputs.

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Modelling state-contingent technology: The case of production and price uncertainty
Raushan Bokusheva* and Lajos Barath*

There have been several applications of the state contingent approach to modelling stochastic technology. To the best of our knowledge, most studies so far modelled stochastic production technology considering only one source of uncertainty, namely production risk. However, price volatility is another important source of uncertainty to businesses and plays an important role in firm decision-making. In addition, due to a negative correlation of output prices with aggregate supply and yields in agricultural commodity markets, output price responses to shifts in aggregate supply influence the extent of production risk effect on farm output and, thus, may also impact farm production and input use decisions. Therefore, in our study we propose an approach allowing to model the production technology considering both types of uncertainty – production and price risks. Using weather and farm accountancy data for specialized crop producers in Hungary, we estimate a stochastic frontier production function allowing output substitutability across state of natures. Subsequently, we test our state-contingent technology model for being output cubical, i.e. for the absence of substitution between states of nature, as well as against a conventional stochastic frontier model.

Trick or treat: Latent class modeling of average treatment effects
Jaap Bos* and Lu Zhang

Identifying causal effects in the dismal science that is economics is notoriously difficult for a variety of reasons. Nevertheless, many recent advances have contributed to our understanding of the measurement of causal effects, through experiments and quasi-natural experiments. In this paper, we address an issue that to the best of our knowledge so far has not been addressed. We focus on cases where there is uncertainty about who has been `treated' and who has been left untreated. We introduce a way of identifying average treatment effects in such cases, and demonstrate the success of our approach, first through a series of simulations and then with an empirical example based on the trade-specialization relationship that has contributed to the changing industrial structure in many EU countries.

Nonparametric three-way conditional heteroskedastic frontiers
Jun Cai*, Willian Horrace and Yoonseok Lee

We propose a nonparametric panel stochastic frontier model based on the “true” fixed effect/random effect model of Greene (2005a, 2005b) that (a) contains an un specified production/cost function with non-separable unobserved heterogeneity, (b) accommodates time-varying, conditional heteroskedastic variance components, and (c) does not require distributional assumptions on the noise term except conditional symmetry. Based on conditional independence assumptions similar to Evdokimov (2010), we use conditional characteristic functions to derive new moment conditions that allow identification of the heteroskedastic variance of inefficiency and noise. Identification only requires a panel with two time periods. We develop a nonparametric estimation procedure for the variance parameters and derive polynomial convergence rates. Monte Carlo simulation shows that the estimator has good finite sample properties for various designs. We apply the proposed nonparametric estimator to a panel of US banks and compare the results to the parametric model.

The term structure of sovereign CDS and currency carry trades
Giovanni Calice, Kerda Varaku, Robin C Sickles* and Yukun Shi

As a profitable strategy for several decades, currency carry trades provide an abnormal high risk-adjusted return and therefore create consistently violations of uncovered interest parity (UIP). In

this paper, we establish a direct link between the term structure of sovereign credit default swaps (CDS) and carry trades efficiency. In a first step, we demonstrate that the term structure of the sovereign CDS exhibits significant explanatory power for crash risk and foreign exchange risk of carry trades. In a second step, by using the Kneip, Sickles and Song (2012, Econometric Theory) time-varying heterogeneity stochastic panel frontier model, we estimate that this impact translates into financially important gains in terms of currency excess returns. Finally, we perform further tests to ascertain whether our findings are also robust with data from a broad range of financial markets. Overall, our results are relevant to investors and to the best of our knowledge this is the first empirical evidence of CDS markets enhancing currency carry trades.

The evaluation of performance of education systems in the light of Europe 2020 strategy: A comparison between fixed and flexible weighting systems for the construction of composite indicators

Ana Camanho*, Dovile Stumbriene and Audrone Jakaitiene

The performance evaluation of education systems is at the top of the agenda of governments and education authorities worldwide. However, research involving cross-country comparisons of the performance of education systems is still incipient. This paper proposes a new composite indicator to summarise the performance of education systems, enabling benchmarking comparisons and the definition of objectives for improvement. Conducing multi-dimensional evaluations requires the aggregation of several individual indicators into a single summary measure of performance, leading to the construction of a composite indicator. This research analyses different modelling alternatives for the construction of composite indicators, based on fixed weighting systems and flexible weighting systems. Data Envelopment Analysis models are used to implement progressive degrees of flexibility using weight restrictions. Our study uses annual data of 29 European countries, collected from EUROSTAT concerning Europe 2020 strategy for education. The results obtained in terms of performance scores and country rankings are presented and their managerial implications are discussed. We conclude that composite indicators estimated using frontier techniques can support the transition from the paradigm of performance assessment (control) to performance management (improvement).

Centralized allocations in free disposal hull technologies

Giovanni Cesaroni*

In recent years, the literature has witnessed a growing interest about the issue of centralized allocations. To the best of our knowledge, the related contributions have only considered convex production technologies, probably as a consequence of the difficulties concerning both the representation of the group technology and the use of the average unit approach. In a non-convex production technology, we solve the analytical problem represented by the evaluation of the efficiency of an industry when outputs/inputs can be reallocated over both an endogenous and exogenous number of firms. Besides establishing a theoretical relationship between the industry technology, the free replicability and the elementary replicability models, the paper proposes a simplified computational approach to the linear integer-programming problems involved by optimal centralized allocations. Empirical illustration of the theoretical results and of the effectiveness of the proposed approach are given with reference to various sets of DMUs employing different multiple inputs and outputs technologies.

The millennium droughts and Australian agricultural productivity performance: A nonparametric analysis

Robert Chambers, Yu Sheng* and Simone Pieralli

Strong agricultural productivity growth in the OECD countries was a key driver of global economic growth in the post-World War II era. Maintaining that growth is crucial to ensuring long-run food security. But a growing body of evidence suggests that growth has slowed dramatically (e.g. Ball et al. 2018). Australia is an important example. Popular explanations include the emergence of severe

climate conditions. And particular emphasis is given to the *Millennium Droughts*. Drought conditions between 2003 and 2011 were estimated to decrease agricultural output by 30 percent (ABARES 2017). The concomitant Millennium Droughts and Australian productivity slowdown define a natural experiment to examine the interaction between climatic factors and agricultural productivity performance. To exploit that experiment, we decompose measured productivity growth into its component parts and analyze how those components changed with the Millennium Droughts. We extend traditional "nonstochastic" productivity accounting methods to a stochastic setting by incorporating climate variates into the accounting.

Applying these methods to Australian broadacre performance for 1979-2013, we find that the observed Millennium-Droughts period productivity slowdown is not statistically associated with a slowdown in average rate of technological change. Instead, it appears traceable to induced differences in patterns of technological diffusion, which appear particularly concentrated in some production regions.

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An efficiency analysis of small maize farms: A case of South Punjab region in Pakistan

Muhammad Omer Chaudhry* and Abdul Rehman Muhammad

Agriculture sector plays a very important role in the economy of Pakistan where majority of people are dependent on agriculture sector for their livelihood directly or indirectly. Agriculture sector accounts for almost 20% share in the GDP of Pakistan. Even though Pakistan is basically an agrarian economy but still the agriculture sector in Pakistan is lagging behind the other sectors of the economy. The main aim of this paper is to analyze the efficiency of the small scale Maize farmers in Lodhran district of Punjab province of Pakistan. This study employs two-stage Data Envelopment Analysis where in first stage the efficiency of 150 small scale Maize farmers is estimated. The major inputs are the fertilizer costs, irrigation cost, machinery cost, labor cost etc. while the output is the total yield per acre. In the second stage the efficiency scores are regressed with exogenous variables like experience of the farmer, education of the farmer, availability of technical assistance and loan, distance from the market etc. The results indicate that there is almost 37% mean inefficiency in the farmers. Whereas, the result of the second stage truncated regression analysis show that experience, education and the availability of loans have positive impact on the efficiency. This study concludes that the public investment in the technical education and assistance is helpful in increasing the efficiency of the small scale farmers.

Directional slack-based decomposition of profit performance: An application in Chinese banks

Xiang Chen*, Tsu-Tan Fu and Emili Grifell-Tatjé

The profit creations in different DMUs are difficult to compare due to the size variation, this study extends the profit indices of Ball et al. (2010, 2015) into the framework of the profit change model introduced by Grifell-Tatje and Lovell (1999; 2015, P256-262) to develop a new profit decomposition model and investigate its sources. Also, addressing the case the profit change may result from the input and (or) output sides, we introduce the directional slack-based distance function (Fare and Grosskopf, 2010a, 2010b) to investigate the effects in the cost and revenue sides when decomposing the productivity effect. For an empirical illustration, this study applies the proposed methodology and uses 43 Chinese banks over 2010-2014 to empirically measure and compare the profit performance and its decomposed components.

Nonparametric analysis of multiproduct pricing behaviour
Laurens Cherchye, Thomas Demuynck, Bram De Rock, Catherine Fuss and Marijn Verschelde*

We propose a nonparametric identification strategy of product-firm-year specific markups and productivity. Our methodology deals in a natural way with the simultaneity issue between input choice and unobserved productivity. Further, we allow for economies of scope and impose no parametric structure on the multiproduct production function. We show that our methodology has empirical bite using data of Belgian multiproduct manufacturing firms since over the period 1996-2014. We study the evolution of societal welfare reducing price-setting behavior by focusing on the evolution of firm-product-year pairs with both high markups and low productivity (i.e., our proxy for the absence of innovation pursuits).

Efficiency of manufacturers in a developing country
Chau Chu*

This paper investigates the impact of a firm's characteristics and business environment on its efficiency for an unbalanced panel of over 4,800 micro, small- and medium-sized manufacturers in Vietnam. A true fixed-effect stochastic frontier approach is employed to control for unobserved heterogeneity that can easily be identified in general stochastic frontier models. Our results reveal that (1) informal household businesses are less efficient than firms in other types of ownership in formal sector; (2) mature yet small firms are generally more efficient than younger and larger firms; (3) high competition is less conducive to efficiency than moderate and low competition. Interestingly, we find that such effects vary when taking a further look at low- and high-industry firms. For those in low industries, mature firms are less efficient than younger counterparts; these low-industry firms also have stronger negative effect of high competition on their efficiency.

Assessing the performance of Spanish banks: An application of conditional efficiency measures with unobserved heterogeneity
Jose Manuel Cordero*, Carlos Díaz-Caro and Nickolaos Tzeremes

The paper applies some of the latest advances of probabilistic approach accounting directly for unobserved heterogeneity in the estimation of efficiencies (Simar et al. 2016, J. Econometrics) for a sample of 33 Spanish banks over the period 2005-2015. Specifically, we apply a time-dependent conditional model accounting directly for unobserved factors that might affect the performance of banks on delivering services to their customers. In our approach we define a model where latent heterogeneity can play a role in fixing the level of the outputs (loans and securities). This can happen when the level of the output is linked to the size of the banks, but there exists a non-observable factor that may also influence the volume of outputs. This could be related to the profile of the customers of each particular bank or the competitive environment in which the bank is operating which are both very difficult to quantify. Our results suggest that unobserved factors play a relevant role on banks´ performance. The results signify that this phenomenon has been more emphatic towards the core of the economic and financial crisis period.

Efficiency assessment of schools operating in heterogeneous contexts: A robust nonparametric analysis using PISA 2015
Jose Manuel Cordero, Cristina Polo* and Rosa Simancas

The participation of the majority of nations in international large-scale comparative studies in education has provided researchers with rich and extensive cross-national databases that can be used to assess the performance and effectiveness of different educational systems. The present study proposes an international comparison of education production efficiency using cross-country data on secondary schools from different countries participating in PISA 2015. Given that countries might differ significantly with regard to multiple institutional features as well as the education system structure, we need to account for those heterogeneous conditions under which they are operating when estimating the efficiency measures of school performance. In this way, each school

can be benchmarked with other units from different countries with a similar operational environment. For this purpose, we use a robust nonparametric approach that allows us to "clean" the effect of contextual factors previously to the estimation of efficiency measures. Since this approach needs smoothing in the conditional variables in the middle of the sample and not at the frontier (where the number of units is smaller), it seems to be a better option than other nonparametric alternatives previously developed in the literature. Likewise, by using this novel approach, we will also be able to explore how those contextual factors affect both the attainable production set and the distribution of the efficiencies.

Environmental efficiency of wheat production in Poland: A parametric hyperbolic distance function approach

Tomasz Gerard Czekaj*, Tomasz Żyłowski and Stelios Rozakis

Agriculture contributes substantially to global greenhouse gases (GHG) emissions and, therefore, to global warming and climate change. Improvement of the resource use efficiency contributes to the mitigation of GHG emissions in agricultural production. We investigate the environmental technical efficiency of farms in Poland to help both policy makers to shape the relevant policy measures and conscious practitioners (farmers) to adjust their management practices. We use a subset of data on commercial family farms drawn from the Polish Farm Accountancy Data Network supplemented with survey information on management practices at the crop level. This unique data set allows us to focus on a single - one of the most important - branch of production in Poland, i.e. wheat production. Thus, we are able to calculate GHG emissions from wheat production in carbon dioxide equivalent (CO2e), which we then use as an undesirable output in our model. In order to properly account for both desirable and undesirable outputs (wheat production and GHG emissions) we model the production process using an enhanced hyperbolic distance function of the translog functional form which we estimate using maximum likelihood estimation approach to stochastic frontier analysis (SFA). We investigate the potential and cost of GHG emissions reduction calculating its shadow price (opportunity cost of foregone crop production).

According to our estimation results, the shadow price of GHG emissions in winter wheat production to be around 121 PLN (28 EUR) per tonne of CO2e. Furthermore, analysed farms could enhance their productivity of winter wheat by improving environmental technical efficiency. An average farm could increase the yield of winter wheat by about 1 tonne per ha and reduce GHG emission by about 0.5 tonne of CO2e per ha.

European bank loan loss provisioning cost efficiency and bank innovations

Aristeidis Dadoukis*

This paper presents an analysis of Loan Loss Provisioning (LLP) of European banks across 26-member states to determine how Technological Change (TC) has affected bank risk management. Technological improvements in banking have seen advances in both back and front office operations with respect to lending. This is created through increased disembodied TC capturing improvements in both non-financial and risk management technologies. In a three-stage approach, we examine the impact of technological advances on LLP, coming from external factors, including changes in regulation, and internal to the bank innovations in risk management. In the first stage we estimate TC using a Stochastic Frontier cost function with endogenous risk and in the second stage, we obtain indicators of exogenous and endogenous to the bank TC. Finally, in the last stage and using a dynamic panel data LLP model, we find that exogenously driven TC has contributed towards prudent LLP practices in European banks. Coefficients estimates from a recursive regression show that the impact of the exogenous TC has had a positive impact on LLP in the later years of the sample, which includes the post-crisis period. Contrary to the exogenously driven TC, endogenous to the bank innovations did not have an impact on the allowance for bad loans. Finally, our findings suggest that EU banks employed cost skimping practices in relation to their lending and monitoring practices, leading to higher losses on loans (through increased LLPs), primarily after the recent financial crisis.

Marginal abatement cost of CO2 in China: Application of convex quantile regression
Sheng Dai*, Timo Kuosmanen and Xun Zhou

Shadow prices and marginal abatement costs of bad outputs are critically important for cost efficient environmental policy and management. The Chinese government applies emission trading scheme (ETS) for carbon dioxide (CO2) emissions regulation in order to achieve the emission target with minimum costs. Although emission permits are already traded in some limited capacity, the trading scheme will extend to cover more industries and regions in the near future. To anticipate the regional impacts of expanding ETS scheme, it is interesting and relevant to evaluate the marginal abatement cost (MAC) of CO2 using historical data. In this paper we estimate the MAC of CO2 using a panel data of Chinese provinces in years 1997-2015. The MAC estimates are compared with the market price of CO2 in order to analyze the expected effects of expanding emission trading. Based on the MAC estimates, a cost-efficient allocation of permits is calculated. We also discuss how extension of trading and limiting permits would affect prices of permits and optimal allocation across provinces.

Polluting-input-based production technologies and efficiency in French dairy farming: A latent class stochastic frontier with class dependency pattern
K. Hervé Dakpo*, Laure Latruffe and Luis Orea Sanchez*

Our article contributes to the efficiency literature by proposing a novel approach to address the issue of environmental impacts of agriculture in assessing its efficiency. The approach that we propose is based on the modelling of 'environmental-friendliness' through production technological heterogeneity. The idea arises from the observation that most environmental impacts from agriculture are nonpoint sources, meaning that they are diffuse and hence prohibitive to monitor. Following the principle of materials balance which is grounded on the laws of thermodynamics (Ayres and Kneese, 1969), a straightforward strategy to reduce environmental impacts from agriculture is to reduce the levels of inputs that generate these impacts. To this aim, we posit that the degree of environmental-friendliness of a farmer can be reflected in: the intensity of his/her use of environmentally-detrimental inputs (fertilizers, pesticides, energy, veterinary products, concentrated feed, outsourced mechanization), the farm grazing pressure and permanent area management, and the farm enrolment in agri-environmental policy schemes. Methodologically, we follow Orea and Kumbhakar (2004) and use the latent class stochastic frontier model (LCSFM). This technique helps to build classes of farmers depending on their degree of environmental-friendliness. We then calculate farmer's efficiency in their own class. The major methodological contribution of our article is to assume that it is costly for farmers to switch class, and if they do, this requires some adjustment costs that may impede their efficiency. We propose a strategy based on the consideration of previous years' prior probabilities to evaluate those costs while measuring efficiency.

Jevons vs. Borlaug – Is efficiency a driver or damper of area expansion of oil palm production?
Bernhard Dalheimer* and Bernhard Brümmer

Smallholder farmers are responsible for more than 40% of oil palm production in Indonesia. Intergovernmental institutions as well as government policy have advocated that increased smallholders productivity and efficiency is key to slow down deforestation. However, it is questionable if this Borlaugian effect manifests itself or whether instead, improved efficiency and productivity much more act as a driver of area expansion, considering higher marginal products of inputs. Using a standard SFA approach, the technical input specific efficiencies as well as productivity growth are estimated on the basis of a short panel consisting of 230 smallholders and 2 points in time. Addressing the endogeneity issue, the estimates subsequently are juxtaposed to land expansion data collected from a third wave. Preliminary results indicate that land efficient producers tend to expand their operations, also into areas of high ecological value more than less land efficient farmers. While smallholder efficiency remains desirable with regard to improved rural livelihoods, environmental policy should account for Jevon's type effects.

Testing restrictions in nonparametric frontier models: New insights
Cinzia Daraio*, Léopold Simar* and Paul W. Wilson*

Simar and Wilson (2001, Communications in Statistics: Simulation and Computation) and Schubert and Simar (2011, JPA) considered the problem of testing restrictions on the structure of the frontier in non-parametric, deterministic frontier models. Several test statistics were proposed, and bootstrap methods were suggested for implementing hypothesis tests. This paper extends the earlier work by exploiting the recent theoretical work of Kneip, Simar and Wilson (2015, Econometric Theory; hereafter KSW15) to provide tests with theoretical justification relying on the central limit theorems for FDH and DEA estimators developed by KSW15. We derive asymptotic distributions of statistics for testing a number of hypotheses about the shape of the frontier. Our approach is along the lines of that used in Kneip, Simar and Wilson (2016, JBES) and Daraio, Simar and Wilson (2018, Econometric Journal). In addition to providing information regarding the shape of the frontier, our tests are useful for deciding whether dimension-reduction along the lines suggested by Daraio and Simar (2007, Adv. Robust and Nonpar. Methods in Eff. Analysis) and analyzed by Wilson (2018, EJOR) should be used to reduce estimation error. We provide Monte Carlo results giving evidence on the performance of our tests in terms of both size and power.

Productivity dynamics in French woodworking industries
Enrico De Monte* and Anne-Laure Levet

We analyse productivity dynamics in French woodworking industries by the application of the Dynamic Olley-Pakes Productivity Decomposition (DOPD) (Melitz and Polanec, 2015). For this purpose we combine the firm-level data sets FICUS (1994-2007) and FARE (2008-2016) to obtain a panel over 23 years. Our study shows that the French woodworking industries have been suffering a significant decrease in the number of active firms over the past years. In fact, in 2016 there were about 30 % less firms active compared to 1994, while total production has increased about 9 %. The estimation of firm-level productivity based on a value-added Cobb-Douglas production function (Wooldridge, 2009), reveals a significant increase in aggregate productivity from 1994 to 2016. Decomposing the productivity growth our results show that survivors and especially exiting firms contribute positively, while entering firms turn out to have a negative impact. Our production function specification also allows to separately identify firms' endogenous technological progress from an autonomous technological change related to time. We find that while in the aggregate firms increase their endogenous productivity, the autonomous technological change has a negative sign.

A stepwise benchmarking approach to DEA with interval scale data
Akram Dehnokhalaji*, Nasim Nasrabadi, Pekka Korhonen and Jyrki Wallenius

The conventional DEA models assume that all variables are measured on a ratio scale. However, in many applications, we have to deal with interval scale data. We proposed a model for efficiency analysis to incorporate interval scale data in addition to ratio scale data (Dehnokhalaji et al (2010)). Our proposed model provides efficiency scores for each unit, but does not suggest target unit(s) for inefficient ones directly.

We investigate the concept of benchmarking in our proposed model. We propose an algorithm which results in a path of targets for each inefficient unit. All units on this path are better than the unit under evaluation in terms of efficiency scores defined for interval scale data. The intermediate targets belong to sequential layers obtained from a layering algorithm and the final unit on the path is an efficient unit. A numerical example illustrates our proposed stepwise target setting algorithm.

Skilled biased technical change and misallocation: A unified framework
Massimo Del Gatto*, Michele Battisti and Christopher Parmeter

We develop a unified framework of skill biased technical change (SBTC) and misallocation. By relying on the assumption of perfectly competitive labor markets, the standard approach to SBTC estimation conflates `true' SBTC and possible labor market distortions preventing firms from

choosing the efficient skilled to unskilled labor ratio. To overcome this limit, we take advantage of recent developments in nonparametric estimation methods (i.e., generalized kernel regression) to develop a novel methodology to decompose the variation in the marginal rate of technical substitution (MRTS) into a SBTC component and a factor accumulation (FA) component by estimating the marginal productivity of inputs (at the country-sector level) directly from aggregate international data. By contrasting the estimated SBTC with the observed ratio of skilled to unskilled wages, we are able to obtain country-sector-time specific measures of 'relative misallocation', arguably associated to frictions/distortions affecting skilled and unskilled labor markets asymmetrically. Using WIOD data, we find a 3% yearly growth rate for the MRTS between skilled and unskilled labor and show that the change is mostly driven by SBTC, rather than FA. We then show that the evolution of MRTS does not follow that of the wage ratio, thus yielding substantial heterogeneity in terms of (increasing or decreasing) relative misallocation path.

Factor-analysis-based directional distance function: The case of New Zealand hospitals
Zhongqi Deng, Nan Jiang* and Ruizhi Pang

This paper develops a new factor-analysis-based (FAB) approach for choosing the optimal direction in a directional distance function (DDF) analysis. It has the combined merits of factor analysis and slacks-based measure (SBM) and incorporates the relative ease with which various input-output could be adjusted. This development relieves the dependency of price information that is normally unavailable in the provision of public goods. This new FAB-DDF model has been applied on a dataset containing all public hospitals in New Zealand (NZ) observed during 2011-2017. The empirical results indicate that the average reduction across different labor is in the range of 3-10 percent, and the corresponding figure for capital input is 25.7 percent. The case-adjusted inpatient-discharge and price-adjusted outpatient-visit are used as measures of desirable output, the average efficiencies are 92.7 percent and 99 percent respectively. Hospital readmission within 28 days of discharge is used as a measure for undesirable output, and the average efficiency score is 90 percent. This evidence supports the suspicion that perverse incentives might exist under the National Health Targets abolished in 2018, which was a set of six indicators used in the last decade to evaluate the performance of local District Health Boards.

Estimation of technical efficiency of Irish public hospitals using monthly panel data
Niall Devitt*, Marta Zieba* and Declan Dineen

The escalation of 'record' numbers of patients being treated on trolley beds has become a long-established trend in the Irish public hospital system. Moreover, the elderly population in Ireland continues to accelerate, and this will add further and considerable pressure to a health system which is clearly struggling with current demand, whilst also imposing a higher financial burden on future generations. With these issues in mind, the aim of this study is to measure the input-oriented technical efficiency of Irish public hospitals using a unique monthly panel data set with multiple outputs and inputs for 49 acute hospitals during the period from July 2017 to June 2018 (565 observations). This novel data set was acquired through public sources as well as directly from the Business Information Unit of the Health Service Executive (HSE) in Ireland. To measure the inefficiency of the hospitals in this study, both parametric panel data SFA and semi-parametric bootstrap DEA techniques are applied. As expected, we find notable differences in the efficiency results depending on the method chosen. The conventional DEA average technical efficiency score for Irish hospitals is 78%, compared to 74% for the bootstrap DEA approach, while the technical efficiency estimate obtained for the Stochastic Frontier Cobb-Douglas input distance function is 96% on average. We also find considerable scale inefficiencies for the Irish public hospitals sector. In addition, the chosen methods account for the simultaneous investigation of potential factors that determine efficiency. These factors include hospital size, the hospital management group and various quality measures as well as environmental indicators.

Impact evaluation in a multi-input multi-output setting: Evidence on the effect of additional resources for schools

Giovanna D'Inverno*, Mike Smet and Kristof De Witte

This paper proposes an innovative approach to evaluate the causal impact of a policy change in a multi-input multi-output setting. It combines varied insights from the econometric impact evaluation techniques and the efficiency analysis. In particular, the current paper accounts for endogeneity issues by introducing a quasi-experimental setting within a conditional multi-input multi-output efficiency framework and decompose the overall efficiency between 'group-specific' efficiency (i.e., reflecting internal managerial inefficiency) and 'program' efficiency (i.e., explaining the impact of the policy intervention on performance). This framework allows the researcher to interpret the efficiency scores in terms of causality. The practical usefulness of the methodology is demonstrated through an application to secondary schools in Flanders, Belgium. By exploiting an exogenous threshold, the paper examines whether additional resources for disadvantaged students impact the efficiency of schools. The empirical results indicate that additional resources do not causally influence efficiency around the threshold.

Banks' efficiency: A National Accounts micro-perspective

Charles-Henri DiMaria*

"The measurement of bank output has long been a difficult and sometimes contentious topic that has yet to see a consensus resolution", such is the introduction of the article written by Inklaar and Wang in 2013. The present paper proposes to replace the measurement of financial services using a macroeconomic approach based on National Accounts (NA) within a microeconomic approach using individual banks. In the micro framework, output is measured as the margin of interest between interest received and the cost of financing (intra-bank borrowing cost). Using data from Luxembourg, it is shown that aggregating the output of individual banks closely follows the NA computations in "normal" times (allowing for negative margins and assuming that cost of refinancing is bank specific). However, during the financial crisis, NA determined output was surprisingly increasing while the micro approach shows a dramatic decrease! Computations made at bank level make it possible to determine which banks were more severely impacted and why. In short, banks sponsors of mutual funds lost money when lending and accepting deposits from their own mutual funds in order to give support to their mutual funds. Additionally, efficiency scores are computed using a slack based data envelopment analysis approach. Results show that inefficiency originates from "traditional" inputs: labour and physical capital, whereas banks are efficient when using financial inputs and producing financial outputs. This result suggests banks should reduce traditional inputs, perhaps replacing them with more outsourcing and artificial intelligence.

How do mergers influence universities efficiency? Empirical evidence from Russia

Aleksei Egorov*, Tommaso Agasisti and Margarita Maximova

Massification of higher education, integration of national higher education systems and struggle for high positions in international rankings force the universities to look for new strategies of the development. Universities' mergers policy is often considered as one of the possible strategies that aimed at responding to mentioned challenges. In this study we explore the mergers policy in Russian higher education system and analyse the influence of this management practice on efficiency of universities. Russian universities were merging for different reasons. This study is focused on one specific type of mergers that took place in 2013-2015 and were based on the results of Monitoring of efficiency – special management tool introduced by the Ministry of education. Using this tool Ministry of education assigned the status of "inefficient university" to those organization that did not meet particular criteria. Organizations with this status were merged with more efficient universities. In order to explore the influence of these mergers on efficiency of universities we employ two-step methodology, where at the first step we estimate the efficiency of universities using bootstrap DEA technique. At the second step we introduce quasi-experimental design and use

differences-in-differences approach where efficiency is a dependent variable in order to make causal inference. Empirical analysis in based on a panel dataset covering the period from 2012 to 2017. During this period 94 Russian universities were reorganized into 42. The results suggest that despite considered mergers were implemented in order to improve efficiency, the effect of mergers on the level of efficiency is not detected.

Measuring the employee productivity in a retail bank – An axiomatic non-parametric approach
Juha Eskelinen* and Markku Kuula

We examined the relationship between employee well-being and productivity of the service professionals at Nordea, a leading Nordic financial services group in a multidisciplinary research project. As a part of this project we developed a model that measures productivity of the front office employees. Inspired by the network approach of DEA we divided the work into two activities: Activity 1 converts the working time to customer interactions and Activity 2 converts the customer interactions to sales of various financial services. The overall productivity evaluation is based on the performance in these two activities. As Activity 2 is a single input -multiple outputs case we used the axiomatic estimation of the production function and applied the convex non-parametric least squares (CNLS) regression.

We used data from the bank's Human Resource and Sales Performance Management Systems and estimated the productivity of 537 employees in three different job roles. The employee productivity indicators were combined with employee survey data. The results confirmed a significant positive link between employee well-being at work and productivity. The employee productivity measurement developed in the project can be applied not only in banking but also in customer services and sales work in other industries.

Axiomatic justifications for the equal-weighted averaging of indexes with respect to different references
Rolf Färe*

We discuss axiomatic justifications for the equal-weighted averaging of indexes with respect to different references. First, we start with the justification found in the recent article of Diewert and Fox (2017), who proposed what is the first time a theoretical justification for the geometric average form of the Bjurek productivity index (also known as Hicks-Moorsteen productivity index). Then we provide another justification based on alternative and natural axioms/properties imposed on the indexes and using functional equations to arrive to a unique solution—equally weighted geometric mean. We focus on the Malmquist input quantity indexes, a component of the Hicks-Moorsteen-Bjurek index. Then, we move to indicators and provide the analogues of these two alternative justifications for the equally-weighted arithmetic averaging for the Luenberger indicators with respect to two different references, introduced in Chambers (2002).

Estimation and application of Lerner type indexes for the public sector
Rolf Färe, Shawna Grosskopf*, Kathy Hayes, William Weber and Heike Wetzel*

The public sector is frequently characterized as inefficient due to lack of competition and regulatory constraints, often accompanied by difficult to measure multiple outputs and lack of associated output prices. On the supply side, frontier efficiency methods have proved to be useful in addressing these difficulties with estimates of frontier cost functions and input-based technical efficiency estimators.

Here we derive generalized Lerner type indexes. The original index (see Lerner (1934)), was used to identify monopoly power as deviations between scalar price and marginal cost, divided by price. Following Fare, et al (2018), we allow for shadow price estimates of multiple outputs by exploiting duality theory, which are then compared to frontier estimates of marginal cost of those outputs. Huang et al (2018) estimate a single output Lerner index jointly with cost efficiency, which they estimate using stochastic frontier methods and apply to a sample of banking sectors.

We provide an application of our approach to a sample of German public theaters operating in the 1991/92-2005/06 seasons. This data was kindly provided by H. Wetzel, the coauthor of two previous efficiency studies of this sector, see Last and Wetzel (2010, 2011).

Pay for performance in health care: A new best practice tariff-based tool using a log-linear piecewise frontier function and a dual-primal approach for unique solutions
Diogo Ferreira*, Rui Marques and Alexandre Morais Nunes

Health care systems worldwide have faced a problem of resources scarcity that, in turn, should be allocated to the health care providers according to the corresponding population needs. Such an allocation should be as much as effective and efficient as possible to guarantee the sustainability of those systems. One alternative to reach that goal is through (prospective) payments due to the providers for their clinical procedures. The way that such payments are computed is frequently unknown and arguably far from being optimal. For instance, in Portugal, public hospitals are clustered based on criteria related to size, consumed resources, and volume of medical acts, and payments associated with the inpatient services are equal to the smallest unitary cost within each cluster. First, there is no reason to impose a single benchmark for each inefficient hospital. Second, this approach disregards dimensions like quality (and access) and the environment, which are paramount for fair comparisons and benchmarking exercises. This paper proposes an innovative tool to achieve best-practices tariff. This tool merges both quality and financial sustainability concepts, attributing a hospital-specific tariff that can be different from hospital to hospital. That payment results from the combination of costs related to a set of potential benchmarks, keeping quality as high as possible and higher than a user-predefined threshold, and being able to generate considerable cost savings. To obtain those coefficients we propose and detail a log-linear piecewise frontier function as well as a dual-primal approach for unique solutions.

The transient and persistent inefficiency of hedge funds
Gary Ferrier* and Albane Tarnaud

During the 1980s and 1990s hedge fund managers generated outstanding performance, drawing the attention of wealthy investors who were willing to pay high fees for high returns (typically an annual fee of 2% of funds under management and 20% of performance). In light of the performance of hedge funds, investment dollars flooded into hedge funds and many new hedge funds opened. This expansion of the industry reduced both the investment opportunities and the quality of managers available to funds; both factors should have reduced mean returns. Furthermore, the efficient market hypothesis (EMH) argues that it isn't possible for a fund to persistently earn above average returns. The literature is unsettled as to whether hedge funds returns are persistent. For example, Agarwal and Naik (2000) argue that persistence in hedge funds performance exists, while Capocci and Hubner (2004) found limited evidence of persistent performance. In this paper we use the stochastic frontier model of Filippini and Greene (2016) to estimate both the transient and persistent efficiency of hedge funds. If the persistent component of inefficiency is zero, then hedge fund managers do not consistently beat the market. We hypothesize that (1) mean efficiency declined as the industry grew, (2) "star" funds experienced transient efficiency, and (3) no funds were persistently efficient. A large sample of hedge funds over almost twenty years is used to estimate our model and test our hypotheses. Robustness checks include using different measures of hedge fund performance and different subsamples of funds.

Determinants of total factor and labor productivity in the Swiss nursing home industry
Massimo Filippini*, Giuliano Masiero and Michael Santarossa*

Enhancing nursing homes efficiency is a challenging task for health policy makers due to population ageing trends and increasing health care costs. Nursing home productivity has been widely analyzed in the literature but questions remain on the determinants of efficient outcomes. In this study, we derive total factor productivity (TFP) from a single-output translog cost function that accounts for characteristics of the output using firm level data for the universe of Swiss nursing homes (1314

homes on average) for the period 2007-2015. Then, we focus on the determinants of TFP and labor productivity. We find that TFP change follows a decreasing trend between 2007 and 2015, indicating a drop in productivity growth over time. The major factor contributing to this trend is the decreasing productivity of labor, though this is apparently not related to changes in the proportion of skilled versus unskilled nurses. Indeed, this trend is associated to an increase in fixed-term contracts. Preliminary findings from IV regressions provide evidence of the causality of this relationship. The share of fixed-term contracts was instrumented using the financial conditions (cost-cutting pressure) of local governments and their heterogeneous access to (less expensive) foreign workers (location in bordering regions). The drop in labor productivity is coupled with an increasing wage trend, which suggests evidence of Baumol's cost disease in the Swiss nursing home industry.

Leaning to win on the PGA Tour

Harold Fried*, Juan Aparicio, Jesus Pastor and Loren Tauer*

This paper investigates how long it takes a golfer to win for the first time on the Professional Golf Association Tour. There is large variation in the time to first win. Jack Nicklaus won three times in 1962, the first year he played in at least ten tour events. Ben Hogan won the second year on the tour in 1938. Bill Hass was a rookie in 2006 and did not win until 2010. And there are golfers who never win. We use a survival function methodology, where the critical event is achieving the first win. The explanatory variables are power off the tee, putting, approach the green, around the green and the ability to perform under pressure. The ability to perform under pressure (the mental side of the game) is quantified by embedding the individual golfer into a production function framework in which the conventional golfing ability measures are inputs and earnings per event is the output. The efficiency score is a measure of how well a golfer is able to translate golfing ability into earnings. Golfers who are inefficient fail to win the maximum, given their physical ability. We argue that this inefficiency is due to performing poorly under pressure, and we use it as an explanatory variable in the survival function. The data are all golfers whose rookie year was between 2004 and 2015. It turns out that the ability to perform under pressure is an important determinant of years to first win.

Performance evaluation of higher education institutions between Taiwan and China using a stochastic metafrontier approach

Tsu-Tan Fu*

With high funding and rewards to colleges with good academic performance in China recently, the competition between Taiwanese and Chinese higher education institutions in the next 10 years would become strong, which may cause big pressure on student recruitment to Taiwanese colleges. To increase competitiveness of Taiwanese colleges, it is important to measure and compare the efficiency performance of colleges across Taiwan strait and investigate possible determinants behind those performance discrepancies. Owing to the fundamental environmental differences in law, education and politics between Taiwan and China, a metafrontier performance evaluation framework with considering the environmental difference is suggested for a proper assessment. In this research, we adopt a stochastic metafrontier model of Huang et al. (2014) and use the data of colleges across Taiwan strait in 2014-2016 for empirical study. As a result, we can compare the efficiency performance on teaching and research of universities and colleges across Taiwan and China. We also empirically examine the possible determinants which influences the technology gap between colleges in Taiwan and China. Empirical results of this research will be useful for colleges to improve their efficiency and productivity and for education authorities to their policy formation. This research is also a pioneer study in education literature on using metafrontier approaches for cross country college performance evaluation. Therefore, this research will have both academic and practical values.

The effect of weather conditions on port technical efficiency
Lorena Garcia-Alonso, Ticiana Grecco Zanon Moura and David Roibas*

Ports are a critical infrastructure for international trade. With more than 80% of global volume of freight transported by sea, the relevance of ports becomes clear. Maritime transport is also one of the sectors most affected by climatic conditions. However, to our knowledge there have been no studies to date using standard productivity analysis tools to evaluate the effect of weather conditions on ports' productivity.

In this research we analyse the effect of wind and waves on ports' technical efficiency. These two specific factors deserve special attention as they condition ports activity in several respects. Ship operations can be hampered by winds and waves. Winds (and waves to a lesser extent) can also generate difficulties in terminal operations. High wind speed creates handling difficulties in crane operations due to the movement induced in loads, the dispersion of solid bulk cargo as well as potential damage to port infrastructures. Additionally, bad weather may increase demand variability, which generates the necessity for some overcapacity which will be used only during demand peaks, remaining unused during low-demand periods. In an application to Spanish ports, we use a stochastic output distance function approach to assess the impact of winds and waves on the technical efficiency and to evaluate its impact by means of a simulation analysis.

Uruguay's dairy farms efficiency: management or environment?
Federico Garcia-Suarez*

Dairy production has been traditionally dynamic in Uruguay's farming sector. Over the years the dairy systems have shifted from an extensive grass-fed model into more intensive farming combining cultivated pastures and larger amounts of high-quality feed. Milk farming sector have shown improvements on productivity allowing for a production expansion turning the exports of dairy as the main market for national production. This production expansion has exposed the dairy sector to the international markets competition even when there are comparative advantages. Production saw a maximum in 2013 and a decline since 2014 explained on both the extensive and intensive margin. This study uses an unbalanced panel of 82 dairy farms along a maximum of 12 agricultural years (2005/06 to 2016/17) with a total of 853 observations. Using a stochastic frontier, we estimated technical efficiency separating persistent from time-varying efficiency. The dependent variable is total milk production. Four explanatory variables were included: total milking cows, total input expenditure, total land used, and a time trend. Our results show that persistent efficiency is estimated to be 68%, residual efficiency 92%, and overall efficiency 63%. These scores indicate that the persistent inefficiency is explaining most of the inefficiency allowing for improvements based on management practices. Therefore, policies for the dairy sector should focus on structural aspects of production in order to improve long term efficiency.

Combining a Markov process model with the DEA framework. A hybrid model in measuring the efficiency of alternative Markov manpower policies
Andreas Georgiou*, Emmanuel Thanassoulis and Alexandra Papadopoulou

This paper develops a DEA method combined with a Markovian framework to identify an efficient course of action to attain a desirable ending structure. The approach is developed using as a vehicle the Markov stochastic manpower planning system. Alternative recruitment policies are treated as DMUs in a DEA framework where a desirable manpower structure is sought for a hierarchical organisation. We use a directional DEA model within a Benefit of the Doubt formulation to explore the space of specified and potential courses of action that could lead to the desired end manpower structure. The approach can be generalised to other Markovian settings. For example, the efficacy in terms of costs or clinical outcomes of alternative treatment interventions can be explored which affect the transition probabilities to clinical need states in the case of patients suffering from a chronic disease.

Do work placements have an impact on university student's final grades and starting salaries? A novel way of dealing with endogeneity in educational production functions
Dimitris Giraleas*

In the UK, the number of undergraduate students undertaking work placements has decreased from 8.2% in 2002/03 to 5% in 2012/13. This suggests that students believe that work placement does not significantly impact for their final university attainment or the first stages of their career both in the short and long term. This is despite the fact that previous studies have suggested that students who went through work placement are more likely to earn graduate-level job in the first 6 months after graduation, reduce the risk of unemployment, and earn higher starting salary (CBI, 2011; Department for Business, Innovation & Skills, 2012; Mason, Williams, and Cranmer, 2009). The issue with the above studies however is that they did not account for potentially self-selection effects that can significantly inflate the perceived effects of work placement.

This study has two goals. Firstly, to investigate the impact of placement towards final student attainment and graduate starting salary accounting for student characteristics (e.g. prior academic attainment, demographic characteristics, socio-economic background) faculty of study (e.g. Business, Engineering, Health sciences, etc) and the aforementioned self-selection bias that is manifested in the models as endogeneity. The second goal is to propose a novel approach with dealing with these endogeneity issues through the use of stochastic metafrontiers, where the dataset is sub-dived into groups based on the effect under examination (in this case going on work placement) and the strength of the effect is measured by the average distance of each groups' frontier to the metafrontier.

Spatial scale and product mix economies in U.S. Banking with simultaneous spillover regimes
Anthony Glass, Karligash Glass* and Amangeldi Kenjegaliev

The literature on bank scale economies focuses on the familiar type of returns to scale that are internal to the firm. Using a spatial approach we analyze returns to scale that are external to a bank. We set out the methodology to extend the non-spatial analysis of ray-scale economies (RSE), expansion-path scale economies (EPSE) and expansion-path subadditivity (EPSU) in banking to the spatial case. This involves introducing direct, composite and decomposed indirect and total RSE, EPSE and EPSU; where each measure is entirely or partially made up of external (i.e., spillover) economies. Direct, indirect and total measures of scale and product mix economies relate to the cost implications for a firm from a change in: (i) the firm's output levels; (ii) the composite/decomposed spillover effect on the firm's output levels; and (iii) the firm's output levels and the composite spillover effect on these output levels combined. We apply our methodology to U.S. banks for the period 1998-2015 using a spatial cost function that allows a bank to simultaneously belong to a number of spatial networks. Key findings for our sample are, on average, zero composite indirect RSE and constant composite indirect EPSE. This suggests a marked difference between expansion of bank outputs attributable to spillovers along: the radial ray and the non-radial expansion-path.

Performance evaluation model with DEA in public sector: A Turkish university example
Ayhan Gölcükcü*, Oğuzhan Özaltın and Hasan Bal

Each university of higher education is a process that converts inputs to outputs. Financial resources, human resources (academic, administrative and other staff), securities and real estate assets are the components of this process. Students and working ours are the inputs, academic activities and production with educated individuals are output of this process as well. Managing this process is an important task, moreover efficiency and performance measurement of this process is an important issue researched by various field of science like public administration, business administration, education management of social science or science of statistics and mathematics. This is a mosaic and every field of this mosaic has its own method of measurement. Our aim is to bring these initiatives together in a common ground and to measure the performance of the process with DEA. For this purpose same selected key performance indicators of higher education will be used to

evaluate the performance of a Turkish university by a developing a performance evaluation model concerning the fuzzy nature of the data.

Impact of weights limits in the efficiency analysis of the power distribution segment in Brazil

Lorena Santos, Jairo Eduardo Alvares, Rafael Gomes*, Maria Angelica Barbosa, Giulia Medeiros, Luana Lima, Anderson Rodrigo Queiroz and José Wanderley Lima

The power distribution segment has characteristics of natural monopoly. In this context, it is necessary to properly regulate it to guarantee the tripod power supply security; tariff modicity; and universal service. The tariff regulation process is key for providing a higher level of control for the regulator with respect to the utilities. In Brazil, the mechanism adopted for tariff regulation is carried out by the National Electric Regulatory Agency (ANEEL). This Agency is responsible to provide favorable conditions for the electricity market to develop, in a balanced environment amongst agents, for the benefit of society, the design of tariffs that will guarantee good serve quality while recognizing sufficient remuneration to cover the efficient operational costs and the investments necessary to expand the capacity. Utilities behave differently from each other and can be distinguished in terms of costs, quality, market and network size, and other factors that ultimately affect their efficiency. As a result, the process to measure and analyze utilities efficiency and evaluate whether they are using resources in the best way is receiving considerable attention in the literature.

In Brazil, the Data Envelopment Analysis (DEA) technique is employed by ANEEL to define efficiency measure of the distribution companies (DisCos). As the DEA model has different variants, ANEEL, through technical studies, has shown that the power distribution sector has non-decreasing returns of scale (NDRS, based on the conclusion that large companies have similar average costs of small ones. The model has a single input defined by the operational expenditures (OPEX), and as outputs: high voltage, overhead and underground distribution grid, weighted market, number of consumers, customer hour-interrupted (CHI) adjusted and non-technical losses adjusted. The quality variables (CHI and non-technical losses) are considered by ANEEL as negative outputs. It also has decided that the variables' weights, defined by DEA analysis, should be limited to avoid unsuitable weight values. However, these modifications reduce the approach flexibility and the transparency of DEA. The goal of this paper is to evaluate the influence of the weights limits in the efficiencies results and measure the sensibility of DEA method to the Brazilian DisCos. The methodology was developed through the R&D project "DEA and REA methodologies as a KPI of DisCos efficiency" sponsored by CPFL Energia.

Productivity growth in total hip arthroplasty in Sweden – An application of Malmquist productivity index

Fanny Goude*, Göran Garellick, Sverre A.C. Kittelsen, Szilárd Nemes and Clas Rehnberg

There is a pressure on the health care sector to provide total hip arthroplasty (THA) at minimum costs and with good outcomes while maintaining or increasing access. This study aimed to analyze the productivity development over time and to identify the sources of the development in the provision of THA, which could help improving productivity in the future.

The Swedish Hip Arthroplasty Register was used to identify patients who underwent THA at 65 orthopedic departments in Sweden between 2005 and 2012. Additionally, data on these patients' hospital stays was collected from the National Patient Register. To facilitate measurement of productivity development, inputs and outputs in the departments' production function were initially specified. Three outputs were defined; the number of non-cemented, hybrid, and cemented THAs. As a single input, we used the estimated costs of THA and adverse events. The input-oriented Malmquist productivity index was applied to estimate the productivity development.

An average increase in productivity of 1.4% per year was found, where changes in cost efficiency, i.e. the catching up effects of departments, contributed more to the improvement (1.1%) than did technical change (0.2%). These findings give some support to the value of public benchmarking of volumes, procedures and quality indicators across providers.

Evaluating the efficiency of structural funds application in the competitiveness of SMEs across different EU beneficiary regions

Maria Gouveia*, Carla Henriques and Pedro Costa

The funds dedicated to the cohesion policy are aimed at attaining the convergence of wealth levels across the European Union (EU) member states. These constitute the second highest group of expenditures in the EU budget and thus their evaluation has been at the forefront of the EU agenda since their inception. The evaluation of each of them can be carried out by means of different tools and methodologies. For instance, macroeconomic models, which allow assessing the potential impact of EU funds on economic growth without taking into account management issues. Despite their ability to measure the prospective growth effects of different types of investments, they tend to disregard the distribution of EU support within themes and sectors in each country. Another one considers direct econometric estimations. This have the advantage of apprehending the impact of EU aid on economic growth, also addressing both management failures and the possibility of identifying wrong themes of intervention or sectors in each region (or country). However, unobserved or omitted variables might bring, biased estimates of the impacts of Structural Funds. A different possible tool is Data Envelopment Analysis (DEA), which is a quantitative, empirical and non-parametric method to measure the relative efficiency of observations allowing for the consideration of multiple inputs and multiple outputs in global performance evaluation. We extend this line of work by considering the Value-Based DEA, which combines DEA with Multiple Critical Decision Aiding (MCDA), as well as a robustness analysis of the results in the face of uncertain information, taking into account the main factors that may have Influence the efficiency of the Structural Funds, specifically addressing the evaluation of its application to the competitiveness of small and medium-sized enterprises (SMEs) in the different beneficiary regions of the EU. Our analysis helped in the identification of best practices, sources of inefficiency and gaps regarding the benchmarks, thus leading to shape opportunities for improvement.

Stochastic frontier analysis in higher education: A systematic review

Sabine Gralka*

This paper provides a systematic review of the literature that employs stochastic frontier analysis to measure the efficiency of higher education institutions. The overview opens with a look at the general development of the literature, before emphasis is laid on the methodical aspects. Focus is thereby placed on the necessary underlying assumptions and the employed specifications, discussing their advantages and drawbacks. Afterwards, the factors that were specified in the literature, including the input and output variables, as well as the determinants of efficiency, are discussed in detail. Based on the insights of the literature review, the paper highlights some of the existing deficiencies and ways forward. The present study provides the first systematic review on the usage of the stochastic frontier analysis to measure efficiency in the higher education sector.

The impacts of repealing certificate of need regulation on total factor productivity growth, and its components, in U.S. Hospitals

Gerald Granderson*

This paper examines whether repealing certificate of need (CON) regulation effects total factor productivity (TFP) growth, and its components, for U.S. hospitals. Certificate of need regulation (which requires hospitals to get approval from a state government agency, prior to obtaining more capital, expanding existing facilities, building new facilities, and providing additional services) was intended to reduce the growth rate in capital, in order to lower the growth rate in medical costs. Repealing CON regulation, which would allow hospitals to purchase more equipment, may enhance the growth rate in capital, which in turn could lead to a reduction in TFP growth over time (assuming there are no changes in the aggregate growth rates in the other hospital inputs, nor any changes in the growth rates of aggregate outputs).

Second, suppose that more technically advanced equipment, and/or more technically advanced procedures, are developed. Having CON regulation in place could limit either the (i) rate of diffusion of new technology (less technically advanced equipment being used, or (ii) use of new technically advanced procedures. Repealing CON regulation, which would likely allow for greater use of the newly advanced procedures (by allowing for greater provision of services), or greater purchases on newly advanced equipment, could enhance the rate of diffusion of new technology, which in turn repealing CON regulation may contribute to higher rates of technical progress over time, which in turn may contribute to improvements in TFP growth over time.

Third, having CON regulation in place can reduce the ability of hospitals to substitute between capital and non-capital inputs when input prices change. Reducing the ability to substitute between capital and non-capital inputs would likely contribute to a reduction in cost efficiency. Repealing CON regulation can allow for greater ability to substitute between capital and non-capital inputs when input prices change, which could lead to an improvement in cost efficiency over time, which in turn may contribute to improvements in TFP growth over time. Using a panel of U.S. general medical and surgical hospitals, this paper estimates a stochastic cost frontier, then uses information from the cost frontier to estimate both TFP growth and its components (technical change, cost efficiency change, scale economies, residual price effect). The paper then analyzes how repealing CON regulation impacts TFP growth and its components.

Performance evaluation in education under uncertainty: A robust optimisation approach

Adel Hatamimarbini* and Aliasghar Arabmaldar

Analysing and enhancing education system performance is of importance to local authorities and policy makers because education improves the human capital, which, in turn, leads to economic growth. This study draws on the secondary data to assess the education performance using data envelopment analysis (DEA). However, the reliability of the efficiency measures calculated by DEA is jeopardised if the inputs and outputs are erroneous, which is likely to occur through secondary data collected by government agencies. This study attends to uncertainty through the lens of robust optimisation, which fits into a DEA application. We propose a robust enhanced Russell measure model to consider the extent of inherent uncertainty in the light of uncertain characteristics. We also present a case study in education to demonstrate the applicability and efficacy of the proposed models in practice.

Irrigation infrastructure and farm productivity in the Philippines: A stochastic meta-frontier analysis

Daniel Higgins*, Boris Bravo-Ureta and Aslihan Arslan

Irrigation is a lynchpin of rural development strategies and a key input to improving the crop yields and farm income upon which the majority of the world's poor rely. Limited land and growing water scarcity means that establishing systems that maximise the benefits from every drop is pivotal. In this paper, we analyse the impact of a canal irrigation project for smallholder rice farmers in the Philippines, focusing on one of the world's most water intensive crops. In doing so, we generate lessons for future projects, for which the existing empirical evidence is limited. Our analysis involves an unusual combination of impact evaluation and efficiency analysis methods. Using a dataset composed of 1,082 treatment and 1,022 control farm plots, we first apply Propensity Score Matching to discard unsuitable plots, before applying a selectivity-corrected Stochastic Production Frontier, which corrects for biases from both observable and unobservable variables. We then analyse the technical efficiency (TE) and frontier output of plots using a common Stochastic Meta-Frontier. We find that the project had a statistically significant impact on frontier output but not on TE, suggesting that improved irrigation technology increased beneficiaries' production potential, but insufficient training and input access meant that farm management was not improved, highlighting the need for suitable complementary support in future projects. We also find that project impact was shaped by several factors which should be considered in future projects, including gender and education of the household head, geographic location, farm size, and plot location along the irrigation canal.

Transient and persistent rice farming efficiency in Vietnam: A generalized true random effect model approach
Trong Phuc Ho*, Atakelty Hailu and Michael Burton

This paper examines the technical efficiency and its determinants of rice farming in Vietnam by using a recently developed panel data stochastic frontier model, the Generalized True Random Effect (GTRE) model. This model allows both transient (short-term or time-variant) and persistent (long-term or time-invariant) efficiency along with random firm-effects (heterogeneity) and statistical noise to be simultaneously estimated. The GTRE model is compared with three other traditional models, which are nested within it. All the models are estimated using both maximum likelihood and Bayesian methods. The data set is comprised of 986 observations from 376 rice households observed over three seasons of the 2016/2017 cropping year in the Mekong River Delta, the largest rice-intensified area (4.19 million hectares) of Vietnam, via a face-to-face interview method. The estimates indicate that the four-component model (GTRE) is more appropriate than the other models in understanding heterogeneity in production, and inefficiency of rice producers. The mean and dispersion of technical efficiency among rice farmers significantly vary across cropping seasons, rice varieties, and geographical areas. Overall technical efficiency is approximately 75% and transient inefficiency is by far the dominant component. This implies that there is still a room for rice farmers to increase output and that rice farmers will benefit more if policies aim at addressing the short-term issues rather than long-term ones as a priority. We also find that education, gender, and soil type have significant effects on technical efficiency.

A count data stochastic frontier model for panel data
Richard Hofler* and Eduardo Fe

Stochastic frontier (SF) models are central to the identification of inefficiencies in the production (and production costs) of continuously distributed outputs. However, in labor, industrial and health economics outcomes are often measured as counts (for example, number of patients arriving in an emergency room in one hour.) Although these fields of inquiry have not emphasized the idea of inefficiency in the `production' of non-tangible and/or non-pecuniary outcomes, recent contributions by Fé and Hofler suggest that inefficiencies are also present in these domains.

It is well known that panel data give increased precision in estimation. Another advantage of panel data is the possibility of consistent estimation in the presence of unobserved heterogeneity that may be correlated with regressors.

Panel data SF model have been used for many years. However, to the best of our knowledge, there are no count data SF models for panel data. We present an original SF model for count outcomes with panel data.

We discuss parametric estimation of the model and a Monte Carlo study is presented in order to evaluate the merits of the new model. Finally, we use the methods discussed in this paper to estimate a function for the number of hours worked in one week by a sample of teenage girls.

Output attributes and hedonic prices: An analysis of airfares
Charles Howell* and Emili Grifell-Tatjé

The man objective of the paper is to study the effect of product differentiation on price formation in the airline industry. For this purpose, we introduce a Konüs (1939) type index of output attributes as a measure of the level of product differentiation in a market. The definition of the Konüs output attribute index is based on cost functions, which capture the cost differential of providing varying levels of output attributes. We then use the Konüs output attribute index, along with measures of market power, to explore how adding market characteristics to a hedonic price model can improve the usability of results. Under conditions of perfect competition, coefficients on product characteristics approximate the intersection of marginal willingness-to-pay and marginal cost. However, under imperfect competition, the coefficients are understood to be biased and to reflect

price-cost markup over marginal cost. The starting point is the hedonic model from Good, Sickles and Weiher (2008), which we adapt to control for price-cost markup by including a set of market characteristics. Furthermore, the parametric cost function used to generate the Konüs output attribute index can provide estimates of marginal cost that are compared to product characteristic coefficients as a check for model robustness and bias. The model is empirically tested on over 170 million observations of quarterly US domestic airfare data between 2002 and 2016. We begin by estimating the level of differentiation based on attributes such as on-time performance and flight frequency, then use the resulting index to help explain airfare prices.

Environmentally adjusted production efficiency and agricultural nitrous oxide emissions in North Africa

Wei Huang* and Assem Abu Hatab

By treating agricultural nitrous oxide emissions as an undesirable output of agricultural production in a directional distance function, we measured the environmentally adjusted production efficiency (EAPE) of agricultural production in four North African countries (Algeria, Morocco, Tunisia, and Egypt) during the period 1980-2015. After estimating a directional distance function with agricultural nitrous oxide emissions as an undesirable output and an environmentally adjusted technical inefficiency model, we calculated EAPE, derived shadow prices of agricultural nitrous oxide emissions to agricultural value added, and calculated the elasticity of complementary or substitutionary relationships among inputs. The average EAPE was 0.979, with that in Egypt being more diversified and that in Algeria being more homogeneous. Based on the Morishima elasticity of substitution between inputs, there was a significant complementary relationship between agricultural land and labor. The relative shadow price of agricultural nitrous oxide emissions was estimated to be -1.868 at the sample mean, which means the 'cost' of agricultural nitrous oxide emissions exceeds the value of producing one unit of good output. These findings can improve understanding of how economic behavior affects the environment in North Africa.

Effectiveness and efficiency in education: System level estimation for European countries

Audrone Jakaitiene*, Saule Raiziene, Dovile Stumbriene, Jogaila Vaitekaitis and Antanas Zilinskas

The terms of economic efficiency and productivity are gradually being embedded in the daily vocabulary of education policy makers around the world. Quantification of education done right promises higher quality with less recourses. The studies on education efficiency are focused exclusively on primary, secondary or tertiary educational stages. However, this type of assessments only provides partial views about effectiveness and efficiency of education system. For the estimation of efficiency and effectiveness we included the input and output indicators of each education level in the models. As a result, we obtain a more wide-ranging assessment of national educational systems. In the analysis we use publicly available annual data collected for 29 European countries from EUROSTAT and OECD. We apply data envelopment analysis, stochastic frontier analysis and free disposal hull for effectiveness and efficiency estimation. No prior assumptions are made or expert judgements included in the models. We provide cross country analysis with some tendencies identified. The application of empirical models for assessing the effectiveness and efficiency of education systems opens the door to the study of their determinants, and consequently have interesting implications for education policy.

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A novel approach to measure energy systems integration

Tooraj Jamasb, Manuel Llorca* and Ana Rodríguez-Álvarez

Energy systems integration is a recently developed paradigm to describe the holistic vision of a society in which diverse energy sources are utilised along with infrastructures to provide goods and services in a more efficient, sustainable, and equitable way. There is an increasing literature that

outlines this interdisciplinary concept from scientific, engineering, and social scientific perspectives. Despite the theoretical advantages of this energy framework, there is no empirical evidence that shows the degree of integratedness that has already been achieved and the benefits that the deployment of this model has yielded so far. Identifying the degree of integration already accomplished and the outcomes attained in specific regions or countries are essential to recognise benchmarks of best-performance and learn from them. In this paper we develop an innovative approach based on stochastic frontier modelling and the estimation of an output-oriented distance function to measure the degree of energy systems integration. This methodology also allows us to analyse the performance of the countries to increase equity and economic development while reducing environmental impact. We apply the proposed approach to an unbalanced dataset of European countries for 20 years. The preliminary results show that there are different pathways to reach an equitable and cost-effective decarbonisation of the economy. Some policy recommendations are offered at the end of the paper.

Human capital accumulation, output growth and income distribution: DEA-based decomposition
Patrik Jankovič* and Eduard Nežinský

The impact of the accumulation of human capital on economic growth has been intensively elaborated from both, theoretical and empirical point of view. As shown by Galor and Moav (2004), the accumulation of physical and human capital is fundamentally asymmetric. With increasing income inequalities, the question of its implications for the human capital accumulation arises. Newly available structured back-projected dataset on education attainment (Lutz et al., 2007) allows us to analyze the changes in knowledge-intensive labour use in European countries and its association with income inequality measured by Gini index. Modifying the methodology of Färe et al. (2018) we decompose the human capital accumulation into factors capturing technical efficiency, technology change, input mix and output mix encompassing economic performance and income distribution.

Metafrontier Malmquist productivity index and the price of a convexification strategy
Qianying Jin*, Kristiaan Kerstens* and Ignace Van de Woestyne

While the construction of metafrontiers based on the union of underlying group frontiers normally yields a non-convex metaset, a large majority in the literature seems to assume that a convexification strategy leads to a reasonable convex approximation of this non-convex metafrontier. However, Kerstens, O'Donnell and Van de Woestyne (2019) recently deliver new results on the union operator on technologies under a variety of assumptions and empirically illustrate that such a convexification strategy is doubtful. The purpose of this contribution is to verify to which extent such a convexification strategy is tenable when computing the Malmquist productivity index with respect to a metafrontier. This methodology is empirically applied on a secondary data set under a wide variety of assumptions: we explore balanced and unbalanced data as well as constant and variable returns to scale. Anticipating our key results, we do establish a potential bias of the convexification strategy for the metafrontier Malmquist productivity index.

Shape constrained kernel weighted least squares: Extensions and computational issues
Andrew Johnson*, Daisuke Yagi and Hiroshi Morita

We estimate production functions for the following Japanese manufacturing industries which produce highly homogeneous products: sugar, bread, coffee, plywood, cardboard, ready-mixed concrete and concrete products. We use full-time labor headcount as instrumental variable (IV) for the labor input since managers are not able to adjust full-time labors easily in Japan and is highly correlated with the overall labor consumed by the firm. Instead, firms try to adjust the labor input through part-time labors, and thus, we control the endogeneity in the labor input by using full-time labors as IV. The estimation results provide a description of supply-side of Japanese manufacturing industry as we report industry-level aggregated productivity and the most productive scale size. We

find the model specification changes the productivity estimates significantly and may lead to different interpretations and economic insights.

Gender and agricultural productivity: Econometric evidence from Malawi, Tanzania, and Uganda
Jacques Julien* and Boris Bravo-Ureta*

In many sub-Saharan African countries, agricultural productivity gaps between male and female farmers hinder economic and social development. Our hypothesis is that, controlling for differences in observable covariates, male and female farmers are equally productive and efficient. We examine this hypothesis using data from the World Bank Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS–ISA) for Malawi, Tanzania, and Uganda. First, we use propensity score matching (PSM), to define a sample of men and women farmers that possess the same observable characteristics. We then estimate a correlated true random effects (CTRE) Stochastic Production Frontier (SPF) (Greene 2005; Farsi, Filippini and Greene 2005; Abdulai and Tietje 2007), which allows us to control for heterogeneity and unobserved characteristics. Results for Malawi reveal no gap in the average total factor productivity (TFP) between males and females. In contrast, men's average TFP is greater than women's in Tanzania and Uganda. All three countries exhibit land and labor market imperfections for both group of farmers. Moreover, women tend to pay more for hired labor than men do. Results from meta-frontier models reveal that in all three countries TE is somewhat higher for men (4-5 percentage points). Thus, even controlling for observables, men appear to be more productive than women. This difference could stem from more limited access to agricultural extension services by women Thus, policy makers need to give careful consideration to gender equity in access to productivity enhancing programs and to social constraints that might prevent women from benefitting from such programs.

The conditional mode in parametric frontier models
Hyunseok Jung*, William Horrace and Yi Yang

The conditional mode of technical inefficiency has received little attention in the parametric stochastic frontier literature. This paper is a complete taxonomy of the conditional mode estimator, when the inefficiency distribution is from a single parameter family (i.e., half-normal or exponential), and we provide several new theoretical results. First, the conditional mode is calculated for the Laplace-exponential model (Horrace and Parmeter, 2018) and its estimator distribution is derived. Second, the distributions of the conditional mode estimator for both the normal -half normal and the normal-exponential models are derived. Not surprisingly, these distributions are not truncated normal, but we show they are truncated normal in the limit, as the variance of the noise distribution goes to zero. Third, the conditional mode estimator is reinterpreted as a LASSO estimator. It is well known that the LASSO estimator may be viewed as the posterior mode estimator when imposing independent Laplace priors on regression coefficients (Tibshirani, 1996; Park and Casella, 2008). In a similar fashion, an exponential assumption on inefficiency in the stochastic frontier model ensures that the conditional mode estimator possesses the same minimax optimality as the LASSO. That is, the conditional mode, based on an exponential prior, minimizes the worst case estimation error for inefficiency in the stochastic frontier model. This has important implications for estimator performance under misspecification. A simulation exercise and an empirical example are provided.

Pitfalls in estimating the efficiency scores in frontier-based regulation: The case of electricity transmission in Brazil
Sara Kamali*, Mohsen Afsharian, Heinz Ahn and Ana Lopes

In the context of electricity transmission in Brazil, the National Electricity Regulatory Agency (Agência Nacional de Energia Elétrica – ANEEL) regulates the sector by running a revenue cap system. Within this approach, costs of operations are determined to fix the revenue for each transmission system operator (TSO) for a pre-determined regulatory period. This paper investigates the way the efficiency of the TSOs has been estimated in 2018 by ANEEL, using panel data concerning the period 2013–2016. The foundation of ANEEL's approach is built upon a DEA model

which takes into account quality of operations as a non-discretionary variable, includes the panel data of the TSOs, and imposes weights restrictions. We discuss in this paper that these settings result in an inappropriate estimate of the production possibility set, generate questionable efficiency scores and accordingly provide misleading results and managerial conclusions. We also propose an approach which aims at appropriately making use of the data that are already available and overcome shortcomings in estimating the efficiency scores.

Strategic management and technical efficiency in local governments: A stochastic meta-frontier analysis

Joanna Kamiche-Zegarra* and Boris Bravo-Ureta*

The performance of local governments depends on strategic management, which includes setting goals, analyzing scenarios and establishing a roadmap for decision making and resource allocation. Our hypothesis is that the application of strategic management improves the technical efficiency (TE) of local governments.

The aim of this study is to analyze the effectiveness of local governments and the contribution of planning tools to TE based on Stochastic Production Frontier (SPF) methodology. We use a three-round panel dataset (2015 -2017) for 1,832 Peruvian municipalities. Inputs for the production process are number of workers, equipment, access to internet and, our variable of interest, the use of planning instruments. To measure output, we build an index of local services that includes library services provided, quantity of waste collected and park area available, using the Simple Additive Weighting (SAW) method. One shortcoming of previous studies is that TE analysis across local governments has been performed ignoring differences in the size of the population and in prevailing poverty conditions. To address this issue, we use a four-group classification of local governments, developed by the Department of Finance in Peru, that accounts for both population and poverty. We then use a stochastic meta-frontier approach to examine TE.

The literature on how planning tools enhance efficiency is scant. Thus, this paper makes three main contributions: (a) Examines how strategic tools contribute to TE; (b) Builds a global output index; and (c) Uses a meta-frontier framework as a benchmark to compare TE across local government groups.

Estimating informational effectiveness of markets based on the BoD model

Giannis Karagiannis*

Informational effectiveness of markets can be measured from the perspective of either buyers/consumers or sellers and it may involve either price or attributes efficiency. In the framework of price efficiency, quality adjusted prices may be computed using either a weighted sum of attributes as a measure of quality or the individual attributes to estimate a multi-dimension frontier without aggregating attributes into an overall quality measure. The former, initially proposed by Maynes (1975), was widely criticized for being subjective in the choice of weights as it is usually based on expert opinion or consumers surveys. In this paper, we propose the use of radial pure inputs or outputs DEA models for estimating an overall quality measure. In particular, we illustrate that an overall quality measure from the buyers/ consumers' perspective can be obtained by using the BoD model, which is an input-oriented model with a single constant input and attributes treated as outputs, while an overall quality measure form the sellers' perspective can be obtained by using the inverted BoD model, which is an output-oriented model with a single constant output and attributes treated as inputs. Using a buyers/consumers' perspective, we compare and contrast the quality-adjusted (i.e., frontier) prices obtained from the above model with those obtained by the relevant DEA price efficiency models, i.e., an input-oriented model with price as an input and attributes, using data on rental prices for residential housing in the city of Thessaloniki, Greece. These data are collected from classifieds in a local newspaper.

The cost metafrontier is nonconvex in the outputs since the metafrontier is nonconvex: The price of a convexification strategy

Kristiaan Kerstens*, Christopher O'Donnell and Ignace Van de Woestyne

Metatechnology frontiers have become a popular method to account for technological heterogeneity among producers. Though it is conceptually clear that the union of group frontiers normally results in a non-convex metaset, an overwhelming majority of authors seems to assume that a convexification strategy leads to an acceptable convex approximation of this non-convex metafrontier. However, Kerstens, O'Donnell and Van de Woestyne (2019) obtain new results on the union operator on technologies under various assumptions with regard to, e.g., returns to scale and convexity. These authors also empirically illustrate that such a convexification strategy is highly questionable. The purpose of this contribution is to transpose these results on the union operator from technologies to the cost function context: this is new to the literature. Furthermore, we explore to which extent such a convexification strategy –which seems almost unanimously pursued by most authors- is tenable when computing a cost function with respect to a metafrontier. We apply this methodology empirically on a secondary data set under the assumptions of constant and variable returns to scale. Anticipating our key results, we do establish a potential bias of the convexification strategy for the cost metafrontier.

Trade liberalization and firm productivity in the manufacturing sector of Pakistan

Umer Khalid, Mazhar Iqbal and Abid Burki*

In post-1995 era, the transition to trade liberalization has produced rapid changes in the industrial structure of developing countries. We investigate the impact of trade liberalization reforms carried out in Pakistan over the period 1997 – 2010 on firm level productivity in Pakistan's manufacturing sector using three rounds of panel data constructed from Census of Manufacturing Industries for the period 2001 to 2011, combined with macro level data obtained from UNCTAD Trade Analysis Information System database on output and input tariffs at the 3-digit PSIC industry level. Firm level productivity is estimated by adapting semi-parametric methods of Olley and Pakes (1996), which accounts for simultaneity and sample selection bias in production function. Trade liberalization and productivity link is explored by regressing firm level TFP on output and input tariffs by including other controls. Our results show that a reduction in output tariff leads to decline in TFP; these results are robust to different specifications and methods. A 10-percent fall in output tariff (final goods tariff) leads to 0.1 to 0.14 percent reduction in TFP. This finding, in contrast to existing literature, may be attributed to falling sales of domestic firms due to cheaper imports in turn pushing them to operate on higher average costs. Efficient resource allocation may also have suffered due to rigid labor markets. Consistent with earlier literature, reduction in input tariff increases TFP; a 10-percent decline increases TFP by 0.31 percent. For robustness checks, we also employ the stochastic frontier approach, which gives consistent results.

Relationship between credit conditions and efficiency in real sector: Firm-level evidence

Viktor Khanzhyn*

In this paper, I study the change in technical efficiency in US manufacturing firms before and after a number of historic episodes in the United States from 1987 – 2018. A nonparametric DEA analysis was used to estimate technical efficiency and difference-in-difference method was applied to study the effects of credit supply shocks on estimated efficiency in a matched sample of bank-dependent and investment-rated firms. I find evidence in support of the hypothesis that technical efficiency was pro-cyclical in bank-dependent firms relative to firms with access to non-credit financing.

Difference in productivity between water-sewerage integrated systems and separated systems: Evidence from Japan

Tomohiro Kitamura*

Water and sewerage industries are operated by local public companies in Japan. There are companies that operate water only, sewerage only, and both water and sewerage. In Japan, it is said that water-operate companies and sewerage-operate companies will face more difficult financial

situations stemming from reduction in population and increase in cost of aged facilities' renewal. To improve their operational situation, government has promoted vertical integration of water and sewerage systems. The vertical integration means that one local public company operates both water and sewerage systems. In 2016, more than 70% of the companies operate both water and sewerage. If we reveal that operating water and sewerage systems jointly improves the companies' performance, we can give a policy implication of promoting integration of water and sewerage systems.

This study empirically examines whether the productivity of water-sewerage integrated systems is higher than that of separated systems. We compute labor productivity and total factor productivity (TFP) of the companies by adopting the cross-sectional data of Japanese water-operate and sewerage-operate companies in 2016. Then we examine whether there is the difference in the productivity between water-sewerage integrated systems and separated systems.

The empirical results show that the productivity of water-sewerage integrated systems is not significantly higher than that of separated systems. This indicates that increasing the productivity of companies by integration of water and sewerage may be difficult. Hence, other ways such as consolidation of facilities should be promoted to improve performance of water and sewerage companies under the difficult financial situations.

Estimation and Inference for Malmquist productivity indices: The case of non-convex technologies

Alois Kneip, Léopold Simar and Paul W. Wilson*

The Malmquist index gives a measure of productivity in dynamic settings and has been widely applied in empirical work. The index is typically estimated using envelopment estimators, particularly data envelopment analysis (DEA) estimators, and therefore incorporating an assumption of convexity. Kneip, Simar and Wilson (2019, unpublished WP; hereafter KSW) establish properties of a DEA-type estimator of distance to the conical hull of a variable-returns-to-scale production frontier, properties of DEA estimators of Malmquist indices for individual producers, as well properties of geometric means of these estimators, thereby enabling inference about productivity change in dynamic settings. Recent work using the test of convexity versus non-convexity of the production set proposed by KSW (2016, JBES) has rejected convexity in a number of settings. Until now, however, no corresponding results exist to enable inference about productivity change when production sets are not convex. This paper establishes properties of an FDH-type estimator of distance to the conical (but not convex) hull of a possibly non-convex production frontier. In addition, properties of FDH estimators of Malmquist indices for individual producers are derived as well properties of geometric means of these estimators. The latter requires new CLT results, extending the work of KSW (2015, Econometric Theory) and KSW (2019, unpublished WP). Simulation results are provided to give applied researchers an idea of how well inference may work in practice in finite samples.

Measuring bank performance using production trade-offs: A network DEA approach

Stavros Kourtzidis* and Nickolaos Tzeremes

This paper applies the relational network data envelopment analysis model in order to examine the efficiency of the largest banks in USA before, during and in the aftermath of the Global Financial Crisis. The network model preserves the dual role of deposits by treating them as an intermediate variable, thus providing a solution to the deposits' dilemma. Furthermore, we incorporate non-performing loans into to our analysis by modifying the traditional relational network model. We assume that non-performing loans are not by-products of the "good" loans and we apply the trade-off approach (Podinovski, 2004) in order to avoid the unlimited production of the bad outputs. The trade-off approach by using realistic production trade-offs ensures that the traditional concept of efficiency as a realistic improvement factor remains intact. In addition, further use of production trade-offs is examined in order to improve the discrimination of the final model. The results reveal a large dispersion of inefficiency levels among USA banks and confirm the impact of the Global Financial Crisis on their performance.

Stochastic cost frontier for chili production in Thailand
Wirat Krasachat* and Suthathip Yaisawarng

In response to a growing awareness of quality, safety and yield of agricultural production, Thai government initiated the "Good Agricultural Practices" (GAP) program in 2003. This is a voluntary program where farmers may adopt it at will. Despite the government and NGOs' efforts to assist farmers in adopting and handling the GAP technology, the majority of farmers still use conventional method, especially in chili production. This practice, if it continues, could result in higher healthcare cost for farmers and consumers. In addition, it could affect the opportunities for Thai farmers to export chili and raise their standard of living.

This paper investigates whether adopting GAP technology in producing chili indeed raises cost of production, compared to conventional method. Specifically, this paper uses a sample of 100 small farms in Thailand for the 2018 crop year to estimate a translog cost function stochastically. Our model includes four inputs: land, labor, fertilizers and others and one output: fresh chili. We also control for technology whether it is GAP or conventional farming as well as growing season (i.e. rainy vs dry season). This paper hypothesizes that GAP farms, on average, are more cost efficient than conventional farms. In addition, we will conduct an in-depth interview of GAP farmers as well as conventional farmers to identify sources of input savings.

Estimation of a four component semiparametric stochastic production frontier model with endogenous regressors and determinants of inefficiency
Subal Kumbhakar, Kai Sun* and Ragnar Tveteras

This paper proposes a semiparametric stochastic production frontier model where the technology parameters are unknown smooth functions of environmental variables, and inputs are allowed to be endogenous. There are four components in the error term of this stochastic frontier model, where two of them are the noise components including the time-invariant and time-varying noises, and the other two of them are the inefficiency components including the time-invariant (i.e., persistent) and time-varying (i.e., transient) inefficiencies. The transient inefficiency is allowed to be a function of the environmental variables as well. We apply the proposed methodology to the Norwegian salmon production data, and analyze the estimated smooth coefficients (i.e., input elasticities), marginal effects of farm age, and persistent, transient, and overall technical efficiency scores.

Shadow prices and marginal abatement costs: Convex quantile regression approach
Timo Kuosmanen and Xun Zhou*

Shadow pricing environmental bads is critically important for efficient environmental policy and management. However, most empirical studies grossly over-estimate the marginal abatement costs for three reasons. First, assuming downscaling of production as the only abatement option ignores abatement through increasing the input use. Second, estimating shadow prices on the frontier ignores the impact of inefficiency. Third, estimating the frontier by deterministic methods ignores the upward bias due to noise in empirical data. To address these problems, a novel data-driven approach is developed. Instead of projecting inefficient units to the frontier, we estimate the shadow prices locally based on the actual level of performance using convex quantile regression. Compared to the traditional approaches, convex quantile regression is more robust to noise, the choice of the direction vector, and heteroscedasticity. Application to the U.S. electric power plants provides empirical evidence and demonstrates the advantages of the proposed approach.

Seemingly homogenous outputs – Improving the output variables capturing the task of electricity distribution companies
Hilde Marit Kvile*, Tore Langset and Ole-Petter Kordahl

Electricity distribution system operators (DSOs) are natural monopolies, and their revenues are usually regulated. Many regulatory authorities apply benchmarking in their regulation model. Results are used to set the DSOs revenues, and it is important to define outputs that are able to

capture the task of a DSO well. The task is to transport electricity from all points that feed into the grid to meet the demand from all customers; both volume and distance will influence the costs of the company. Commonly used variables are number of customers, length of the grid and energy supplied. Such models will disregard how the combination of distance and volume influence costs, and might lead to biases as seemingly identical grids actually solve different tasks. Also, energy supplied is usually measured in MWh, but it is the maximum demand for power (MW) that decide the dimension of the grid and thus drives the costs. The electricity industry is changing following the climate targets introducing more variable production (solar and wind), more local production, more demand for power (MW) and the electrification of transport. These tendencies increase the need of an output that is able to capture this heterogeneity between companies.

In this paper, we will explore this topic further and discuss how distance and volume can be combined in a power-distance or electricity-distance variable. In Norway, the Regulatory Authority (NVE) has used DEA in their regulation since 1997, and we will use their models to explore this topic further.

The panel stochastic frontier model with endogenous inputs and correlated random components
Hung-Pin Lai* and Subal C. Kumbhakar*

In this paper, we consider the four-component stochastic frontier (4CSF) panel model, where the inputs are endogenous and correlated with the composite error e[it] = tau[i] –eta[i]+v[it]-u[it]. We assume that the correlation of inputs can be with one or more of the inefficiency components (u[it] and eta[i]), or with all four random components in the production function. Furthermore, instead of assuming the four components are independent of one another (as assumed in the original 4CSF model and its recent extensions that accommodate determinants of inefficiency), we allow correlation between the time-invariant and time-varying components, i.e., (tau[i]-eta[i]) and (v[it]-u[it]). This correlation can arise in various ways. For example, the correlation can arise due to dependence between (i) the long- and short-run inefficiency components (eta[i] and u[it]), (ii) firm-effects (tau[i]) with short-run inefficiency (u[it]), (iii) firm-effects and the noise term (v[it]). The correlation between eta[i] and u[it] allows the possibility of a trade-off between the long- and short-run inefficiency. If there are factors that affect them and these factors are correlated, then eta[i] and u[it] will be correlated. Similarly, the correlation between tau[i] and u[it] allows the possibility that firm-effects (say management) can influence short-run inefficiency. We do not dig into the details as to whether the correlation between the time-invariant and time-varying effects comes from (i) or (ii) or (iii) or all. We propose a three-step procedure to estimate the model parameters. In the first step, we use either within or difference transformation to eliminate the time invariant endogenous components. We use the approach proposed by Lewbel (1997) to generate the instruments and obtain unbiased and consistent estimator the parameters in the frontier part, except the intercept. In the second step we use the maximum likelihood procedure to estimate the parameters associated with the distributions of the time-varying random components (v[it] and u[it]). In the third step, we estimate the intercept and the parameters associated with tau[i] and eta[i]. We propose using copula approach to model the dependence between the time-varying and time-invariant components.

Frontier analysis providing a Copernican view to flat-earth economics issues in smart farming
Ludwig Lauwers* and Jef Van Meensel

Nowadays, we are at the eve of massive digitization in agriculture. Rise in data acquisition, governance and combination is expected to lead to smart farming, in which a more efficient and economically optimised production is aimed at. Economically optimizing may, however, be a disappointing exercise because of the flat-earth-economics phenomenon, which shows that deviating from optimum not greatly impacts profit. Flat earth economic is known for decades but frequently ignored, and –to our knowledge- absent in evaluating frontier analysis and using its results for decision making. In particular in precision farming, where marginal but miniscule extra

economic benefits are sought with expensive investments, detecting efficiency pathways is fundamental. On the contrary, technological progress might give more substantially profit gains. The question is thus to distinguish both.

This paper clarifies both phenomena with some cases (rotational livestock or aquaculture production, individual animal monitoring) and examines with both artificial data and real-case data what the potentials and pitfalls of frontier methods may be.

The paper is elaborated as follows. First, some theoretical grounds of flat earth economics and technological progress are discussed in terms of consequences for frontier analysis in practice. Second, we use three, four cases of own published and non-published research to deliver anchor points to discuss potentials and pitfalls of frontier analysis of flat earth phenomena. Finally, discussion will be consolidated into a framework that may allow to position frontier analysis in precision agriculture research and smart farming practice.

A Bayesian estimation of panel stochastic frontier models with determinants of persistent and transient inefficiencies in both location and scale parameters

Ruei-Chi Lee and Sheng-Kai Chang*

By incorporating factors to explain both persistent and transient technical inefficiencies, we estimate the four-random-component stochastic frontier model by means of the Bayesian approach. The impacts of those persistent and transient technical inefficiency factors in terms of both location and scale parameters of inefficiency distributions are considered and marginal effects of the determinants for both persistent and transient technical inefficiencies are computed in the paper. We also apply the proposed Bayesian estimators to study Taiwanese banks over the period 2008 to 2016. It is found that bank capitalization has a positive effect in the short run and total assets have a negative effect in the long run. Moreover, in terms of the Deviance Information Criterion (DIC), it is shown that the model with determinants of inefficiencies in both location and scale parameters performs better than the models with determinants of inefficiencies in only location or scale parameters.

A network data envelopment analysis of the Teaching Excellence Framework evaluation of teaching in universities in England

Boon Lee and Jill Johnes*

The Teaching Excellence Framework (TEF) is an assessment of undergraduate teaching quality across higher education institutions (HEIs) in England, Wales and Scotland. The TEF was introduced by the UK government in order to help prospective students make an informed choice about their university, and also to feed into the government's decision regarding the level of tuition fees that HEIs can charge, although following the publication of the TEF results, the government announced a freeze on tuition fees. Results for those HEIs opting into the assessment (this was voluntary) were first published in June 2017, and HEIs were awarded gold, silver or bronze based on key data and an environment statement. The purpose of this paper is twofold. First, to apply a two-node network data envelopment analysis (NDEA) to data used in the TEF supplemented by some additional variables to establish the efficiency of teaching of universities in England. In the first node, universities are seen to use their staff to student ratio and their expenditure to student ratio to produce four outputs namely the proportion of 'good' graduates, and three student satisfaction responses derived from the National Student Survey. In the second node, the first node output (proportion of 'good' graduates) is treated as an input along with the non-academic staff to student ratio, and these produce graduate employment and highly skilled graduate employment outputs. This NDEA approach will allow insights into where precisely inefficient universities are particularly weak (node 1 or node 2). Second, the factors underlying the efficiency results of node1 and node 2 are investigated using a fractional regression model. This paper provides an early analysis of the TEF exercise and the data underpinning it, and as such will have clear policy implications concerning both the efficacy of the TEF and the efficiency of universities' teaching activities.

The impact of heterogeneous terrorism risks on trade efficiency – Evidence from countries surrounding the China-Pakistan economic corridor

Zhirui Li*

This article examines the impact of dyad-specific terrorism risks on trade efficiency using panel data from countries surrounding the China-Pakistan Economic Corridor (CPEC) over the period 2005-2015. Using the heterogeneous stochastic frontier gravity model (SFGM), while considering the endogeneity of terrorism risks, the causal mechanisms between the heterogeneous terrorist attacks and trade efficiency in the short-term and medium and long-term are analyzed respectively. We find compelling evidence that heterogeneous terrorist attacks will reduce the trade efficiency of two countries in a dyad in the short-term and this conclusion is robust across each sub-dimensional terrorist attack index; in the medium and long-term, heterogeneous terrorist attacks and dyad-specific trade efficiency has a plausible positive correlation from the aspect of statistical distribution. The possible reason may be that while considering the dyad-specific fixed effects, the adverse consequences of terrorism risks on trade efficiency have been absorbed and internalized by the remaining facilitation factors of geopolitics and geo-economics in the trade inefficiency model, which creates illusion that heterogeneous terrorist attacks in the medium and long-term will promote trade efficiency.

Mind the gap: A global Phillips curve and the effects of labor market frictions

Ming Li*, Jaap Bos and Matteo Millone

Price rises and job losses can change lives and often carry considerable social costs. Managing inflation and curbing unemployment are therefore at the heart of many policy makers' recurring agenda. Some countries appear to fair much better than others, achieving the same inflation with much lower levels of unemployment, surviving with the same level of unemployment but much lower levels of inflation, or even `beating' similar countries on both accounts.

In this paper, we benchmark the extent to which countries can minimize inflation and unemployment. In doing so, we build a global best practice frontier (the Phillips curve), that describes optimal combinations of low unemployment and inflation that are deemed feasible given the data at hand. We also account for gaps from this frontier and relate those gaps to labor market frictions, in particular to labor market policies. Our paper contributes to our understanding of inflation and unemployment policy in three ways. First, whereas most studies estimate a Phillips curve for an individual country, and subsequently compare curves across countries, we build a single frontier, but allow for deviations from that frontier. Second, we investigate whether institutional labor market reforms can help close the gap between the best performing, 'frontier' countries and the rest. In addition, we show labor market frictions can not only affect gaps, but also the slope of the Phillips curve. Third, in estimating our best practice frontier, we distinguish between uncertainty and inefficiency, and allow both to vary depending on the mix of inflation and unemployment.

Technical efficiency of the Chinese health care sector: The choice between market-orientation and government-orientation

Sung-Ko Li*, Xinju He and Valentin Zelenyuk

China has been switching back and forth between market-oriented and government-oriented policies in the health care sector. Both government and academics have not reached a consensus in selecting the optimal strategy. This paper investigates the impacts of these two policies on the technical efficiency of the Chinese health-care sector from year 2009 to 2014. We measure the technical efficiency of representative hospitals in several directions with respect to Kuosmanen's (2005) empirical production frontier. For easy comparison, the formulae in the unified framework of Färe et al. (2019) are adopted. To lessen the curse of dimensionality, we follow Daraio and Simar's (2007) suggestion to reduce the dimension of variables. It was found that, on average, the technical efficiency of the Chinese health-care sector was more or less constant over the studied period when desirable outputs are involved. When only undesirable outputs are considered, the technical efficiency has been improving over the studied period. The truncated-regressions with bootstrap

showed that market-oriented ownership reform did not worsen the technical efficiency of the health care sector. In contrast, financial support from the government could always improve the technical efficiency. Considering the low ratio of financial support to the health care sector in current government spending in China, we recommend the Chinese government to allocate more resources to subsidize health care organizations.

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Cost efficiency, economies of scale and determinants of economies of scale: Evidence from regional commercial banking sector in China

Yuzhu Li* and Richard Simper

This study utilizes stochastic meta-frontier technique to investigate cost efficiencies, economies of scale and their determinants in Chinese commercial banks. 136 regional Chinese commercial banks from 2005 to 2015 with 1049 observations are examined in the study. We follow Delta method applied in Badunenko and Kumbhakar (2017) to obtain confidence intervals for returns to scale. Compared to meta-frontier technology, regional banks in the coastal and northeast region exhibit highest level of cost efficiency with constant returns to scale. We also find that regional banks in core financial centres in China will start to have increasing returns to scale once they adopt meta-frontier technology. In terms determinants of economies of scale in Chinese regional banking sector, our results largely support Beccalli et al. (2015)'s findings in European banks. From both fixed effects and GMM estimations on the whole sample, we find that investment banking activities and higher liquidity contribute to economies of scale. However, Chow tests indicates that the determinants of economies of scale differ for banks with increasing returns to scale and banks with decreasing returns to scale. For banks already enjoying economies of scale, banks' profitability from traditional lending activities also determine scale economies while investment banking activities do not seem to have an impact. For banks operating with diseconomies of scale, apart from investment banking activities and profit from lending, returns to scale are also adversely affected by capital level and more so during global financial crisis.

Specialized agricultural services and technical efficiency – Evidence from crop planting in China

Qian Liu* and Wei Huang

Specialized agricultural services are regarded as one of the main division standards of land property rights forms and play an important role in China's agricultural modernization. A lot of research to date focus on the effect of land property rights on agricultural production while there is lack of research examining the relationship between specialized agricultural services and crop planting efficiency for China's crop farmers from an economic perspective. The purpose of this paper is to evaluate the technical efficiency for rice-wheat and maize planting, examine regional variations in terms of different specialized agricultural services under various land property rights forms and determine if specialized agricultural services contribute to increase farm productivity. A multi-output multi-input stochastic frontier production function and technical inefficiency model are applied to estimate the technical efficiency by incorporating specialized agricultural services as an input and a determinant of inefficiency. Variables for whether farmers are provided with services (i.e. market information, technical instruction, purchasing of agricultural products) are used in technical inefficiency model. The estimates are based on a cross sectional data set from a field survey of 724 households implemented in six provinces of China (i.e. Sichuan, Jiangsu, Shandong, Henan, Hebei, Zhejiang) between 2016 and 2017. This study is expected to find evidence of improvement in average efficiency on crop planting by providing specialized agricultural services and enable the

development of optimized land policies in China which suggest to improve specialized agricultural services and develop appropriately scaled agricultural operations of various forms.

Are capital structure, fragility and efficiency drivers of bank market value?
Ana Lozano-Vivas* and Claudia Curi

While regulators focus on book values for scrutinizing financial fragility, the financial crisis has shown that market value are more useful indicator of bank fragility. Calomiris and Nissim (2014) suggest that the fact that the banks after the crisis display franchise value (or market to book value ratio) below one indicates that some of those banks' investments are projected to generate negative economic profits in the future, concluding that attention to market values and their drivers is important for analyzing the vulnerability for banks.

Since bank's capital structures based on the market view are the outcome of pressures emanating from shareholders, debt holders and depositors and franchise value is related with bank efficiency (Demsetz et al., 1996), we investigate in this paper whether bank efficiency and bank capital structure drive bank market value. Additionally, we analyze whether the market value and such drivers affect the fragility of the banks.

We apply recently developed non-parametric methods with bootstrap to estimate group bank efficiency, to test for differences across groups with similar market value and finally to analyze the link between bank market value, bank efficiency and bank capital structure. In addition, using the probability to default (PoD) as proxy of the fragility of the banks by define a unique framework, the impact of the bank market value and its drivers is analyzed. We applied our empirical exercise for the banks belonging to 15 countries of the European Union during the period 2002-2016.

The results suggest that bank market value is explained by bank efficiency and capital structure where the bank leverage plays an important role before the financial crisis. Additionally, bank fragility is affected by bank market value and its drivers. So it seems that regulators should pay attention to market value in place to book value in order to inspect bank stability.

Heterogeneity and near-zero-inefficiency in stochastic frontier models
Kamil Makieła and Błażej Mazur*

Accounting for heterogeneity of inefficiency is an important topic in SFA. Usually it is handled with VED (Koop et al., 1997), or more recently with ZISF-type models (Kumbhakar et al., 2013, Rho & Schmidt, 2015, Tran & Tsionas, 2016). In the latter case the inefficiency distribution has point-mass at zero, reflecting full efficiency. We generalize this model class in two directions. Firstly, we assume that inefficiency distribution is a mixture of two half-GED densities (with restrictions on the "more efficient" regime). Secondly, we assume that the symmetric error term is distributed as generalized t, which allows for heavy tails. The resulting model encompasses existing ZISF specifications offering considerably higher flexibility.

Following previous works we analyze the U.S. banks dataset. We investigate likelihood-based parametric estimation, identification and relevant prior assumptions for Bayesian analysis and conduct simulation experiments to illustrate possible pitfalls of existing ZISF-type approaches. We discuss: whether allowing for heavy tails in the symmetric error component affects probabilities of firms being (nearly) fully efficient; whether there exists empirical support for "near" zero inefficiency; which inefficiency characteristics should dependent upon covariates to account for heterogeneity (the latent regime probability or regime-specific scale/shape parameters). Since the models under consideration deal with subtle distributional features of error terms, statistical information from the data might be weak. Consequently, there is an obvious need for reliable techniques of model comparison and inference pooling methods to deal with model uncertainty (though the latter is very demanding). We discuss trade-offs between different solutions to those issues.

Stochastic frontier analysis with generalized errors: The generalized t–GB2 SF model
Kamil Makieła* and Błażej Mazur

The aim of this study is to formulate and operationalize stochastic frontier models based upon generalized stochastic assumptions. For the symmetric disturbance term we suggest the generalized t distribution (GT), while for the inefficiency term we assume the generalized Beta distribution of the second kind (GB2). The GT distribution might be perceived as a two piece (or folded) form of the restricted GB2 distribution (the restriction is necessary to assure that the density of the symmetric term is symmetric, unimodal and continuous). The setup allows for heavy tails in both terms, and the inefficiency distribution generalizes almost all distributions that are currently in use (e.g., half-normal, half-t, half-GED, gamma). As to the symmetric term the GT form encompasses, e.g., the GED and the Student-t cases. The proposed GT-GB2 model may be seen as too complex and thus impractical to use. However, it is worth noting that it can be estimated and thus operationalized using contemporary methods (we consider Bayesian and non-Bayesian techniques). Crucially, the model encompasses most contemporary SF specifications (some as limiting cases), so it can be perceived as a powerful tool for specification search or model comparison and inference pooling. The model is estimated using reference datasets (Spanish dairy farms and U.S. hospitals). The empirical results support the generalization of distributional assumptions for the symmetric term. We also run simulation-based experiments that illustrate possible issues of weak identification and show performance of simple and approximate model comparison techniques.

Who got it right? Comparing the efficiency of justice across countries: Italy vs. Sweden
Jonas Månsson, Antonio Peyrache and Angelo Zago*

For several years there has being a growing number of studies assessing efficiency in district courts within a country. One of the policy outcomes of these studies is that inefficient courts can learn from efficient courts. However, efficiency is defined in relations to peers within the same country, e.g., Swedish courts are only compared with other Swedish ones. This means that country specific DEA studies can be viewed upon as a national championship – but does best in the country necessary means best in a greater context, e.g., European championship? Our study expands previous research on efficiency in district courts by comparing two countries, Italy and Sweden. What makes this comparison interesting is that the average length of trials in Italian courts is among the highest in the developed world. It is thus not surprising that many see it as a very inefficient judicial system. On the contrary, Sweden justice system is considered quite efficient. In this paper, using a unique set of data based on similarity and relevance of inputs and outputs, we compare efficiency of the Italian and Swedish courts of justice for the period 2011 and 2012. In the paper we undertake a meta-frontier analysis of the two justice systems and divide total inefficiency in within country (managerial) and between country (system) inefficiency. Preliminary results indicate that the main source of inefficiency in Italy relates to within, or managerial, aspects, while a large portion of the inefficiency in Swedish courts are related to between, or system, inefficiency.

Ranking virtual networks accurately using output-oriented multiplicative DEA model with variable return to scale
Francisco Daladier Marques Júnior*, Ali Emrouznejad*, Ana Lúcia Miranda Lopes, Jorge Luiz de Castro E. Silva, Kelvin Lopes Dias and Paulo Roberto Freire Cunha

This paper aims to introduce a method for fractal evaluation and forecasting in layer-3 from TCP/IP stack on virtual networks infrastructures. We gathered information from huge number of virtual network hypervisors which they formed our decision-making units. Thus, we propose an output-oriented multiplicative DEA model, and use DEA efficiency scores as base for ranking the networks. The decision variables are related to both transport protocols such as transmission control protocol (TCP) and the jitter of the user datagram protocol (UDP). The synthetic traffic generator tool used on measurements is the “iperf”. The input variables for comparison of spatiotemporal data for each virtual network are the fractal dimension using the “genton” method from TCP transfer rate, the

fractal dimension employing the “box-count” method from UDP jitter, and the average from UDP jitter. The output variables are the TCP transfer average, the “hurst” parameter from TCP transfer, and the “hurst” parameter from UDP jitter. The results are evidencing that the multiplicative DEA model introduced in this paper provides a better ranking than the standard BCC output-oriented model due to the convexity and proportionality axioms linked to multiplicative formulations.

Assessing the effect of different agricultural subsidies on beef production efficiency in the EU. A stochastic metafrontier approach

Maria Martinez-Cillero*, Fiona Thorne and Michael Wallace

The Common Agricultural Policy reforms since the early 2000s allowed for the implementation of different types of agricultural subsidies, such as direct support in the form of decoupled and coupled payments, or environmental payments. As a result, there are significant differences in agricultural subsidies granted in each Member State. However, there is limited cross-country comparative empirical evidence regarding the effects of the implementation of different levels and types of subsidies on farm efficiency. This analysis contributes to the literature by exploring the effects of different types of payments on technical efficiency of beef farms in Ireland, France and Germany. We implement the stochastic metafrontier approach proposed in Huang et al. (2014) in order to establish consistent cross country comparisons, and also explore the effect of subsidies on each country and on the gap between the metafrontier and the country specific frontiers. Our estimates show differing effects of technical efficiency drivers across countries. Decoupled payments have a positive effect on efficiency in France and Ireland, however the retention of coupled support has a significant negative impact on technical efficiency of French beef farms. This suggests that the maintenance of coupled support might be compromising farm economic performance in the sector. The effect of the share of decoupled payments on total payments on the metafrontier gap is positive, indicating that the level of decoupling contributed positively to cross-country differences of technical efficiency. The heterogeneous effects of subsidies suggest that EU regulations have some effect on the adoption of production resources.

The effect of weather and climate extremes on agriculture: Empirical evidence and methodological issues

Emanuele Massetti*

The talk will start with a review of empirical evidence on the effect of extreme weather and extreme climates on agriculture, using data from the United States and Europe. Methodological challenges to identify the effects of weather and climate will be discussed. In particular, the hypothesis of time-separability of temperature effects, a standard assumption in the literature, will be critically reviewed. Crop yield and Ricardian models will be used to compare the effect of short-term unexpected weather extremes and long-term extreme climate. Finally, the potential of high frequency/high resolution data and machine learning in the literature will be assessed.

Empirical evidence on the transmission of monetary policy through the banking system

Camilla Mastromarco* and Paul W. Wilson

This paper examines empirically the monetary-transmission mechanism by considering the effects of the US Federal Funds Rate (FFR) on bank lending as well as bank performance. Fully nonparametric methods are used to estimate technical, cost, and input allocative efficiencies for US banks over 1986--2016. Recently-developed statistical results are used to test for changes in efficiencies as well as productivity over time, and to test for changes in technology over time. In addition, we test “separability” of the production process with respect to the FFR using the recent work of Dario et al. (2018, Econometric Journal). Initial results suggest a negative relation between bank loans and the FFR, suggesting that banks substitute away from loans and toward securities when the FFR increases. Our work extends previous work by Kashyap and Stein (2000, AER) and Dreschler et al. (2017, QJE) who examined the link between the FFR and loans (as well as deposits in the case of Dreschler et al.) but only in a reduced-form setting without considering the effects on banks' performances.

Revisiting the efficiency-equity trade-off: A multi-objective linear problem combined with an extended Leontief input output model
Bernhard Mahlberg and Mikuláš Luptáčik*

In recent years there has been increasing interest in the question of how inequality affects economic growth. This growing interest has recently stimulated new theoretical as well as empirical research. Some existing theoretical models propose income inequality is detrimental to growth, but alternative theoretical models point at inequality as a determinant furthering economic growth. The main goal of this paper is to obtain deeper insights into the so-called efficiency-equity trade-off. Recently the Stiglitz-Report (Stiglitz et al., 2010) revealed several limits of GDP as an indicator of economic performance and social progress and recommended to shift emphasis towards measuring people's well-being. Following this recommendation, we develop a new multiple criteria decision making model coupled with an extended Leontief input-output model taking into account the social dimension and obtain deeper insights into the so-called efficiency-equity trade-off.

Efficiency aggregation in stochastic frontier analysis with hierarchical data
Yashree Mehta* and Bernhard Bruemmer

Data regarding agricultural production often bear a built-in hierarchical structure. Ownership of multiple plots by a farmer is one such case. Technical efficiency, in this case, can be defined at the plot level as well as the farmer level. When there is more than one level of observation at which technical efficiency can be estimated, the process of its aggregation from a micro unit of analysis to a higher, aggregate level, poses a topic for a methodological debate. We use production data with a hierarchical structure, of maize farmers in Kenya and estimate farmer technical efficiency separately from two model specifications: (i) Linear Mixed Model with a farmer random intercept, (ii) plot-level stochastic frontier model with a cross-sectional treatment. In the latter case, we arrive at farmer-level efficiency estimates by computing four averages from plot efficiency scores: Arithmetic and Geometric Means as well as their weighted variants, wherein, the weight is the quantity of production of the concerned plots belonging to the same farmer. Thus, we arrive at two efficiency scores estimated from the two models for each farmer. We compare them using Spearman's rank correlation coefficient and find that the weight erodes comparability. Geometric aggregation yields closer estimates in terms of ranking. In order to verify whether the observed patterns are an incidental characteristic of the data or there lies a methodological conclusion, we now resort to simulation.

Dealing with imperfect compliance in frontier evaluation: A probabilistic efficiency model approach
Anna Mergoni*, Giovanna D'Inverno* and Kristof De Witte

The objective of this research is to study the effect of a policy intervention on schools' efficiency when there is imperfect compliance. Specifically, we investigate the impact of additional funding assigned to schools with a high share of disadvantaged students, exploiting a database containing information on students and schools exposed to the 'Equal Educational Opportunities program' proposed by the Flemish Ministry of Education, starting from 2002.

The paper contributes to the emerging line of research related to causal inference in efficiency frontier analysis, in the context of quasi-experiment. In this framework the efficiency estimation can be undermined by two issues, namely endogeneity and imperfect compliance. These issues can be controlled by integrating policy evaluation tools with efficiency analysis techniques. Specifically, we adapt the idea behind the fuzzy RDD in frontier estimation framework by exploiting the probability of being treated. As suggested by the fuzzy RDD literature endogeneity and imperfect compliance can be controlled by focusing on schools around the cutoff of the forcing variable (that in our case is the 'share of disadvantaged students' and the level is 10%), weighting them for their probability of being treated.

A dynamic stochastic frontier approach with unobserved heterogeneity, persistent and transient inefficiency

Jean Joseph Minviel and Timo Sipiläinen*

Recent advances in Stochastic Frontier Analysis (SFA) devote a special attention to dynamic efficiency analysis (Serra et al., 2011; Minviel and Sipiläinen, 2018) and the separation of firm heterogeneity, persistent and transient efficiency (Colombi et al., 2014; Kumbhakar et al., 2015; Filippini and Greene 2016). These two advances have been developed separately but we believe that their potentials can be integrated in a more general framework. As such, the aim of the present paper is to introduce a dynamic stochastic frontier Analysis (SFA) framework with unobserved heterogeneity, persistent and transient inefficiency effects.

The empirical application is based on a sample of 1,132 French mixed farms over 20 years. The estimates provide useful insights for the estimation of technical efficiencies as well as for the analysis of the effects of contextual drivers (such as public subsidies or indebtedness) on technical efficiency. The estimated efficiency scores indicate that the average transient technical efficiency (0.94) is higher than the average persistent one (0.88), implying greater potential for production improvement by eliminating structural causes of technical inefficiency rather than focusing on the transient factors. This is an important finding because transient factors may be unpredictable events like extreme weather conditions or pest outbreaks, which are beyond the farmers' control. The average overall technical efficiency score found in the present study (0.83) is higher than the corresponding score (0.77) found in Minviel and Sipiläinen (2018) who estimated a dynamic SFA using the same dataset but without separating unobserved heterogeneity effects from inefficiency. This suggests that a part of technical inefficiency in Minviel and Sipiläinen (2018) can be attached to unobserved heterogeneity. As regard contextual drivers, we find that public subsidies are positively associated with farm's persistent technical inefficiency. This suggests that public subsidies encourage sluggish adjustments of production factors, low restructuring of farms' production activities, or lagged technology adoptions (Matthews, 2013; Minviel and Sipiläinen, 2018)

A semiparametric smooth coefficient approach to estimate effects of farmers risk attitudes on productivity: Analysis of rice production in India

Ashok K. Mishra, Subal C. Kumbhakar and Gudbrand Lien*

In this article we estimate effects of farmers risk attitude on productivity, within a production function framework using a semiparametric smooth coefficient (SPSC) model. The attractiveness of this model specification is to analyze effects of risk attitude on productivity with minimum distributional assumptions. We use farm-level cross-sectional data (2015) from 1000 Basmati rice farmers in India. Output in the production function is gross revenue and inputs are land area, labor (man-years), and other costs. As a proxy for risk attitude (Z-variable in the model) we use farmers willingness to take risk (WTTR) based on their own responses on a 10-point scale, with 1 representing completely unwilling and 10 representing completely willing. The study shows that WTTR has a direct negative effect (on average) on productivity/gross revenue. The indirect effect (on average) of WTTR on gross revenue is negative for land, positive for labor, and negative for other cost (material). In other words, a highly risk averse farmer, compared to a less risk averse farmer, will use more labor and less land and material. The marginal effect (on average) of WTTR on productivity is negative. However, the results show a high degree of heterogeneity across the farmers.

Sustainability and energy efficiency in Indian manufacturing

Kankana Mukherjee*

India's rapid growth since liberalization has been primarily propelled by the service sector, with the manufacturing sector remaining relatively stagnant at about 15% - 17% of GDP. Future growth plans for the economy heavily relies on rapid growth of the manufacturing sector. However, a major crisis that the economy faces is significant energy shortage. Continued rapid growth of the economy

cannot be sustained without commensurate increase in the supply of energy. Given the supply constraints and heavy dependence on imports for energy, a sustainable growth path for the manufacturing sector depends on achieving efficiency in energy use. This paper examines the energy intensive industries in India over the period 2008-09 through 2015-16 and utilizes Data Envelopment Analysis to study sustainability and energy efficiency in Indian manufacturing. The roles of technical efficiency of production, capacity utilization, adoption of energy efficient technology and other factors in determining energy efficiency and a sustainable growth path for these industries are analyzed.

Modeling emission-generating technologies: Reconciliation of axiomatic and by-production approaches

Sushama Murty, Robert Russell*

We study the link between two recent approaches to modeling emission-generating technologies: the by-production approach and the axiomatic approach. The by-production approach models these technologies as intersections of two independent sub-technologies reflecting, respectively, the relations between goods in intended-output production designed by human engineers and the emission-generating mechanism of nature governed by material-balance considerations. The axiomatic approach proposes a set of axioms that a pollution-generating technology should satisfy. We show that the by-production technology satisfies these axioms and that, conversely, any technology satisfying the axioms can be decomposed into two sub-technologies satisfying the by-production properties. In either approach, the technology can be functionally represented by two radial distance functions with well-defined properties. These distance functions can also serve as measures of technological and environmental efficiency. We exploit the link between the by-production and axiomatic approaches to offer preliminary suggestions about suitable functional forms for the empirical estimation of the two distance functions.

Estimating parameter uncertainty in the StoNED model

Ørjan Mydland*, Jonas Andersson and Endre Bjørndal*

In this paper we present, and investigate the performance of estimators for parameter uncertainty in the Stochastic semi-Nonparametric Envelopment of Data (StoNED) model. The model, introduced by Kuosmanen and Kortelainen (2012), is a semi-parametric alternative to the parametric Stochastic Frontier Analysis (SFA) and the nonparametric Data Envelopment Analysis (DEA) for production- and efficiency analysis. We study the performance of the bootstrap for making inference on the estimation of parameters, marginal costs, in the cost function of the StoNED model. The estimators, based on different versions of the bootstrap, are investigated by means of a Monte Carlo Study. Finally, we apply the method to a dataset from the Finnish power distribution market and illustrate the importance of measuring the uncertainty in the estimates.

Including determinants of allocative and technical inefficiency in a stochastic frontier analysis framework

Ørjan Mydland*, Subal Kumbhakar, Andrew Musau and Gudbrand Lien

Within productivity and efficiency analysis on electricity distribution firms, there have lately been developed methods to distinguish between allocative and technical inefficiency, and furthermore distinguish between transient and persistent technical inefficiency. Kumbhakar et al. (2019) use data from the Norwegian electricity distribution industry to estimate both the persistent and transient components of technical inefficiency and input misallocation of Norwegian electricity distribution firms, also including determinants of persistent and transient technical inefficiency. In a regulatory context, it is interesting to identify the costs of inefficiency that arise from input misallocation, and not only from the technical inefficiency. By extending the method used in Kumbhakar et al, we can include determinants for both allocative and technical inefficiency to seek a deeper knowledge on what are the sources of the costs that arise from different measures of inefficiency. Our analysis

provides methods and insights to the industry and policy makers on how to improve productivity and efficiency in the electricity distribution industry.

Searching for the optimal territorial structure: The case of Spanish provincial councils
Isabel Narbón-Perpiñá*, María Teresa Balaguer-Coll, Diego Prior and Emili Tortosa-Ausina

Modern states are organized in multi-level governance structures with economic and political authorities dispersed across them. However, although the consensus is relatively high when evaluating this form of organization versus a centralized authority, it is lower regarding the jurisdictional design—i.e., how to shed authority from central states to both supranational and subnational levels.

This lack of consensus also exists in contexts with explicit initiatives to strengthen their political ties such as the European Union (EU), and even within EU member countries. The lack of consensus is aggravated with the relative scarcity of contributions that measure the advantages and disadvantages of different territorial organizations. We deal with these issues focusing on the case of a EU country, Spain, whose provincial councils ("diputaciones") are often under debate and controversy due to their contribution to increase public spending while simultaneously being (according to some) sources of inefficiencies, corruption and lack of transparency. Specifically, we evaluate how they impact on local governments' performance combining a variety of activity analysis techniques. Results suggest that, in general, the existence of a provincial council has a positive impact on local governments' performance, but when their activity levels are too high the effect can be even pernicious.

Impact of automation on labour use: Decomposition approach
Eduard Nežinský* and Mikuláš Luptáčik

Automation has recently been in the focus of theoretical and empirical research. Empirical studies on the firm level show positive effect on productivity. Besides that, automation is considered a driver of wage and income inequalities as well as of changes in labour market. On the country level, we concentrate on determining effect of automation on labour use in European countries. Utilizing number of robots as input in the production process and adopting the decomposition technique from Färe et al. (2018) we decompose two periods' performance to present the labour use ratio as a product of four terms attributable to changes in efficiency, technology, input mix as well as the output. As DEA models allow for multiple inputs and outputs, the methodology can be extended to technologies encompassing other aspects of welfare or input use such as ecological damage and income inequalities or digitalization.

Will the real weather/climate specification please stand up?
Eric Njuki*

We investigate how weather shocks and climate shifts are transmitted to agricultural productivity growth in the United States. Importantly, we explore various methodological approaches as well as weather/climate specifications. Using state-level, county-level as well as farm-level data, we find that these weather/climate specifications are highly dependent on the agricultural sector and region under study. Finally, we construct a total factor productivity index that isolates the weather/climate effects.

Estimating the effects of weather and climate change on agricultural productivity
Christopher O'Donnell*

Measures of productivity are measures of output quantity divided by measures of input quantity. Explaining changes in productivity involves explaining how output and input quantities are determined. I consider a model in which (a) agricultural input choices are partly driven by expectations concerning weather variables, and (b) agricultural outputs are largely determined by input choices and realizations of weather variables. I go on to explain how models of this type can be used to estimate the effects of weather and climate change on agricultural productivity.

Technology, efficiency, and productivity: Evidence from U.S. local governments
Caitlin O'Loughlin* and Paul W. Wilson

This paper examines the performance of U.S. municipal governments prior to, during, and following the financial crisis from 1997 – 2012. Technical efficiencies of cities, both over time and by U.S. Census Region, are estimated via fully nonparametric methods utilizing newly-developed statistical results. The results strongly suggest non-convexity of the local governments' production set, calling into question the results of previous studies. Furthermore, the results suggest that in some cases mean efficiency of governments declined during the financial crisis and have yet to return to their pre-crisis levels.

Regularity conditions for full dimensional efficient facets in DEA
Ole Bent Olesen* and Niels Christian Petersen

Facet extensions of the empirical Production Possibility Set in a Constant or a Varying Returns to Scale technology have attracted some attention in Data Envelopment Analysis, because the associated piecewise linear production frontier by construction does not include weakly efficient segments. The identification of strongly efficient facets is facilitated by the incorporation of a regularity condition with the aim of characterizing any face passing through the origin and with $(m+s-1)$ strongly efficient observed DMUs positioned on it as a strongly efficient facet of maximal dimension $(m+s-1)$ in a Constant Returns to Scale technology in an input-output space of dimension $(m+s)$. A similar regularity condition is incorporated for the Varying Returns to Scale technology with the aim to characterize any face with $(m+s)$ strongly efficient DMUs positioned on it is a strongly efficient facet.

The regularity conditions are stated as necessary conditions in the literature. We show that the imposed conditions are not sufficient, because facets of maximal dimension defined by subsets of strongly efficient DMUs that fulfil the relevant regularity condition may not be strongly efficient. New regularity conditions that allow for the characterization of any face spanned by $(m+s-1)/(m+s)$ strongly efficient DMUs in a CRS/VRS technology as a strongly efficient facet are suggested. Binary tests for the fulfilment of the new conditions are developed.

A two-level top-down decomposition of aggregate productivity growth: The role of infrastructure
Luis Orea*, Inmaculada Álvarez and Luis Serven

In this paper, we provide evidence as to the effects of infrastructure provision on aggregate productivity using industry level data for a set of developed and developing countries. A distinctive feature of our empirical strategy is that it allows the measurement of intra and inter-industry resource reallocations which are directly attributable to the infrastructure provision. In order to achieve this, we propose a two-level top-down decomposition of labor aggregate productivity that extends the decomposition introduced by Diewert (2015) using a time-continuous setting. We illustrate our decomposition using the industry level data of a set of developed and developing countries over the 1995-2010 period. As expected, aggregate productivity growth is mainly explained by improvements in industry-specific productivities. We find that the infrastructures that have promoted within industry productivity the most are the investment in road and telecommunication networks. The latter network has also promoted a better allocation of resources among firms operating in the same industries. Although the inter-industry labor reallocation effects are mainly attributed to other factors, the effect of access to electricity is remarkable. We finally find that the output price effect is practically zero. We show theoretically that we should always expect this result using sectoral-level data.

A stochastic frontier hedonic model of a price-setting firm facing uncertain demand
Alecos Papadopoulos*

We apply stochastic frontier analysis (SFA) to the case of a price-setting firm. We show that the profit-maximizing price is a frontier and that deviations from it reveal the existence and measure the

effects of other parallel goals of the firm like a minimum revenue target or a customer-base target. We then consider discrete-choice demand in a hedonic and willingness-to-pay framework, using SFA modeling to allow for consumer heterogeneity. We bring the two sides of the market together creating an indirect Two-tier Stochastic Frontier model (2TSF), and we obtain the determination of the product price as an implicit relation of product characteristics appearing twice in the equation, once carrying their hedonic value and a second time reflecting their contribution to marginal cost. These can be separately estimated. To account for inherent regressor endogeneity, we augment the statistical specification by a Copula.

The model estimates jointly a host of important aspects of business activity: the firm's beliefs related to the consumers willingness-to-pay for its products allocated to the product's main characteristics, a decomposition of marginal cost into the same product characteristics (and the comparison between the two per characteristic), the value that the firm assigns to its brand, but also the degree to which the firm deviates from profit-maximizing price-setting.

We use a single-firm sample of advertised prices from the personal computer market, to showcase the empirical workings of the model.

Do farm advisory services affect total factor productivity growth?
Iordanis Parikoglou*

The dairy sector is a prominent industry in Ireland, pillar to the Irish agriculture and possess a competitive performance in EU market (DAFM 2015). The dairy sector in EU has experienced a gradual switch towards to a more liberalized market over the last years. In 2015, the abolition of the EU milk production quotas in 2015 has forced dairy farmers to operate in a more liberalised market, allowing farms to expand their production and increase competition for market share.

Productivity differences can indicate competitiveness in both domestic and international levels (Newman and Matthews 2006). In this light, innovation can play an important role in TFP growth. Innovation at the farm level depends on the interaction between different actors as farmers, advisors, researchers, educational systems, etc, referred as Agricultural Innovation System (AIS) (Klerkx et al. 2012; Lamprinopoulou et al. 2014). In this study, we measure the Total Factor Productivity (TFP) growth at the Irish dairy farm level between 2008 and 2017, accounting for the role of Farm Advisory Services (FAS).

We expect a priori that farmers who participate in FAS will have higher technical change. However they might face higher adjustment costs and as a result their efficiency might decline, or increase with slower rate. Unobserved technological heterogeneity is common in agriculture and in order to account for it, we use a Random Coefficient Model (Kalirajan and Obwona 1994; Tsionas 2002), estimated in a Bayesian framework. Our data are taken from the National Farm Survey (NFS) for Irish dairy farms. We expect that our results could provide also useful policy implications.

Some *skewed* results on the stochastic frontier model
Christopher Parmeter* and Alecos Papadopoulos

The distributional specifications for the composite regression error term most often used in Stochastic Frontier Analysis (SFA) are inherently constrained as regards their skewness coefficient. This provides a simple diagnostic tool and model selection/rejection criterion for empirical studies which appears to have been overlooked by practitioners. We derive a general expression for the skewness of the composed error term in SFA models based on the ratio of standard deviations of the two components as well as theoretical ranges for the most popular empirical specifications. We also generalize existing test of skewness to test for skewness of a given level, essentially allowing one to develop a semi parametric test of correct distributional form. Simulation results are presented to detail the small-sample effects as well as to speak towards the practical relevance of this diagnostic tool, the testing device, and the consequences of misspecification.

The local circularity test and a new local Hicks neutrality condition
Jesus T. Pastor* and Knox Lovell*

The Malmquist productivity index does not satisfy the desirable circularity property unless restrictions are imposed on the structure of technology and how it changes through time (a form of Hicks neutrality), or restrictions are imposed on the underlying data beyond the standard non-negativity requirement. Working in a DEA framework, we restrict the data domain to the original finite sample of data and show that satisfaction of Hicks neutrality locally is not inconsistent with failure of Hicks neutrality globally. It follows that the Malmquist productivity index can satisfy the circularity property locally without satisfying it globally.

The values change management cycle: Ethical efficiency
Dinah Payne*, Rajni Soharu and Pamela Kennett-Hensel

Efficient change is necessary for businesses to succeed; it is particularly relevant in this world of rapidly changing geographic or business environments, characterized by dynamic innovation. With increasing globalization and deregulation, the rapidity with which technological innovation occurs, a growing knowledge workforce and shifting social and demographic trends, it is arguable that management's most important function is effective organizational change (Graetz, 2000; By, 2005). A burning question, then, for business and academic leaders is how to effect positive, efficient change. Leaders can steward effective change that will serve the organization and our society well. We argue that the most necessary element, beyond business acumen or skill, for change management success is ethical leadership. "(L)eadership and change go hand in hand. … (there is a) positive relationship between value alignment, leadership behavior, employee commitment and goal achievement (Burnes and By, 2012: 239-240).

While much has been written on the subjects of leadership and of ethics, there is limited research on the issue of ethical leadership in the efficiency of change management (Burnes and By, 2012; Kennett-Hensel and Payne, 2018). We build on Burnes and By's 2012 work on this issue. Our ethical leadership cycle integrates additional elements to the process than those offered by Burnes and By: we argue that folding these ethical elements into a cyclical process, into the organization's culture and the leader's own style, will make a positive difference in the efficient and effective management of change.

The optimal size of firms with fixed equity: Microeconomic theory and an application to Danish family farms
Michael Friis Pedersen and Arne Henningsen*

We theoretically and empirically investigate the optimal size of firms without access to equity markets by examining relationship between the firm's capital structure, its marginal cost of debt, and its profit-maximising scale of operation. If all markets work perfectly, the profit-maximizing firm size coincides with a most productive scale size (MPSS). However, in real life, many markets are far from working perfectly. For instance, many owner-operated firms do not have access to equity markets so that a change of the firm size requires interactions with the credit market and, thus, implies changes of the capital structure, e.g., the debt-to-assets ratio (D/A). Based on an unbalanced panel data set for the years 2008 to 2015 that includes accounting data of 6,162 Danish farms that usually cannot access equity markets, we show that a firm's marginal cost of debt depends on its capital structure (D/A). Hence, without access to the equity market, the wealth of the firm owner determines the firm's equity and, thus, affects the shadow price of the capital input. This further implies that the profit-maximising size of the firm depends on the owner's wealth. While the firm owners' wealth and the firms' equity has been largely overlooked in the literature on firm sizes and firm structure, our study shows that this must be taken into account when analysing firm sizes and firm structure in the agricultural sector or other sectors with many firms without access to equity markets.

Using a Choquet integral-based approach for incorporating decision-maker's preference judgements in a data envelopment analysis model

Miguel Pereira*, José Figueira and Rui Marques

In a world in permanent (r)evolution that revolves around money, seeking new ways to contain costs, better allocate resources, and, overall, improve performance is a constant across all fields. Hence, the use of computational methods based on operational research and statistical science is crucial for achieving an appropriate combination of efficiency and effectiveness, especially in domains where the decision-making process is a complex task. This is where Data Envelopment Analysis (DEA) comes in. However, as a non-parametric and, usually, purely objective technique, DEA makes up for what it lacks in incorporating preference information with flexibility and adaptability, which is particularly important in areas where the decision-makers' judgements are crucial. This work proposes a cutting-edge and original approach to fill in this knowledge gap by linking DEA and multiple criteria decision-making with an additive DEA model that takes into account criteria interactivity, by using an inference methodology to determine their weights, and decision-makers' preference information incorporation, by taking advantage of the Choquet multiple criteria preference aggregation model. Thus, this approach was applied to a case study of performance assessment of Portuguese National Healthcare Service secondary healthcare providers across robustness-testing perspectives, generating credible weights stemmed from the decision-maker's judgements and yielding acceptable and valid results.

Variable selection in data envelopment analysis

Antonio Peyrache*, Christiern Rose and Gabriela Sicilia

The selection of inputs and outputs in data envelopment analysis (DEA) is regarded as an important step, that is normally conducted before the DEA model is implemented. In this paper, we introduce cardinality constraints directly into the DEA program in order to select the relevant inputs and outputs automatically, without any previous statistical analysis, heuristic decision making or expert judgement (though our method is not incompatible with these other approaches and indeed may help to choose among them). The selection of variables is obtained solving a mixed integer linear program (MILP) which specifies the maximal number of variables to be used. The computational time of the program is fast in all practical situations (with a sample size of 5,000 and around 100 variables to choose from, it solves in less than 10 seconds). We explore the performance of the method via Monte Carlo simulations. Some empirical applications are considered in order to illustrate the usefulness of the method.

Productivity and firm sizes: Evidence from Vietnam

Hien Pham, Nhan Phan* and Shino Takayama

Using Vietnamese firm-level data, we estimate each firm's production efficiency, technological heterogeneity and its relationship to firm size distribution. Recently, there has been growing interest in the relationship between firm size distribution and productivity in developed countries. Our paper is one of the first attempts to look at the same issue in a developing country. Our results demonstrate that middle-sized firms' production efficiencies tend to be lower than those of other-sized firms and that efficiencies are more diverse for middle-sized firms. We also find that there is a significant difference in technologies where this difference varies substantially across size groups. We adopt three different methodologies to ensure the robustness of our results. Finally, we provide a theoretical model to show that when a firm faces a higher variation of its productivity term, it is more unlikely that a firm decides to expand in size. Our analysis provides new insights into the relationship between productivity, technology and firms' size distribution.

Estimating the impacts of soil on the climate sensitivity of European agricultural productivity
Simone Pieralli*

The aim of this study is to estimate the climate sensitivity of European agricultural productivity and to decompose the effects of inputs, climate, soil moisture, and technological change on European agricultural productivity. On one hand, we consider the impacts of changing weather rhythms on agricultural productivity. We consider the time exposure of the crops to different ranges of temperatures, in a certain growing season of the year, either during the night or during the day. On the other hand, we consider the active role of soil in mitigating the effects of climate change on agricultural productivity. We use an unbalanced panel data set of French field crop farmers from the European Commission Farm Accountancy Data Network (FADN), observed between 1990 and 2015, matched with a set of core climatic variables from the European Joint Research Centre AGRI4CAST Dataset and soil data from French GISSOL database. Exploiting the translation property of a directional output distance function from the methodology in Guarda et al. (2013) one can obtain an econometrically estimable form. One can then easily decompose the changes in productivity due to soil, climate inputs, time, and other inputs into different portions, through Luenberger-type indicators. We obtain the effects by estimating econometrically the differences in the production technology. Potential endogeneity of farm inputs due to weather is avoided through a generalized method of moments panel model estimator.

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The economics of escaped farmed salmon
Ruth Pincinato*, Frank Asche and Kristin Roll

Escapees are together with sea lice the most important environmental issue challenging the sustainability of salmon farming. Escapees and other forms of mortality is costly to a farmer, and the farmer would prefer to avoid them. However, the cost of prevention tends to increase as the problem is reduced, and the farmer may find that it is too costly to reduce the problems to zero or negligible levels, thereby creating a negative externality. Applying the theory of bad outputs to model the economics of escapees, this paper investigates the economic effects of escapees in the Norwegian salmon production. A multi-product cost function with escaped salmon as the bad output and farmed salmon as the good output provides the opportunity to examine how escapes affect the costs directly, through shadow values, and indirectly, through multi–output characteristic of the escapes in terms of jointness and separability. Results indicate escapes neither affect the production cost directly or indirectly. Farmers do not have cost related incentives to reduce escaping. This suggests that regulations are the main tools for further improvement if society wants to reduce the externality below the levels that the farmers would do voluntarily.

The measurement of transient and persistent technical efficiency of Polish crop farms
Andrzej Pisulewski* and Jerzy Marzec

Accounting for heterogeneity in the measurement of farm efficiency is crucial to avoid biases related to climate and soil quality diversity in a given area. Therefore, this paper investigates the level of technical efficiency (TE) of Polish crop farms based on several stochastic frontier panel data models with different approaches to the measurement of unobserved heterogeneity, short- and long- run inefficiency. In our study, we show that ignoring farm heterogeneity can lead to underestimation of the level of TE compared to conventional stochastic frontier panel data models. Moreover, we have found empirically that not accounting for heterogeneity in the Generalized True Random Effects model may lead to incorrect estimates of persistent TE. The obtained results for Polish crop farms indicate that the level of transient TE (0.81) is lower than the level of persistent TE (0.88).

Returns to scale in polyhedral production technologies: Theory and examples
Victor Podinovski*

Almost all convex production technologies developed in DEA are polyhedral sets, i.e., polyhedral technologies. Examples include the standard VRS and CRS technologies, their extensions by weight restrictions or production trade-offs, technologies with multiple components processes, technologies with bounded input and output measures and many network technologies. One of common questions regarding polyhedral technologies is the returns-to-scale (RTS) characterisation of their frontier units and related issues of scale efficiency. Based on recent developments in this area, we discuss a universal approach to the determination of RTS in any polyhedral technology, which removes the need to develop a bespoke method for each new technology. We provide several examples illustrating the application of the described approach.

The complementary effect of organizational practices and workers' type of education
Filippo Pusterla*

This paper investigates complementarities between organizational practices and workers' type of education in affecting firms' productivity. Using Swiss firm-level panel data covering the period 1996-2015, I estimate complementarities among workers' type of education and a large set of organizational practices which are aggregated to three domains: decentralization, incentive pay, and work design---where work design comprehends job rotation, teamwork, and hierarchical layers. I consider workers with four types of education: no post-compulsory education, upper secondary vocational education and training, tertiary professional education, and tertiary academic education. The results indicate that the complementarity between the extent of firms' decentralization and education is similar for workers with no post-compulsory education and workers with an upper secondary vocational education and training, while complementarity is higher for tertiary educated workers. In contrast, the estimations reveal no complementarity between incentive pay schemes and higher level of workers' education. Finally, the results indicate complementarity between work design and tertiary educated workers, both professional and academic ones.

Evaluating agricultural productivity and policy in Russia
Nicholas Rada*, William Liefert and Olga Liefert

Russia’s transition to a market economy in the early 1990s shocked its agricultural sector, creating potential for profit and gains from specialization and productivity improvements. However, subsequent regional agricultural development has been highly uneven, and sources of the sector’s productivity improvement remain murky. Drawing on a newly-assembled Russian regional farm production and policy dataset, we evaluate agricultural total factor productivity growth from 1994 to 2013, decomposing that growth into technical progress and efficiency gains, for the nation as a whole and for the major agricultural districts of the South and Central. We then test how investments in road and rail infrastructure, human capital, and innovation have influenced those gains. The South substantially outperformed the Central district and the nation at large with respect to all three performance indicators. Market-oriented investment and management and technology transfer, such as that brought by new operators, may well explain much of the quick rebound and growth there. However, as the South’s TFP gap narrows, additional productivity gains will be increasingly challenging to achieve lacking a long-term stream of innovations from the agricultural research system to expand producers’ production possibilities. The implication is to expect slowing TFP growth in the South as more regions huddle on the technological frontier, and gains plateau as modern agribusiness practices become more widely adopted. Potential gains could come in the Central district, from some of the same types of improvement that appear to have propelled the South.

Exploring the relationship between VEA and types of weight restrictions
Panagiotis Ravanos* and Giannis Karagiannis

In this paper we explore the relationship between various types of weight restricted Data Envelopment Analysis (DEA) models and Value Efficiency Analysis (VEA). VEA is a modification of DEA which restricts the range of acceptable weights for decision making units so as to maintain a given set of (one or more) efficient units, the Most Preferred Solutions (MPS), on the frontier. More specifically, we show that: (a) the CRS Assurance Region II (Production Trade-Offs) cone-ratio variant with general linked-cone constraints between input and output multipliers is equivalent to the VEA model as long as the coefficient matrices of the former attached to output and input multipliers contain the outputs (respectively negated outputs) and the negated inputs (respectively negated inputs) of the MPS DMUs of the VEA model, (b) the special case (K-cone) predilection-cone ratio DEA variant which extends all common (but not necessarily full dimensional) facets of a set of model DMUs is equivalent to a VEA model if the model DMUs in the former coincide with the MPS DMUs in the latter, (c) VEA is the upper limit of a cone ratio DEA variant which extends all common and full dimensional facets of a set of model DMUs if the latter coincide with the MPS DMUs in VEA and (d) VEA is the lower limit of a cone ratio DEA variant which extends all (not necessarily common or full dimensional) facets of a set of model DMUs if the latter coincide with the MPS DMUs in VEA.

German distribution grids in the context of the Energiewende – New evidence from efficiency analysis
Julia Rechlitz, Astrid Cullmann and Maria Nieswand*

The increasing share of renewable energy represents a challenge for distribution system operators (DSOs). Affected DSOs need to invest in order to adapt their electricity networks to secure grid stability. To better understand to what extent renewable energies affect the cost efficiency of DSOs, we estimate a cost frontier of German DSOs, which have faced the challenge of integrating renewable energies during the last decades.

Since the level of renewable energies differs between German DSOs, it is necessary to control for this exogenous variation. We estimate a cost frontier using a semi-parametric smooth coefficient model that allows us to control for the level of renewables in the firm-specific gird in a flexible manner. The coefficients of the frontier are estimated as non-parametric functions of the share of renewables and can provide new insights into the changes in the cost structure of affected DSOs. Also, the firm-specific efficiency scores depend on this exogenous variable. The empirical approach builds upon a comprehensive panel data set of publicly owned German DSOs covering the years 2006 to 2013.

The results will shed light on the development of the efficiency levels of German DSOs, controlling for the share of renewable electricity in their grids. The variation of the slope coefficients of the cost frontier will lead to further insights on how the firms' cost structure affected by the Energiewende.

Technical efficiency of coffee production in the Colombian Coffee Cultural Landscape: The role of payments for environmental services
Orlando Rodriguez*, Maria Vrachioli* and Johannes Sauer

The coffee price in the world market started to decrease in 1990s due to the increasing coffee production from post-communist economies (Ponte, 2000). That crisis led to land use change in Colombia with coffee producers moving to alternative activities without planning. Land use change put a particular pressure on the environmental sustainability. To protect coffee regions, UNESCO (2011) included the Colombian Coffee Cultural Landscape in the World Heritage List in 2011. The government in collaboration with private firms and NGOs have supported coffee producers by payments for environmental services (GEF, 2014). This study explores the extent to which payments for environmental services across the border of the World Heritage at the Colombian Coffee Cultural Landscape can affect coffee producers' technical efficiency. Technical efficiency scores are estimated

using the Stochastic Frontier Analysis framework (Coelli & Fleming, 2004; Wollni & Brümmer, 2012; Lackner et al., 2011). The study focuses on how the highest possible amount of output (a combination of revenue from coffee production and amount of payments for environmental services) can be achieved from a set of inputs following the multi-output approach that has been proposed by Sauer, Walsh & Zilberman (2012). The survey data used in this study allows us to compare 403 coffee producers around the Andes covering the cropping year 2017-2018. Also, the location of each coffee farm recorded by GPS coordinates is used to study whether being inside or outside of the World Heritage borders can be associated with receiving higher or lower payments for environmental services.

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Identifying best practices and potentials for performance improvement in EcoDriving: An efficiency analysis approach

Kenneth Løvold Rødseth*

The transport sector is among the world's biggest polluters. While the EU has implemented stricter type approval of vehicles, CO2 emissions per vehicle-kilometer have not decreased in recent years. Although driver behavior is considered important in explaining this development, information about how drivers use their vehicles is scarce.

This paper develops an environmental production analysis framework for analyzing driver performances using readouts from vehicles' OBD2-protocols that provide continuous information about driving characteristics, e.g., speed and acceleration. The OBD2-device reports approximately every 5 seconds, implying that a short trip of 8 minutes alone will comprise about 100 datapoints. Hence, with several drivers, each having a long trip history, the source dataset can be classified as a "large dataset". We discuss the aggregation of source data to time- and distance intervals, examine its impact on the efficiency measurement, and treat the selection of relevant inputs, outputs, and contextual variables for evaluating driver performances. Using information about time and geographic position, additional information about factors that impact driving, including congestion, intersections, and roundabouts, is added. Exploiting variation within drivers and trips, we propose a panel data frontier model for analyzing persistent and time-varying driver efficiency.

We are unaware of other studies that have attempted using frontier methods to identify best practices and inefficiencies in driving. Beyond offering a novel application for efficiency measurement, we believe our study will bring new insights into the scope for mitigating the transport sector's gaseous emissions by pinpointing reasons for and obstacles to good driver behavior.

Fifty states of human development? Measuring human development in the US using a 'Benefit-of-the-Doubt' human development index

Nicky Rogge*

This paper measures and analyses human development in the 50 states and their 3142 counties in the US. It is argued that the multidimensional nature of human development and the disparate policy priorities of states/counties calls for a reconciliatory evaluation framework, for which this

paper advocates the use of Benefit-of-the-Doubt (BoD) weighting. In particular, starting from county-level data, a BoD-weighted version of the American Human Development Index is computed for the counties and states. To account for the presence of certain exogenous conditions, the conditional robust order-m version of the BoD-model is applied. To derive state-level measures of human development, county-level human development scores are aggregated using the aggregation procedure after Färe and Zelenyuk (2003) presented recently in the BoD-setting by Rogge (2018).

Modelling the effects of weather on extensive dairy farming

David Roibas* and Alan Wall

Extensive dairy farming is characterized by the production of final goods (milk, animal products) and intermediate goods (foodstuff). Weather variables can affect both types of goods, through their effects on animal welfare in the case of final goods and through quality and quantity variability of forage in the case of intermediate goods. These two types of weather effects may work in opposite directions; thus, both should be carefully modelled in order to correctly identify the effects of weather on production.

A linear programming model for generating positive weights in DEA

Paul Rouse*, Maryam Hasannasab, Dimitris Margaritis and Israfil Roshdi

There is no guarantee that the optimal multipliers obtained from a Data Envelopment Analysis model are always positive. In many instances, the LP solution returns zero multiplier weights for inputs and outputs as a result of the Simplex algorithm stopping once it has found an optimal feasible solution. However, alternative optima may exist that provide nonzero weights for the same inputs and outputs. A problem arises when the weights are to be used in further analyses such as estimating marginal productivity, rates of transformation and substitution, the relative importance of the inputs and outputs and scale elasticity using the multipliers. These measures can be greatly affected by the presence of zero weights and yield unrealistic values. A valid and more reasonable value can be obtained by consideration of an optimal solution with a minimum possible number of zero weights. In this paper, we offer two LP models. The first LP generates a profile of weights with a maximum number of positive weights. This LP allows weight flexibility while finding a set of weights with the most possible positive elements independent of the solver. The second LP, provides a profile of weights with the same characteristic but is specific to each DMU. Additionally, it recognises the Pareto efficient DMUs and introduces the maximal reference set for the DMUs which are not Pareto efficient. This extends previous work by Bougnal, Dula and Rouse (2012) which used interior point methods to obtain non-zero multiplier weights, and has the attraction that the issue of weight positivity is directly addressed in our LPs.

By-production approach to modeling pollution-generating technologies: Assessment of critiques and proposed extensions

Robert Russell* and Sushama Murty

Murty, Russell, and Levkoff [2012] showed that the traditional approach of modeling pollution as an input with standard disposability assumptions implies implausible trade-offs among pollutants, conventional inputs, and outputs. Reprising ideas in Frisch [1965], they rectified this problem by modeling pollution-generating technologies as the intersection of two sub-technologies with different disposability restrictions: a conventional production sub-technology and a pollution-generation and abatement technology. This approach, unlike the traditional approach employing a single functional or set-theoretic restriction, generates a number of monotonicity degrees of freedom that is sufficient to capture the empirically compelling trade-offs of a pollution-generating technology. Recent papers, most notably Dapko, Jeanneaux, and Latruffe [2016] and Ray, Mukherjee, and Venkatesh [2018], have critiqued and built upon the MRL approach. The purpose of this paper is to evaluate these critiques and proposed extensions and to suggest productive avenues for future research.

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An analysis of the bank merger gains using the directional distance function model with undesirable outputs

David Saal, Pablo Arocena and Takayoshi Nakaoka*

Merger gains in the banking industry have been debated among researchers and practitioners for the last two decades. However, it is still controversial and unclear whether the merger contributes the efficiency improvement in the banking production process or not. In this paper, we apply to the Directional Distance Function (DDF) model with undesirable outputs for measuring banks' production efficiency score and examine the effect of the mergers on the efficiency. Using a sample of Japanese banks during the merger wave in the 2000s, we show that production efficiency for merged banks increases after the merger events. Furthermore, we find that the efficiency gains depend on the merging bank asset sizes, board member sizes, and the degree of overlapping of branch networks.

Modelling wastewater costs with an average system model: A simple method to control for complex inter and intra firm heterogeneity in wastewater system design

David Saal, Maria Nieswand* and Pablo Arocena

Network based utility systems generally have multistage production with the siting of production/treatment facilities influenced by various engineering, demographic, topographical, and economic factors. It is therefore common to control for cost complementarities between production and network activities. However, as often only firm level data is available, many regulatory cost assessment models effectively make the assumption that each firm operates a single system in which it optimizes its aggregate production and network costs. But this is inappropriate and likely to result in biased regulatory cost estimate if firms optimize multiple independent systems, as for example, demonstrated by the fact that the 10 wastewater firms in England and Wales actually operate over 6,300 geographically distinct wastewater systems. Given this issue, we develop an average system model that uses firm level data, but nonetheless captures differences in cost complementarities between treatment plants and network costs for different types of wastewater systems operated by a firm. Our application of this model to the English and Welsh wastewater sector finds significant differences in estimated cost complementarity between treatment and network activities for different plant types, and thereby suggests that the initial cost assessment models provided by Ofwat in January 2019 for use in its December 2019 regulatory price review are likely to be biased.

Cost interactions and their implications for disaggregated regulatory cost assessment: Examples from Japanese and British water and wastewater regulation

David Saal*, Maria Nieswand, Takuya Urakami and Tomohiro Kitamura

Regulators in network-based infrastructure industries often assess relative cost performance at a disaggregated level inconsistent with the company/decision making unit providing the regulated service. Such disaggregated cost assessment is justified for a variety of reasons, including reporting of data to different regulatory entities (as is the case for water and sewerage services provided by the same companies in Japan), and arguments that such separate assessment is required to facilitate the introduction of competition in what were once considered to be “natural monopoly” industries (internationally in gas, water, electricity, rail, etc). However, substantial biases are likely to result

from such disaggregated assessment, if it fails to account for potential cost interactions between different parts of the value chain, Moreover, the substantial academic literature on vertical and horizontal scope economies as well as the determinants of scale economies in multiple output network-based industries, provides ample academic evidence suggesting that such cost interactions can be considerable in magnitude. Given these concerns, this paper will present evidence from the Japanese and British water and sewerage industries with regard to the potential biases in cost assessment attributable to such disaggregated cost assessment.

Business model innovation and productivity management among small and medium-sized enterprises in the UK manufacturing sector

Fauzi Said* and Chander Velu

Productivity growth among small and medium-sized enterprises (SMEs) in the United Kingdom (UK) has slowed down over the last decade, resulting in a persistent large productivity gap between large established firms and SMEs. SMEs accounted for 99% of all business establishment in the UK and regarded as the pillar of the economy. Although all sectors contributed positively to productivity growth before the 2008 financial crisis, the manufacturing sector shows significant divergence. However, we have a limited understanding of how SMEs implement productivity management initiatives within the firm. Besides, our knowledge is limited on how management incorporates business model innovation in such productivity initiatives.

Case studies of selected manufacturing SMEs in the various sector were conducted to examine these issues. In order to explore this, semi-structured interviews were carried out with SME leaders to cover five main areas: (1) managerial attitude about productivity, (2) concern about productivity, (3) productivity goals and goal conflict, (4) formal management approaches in productivity, and (5) effects of business model innovation to productivity. Our main finding reveals that SMEs are less likely to apply productivity management initiatives, although firms that do adopt such initiatives show increases in their productivity. Another finding is that the majority of the firms see productivity improvement from the perspective of process efficiency rather than business model effectiveness. Finally, we find there is awareness to incorporate business model to achieve firm productivity which is driven strongly by the firm leadership.

Assessing the impact of different organizational models on the performance of primary care providers

Sérgio Santos*, Carla Amado and Cristiano Teixeira

The Portuguese primary health care sector has undergone a major reform since 2005. Following this reform, Family Health Units (FHUs) were established. These are voluntary and self-organised multi-professional units that have organizational, technical and functional autonomy to provide personalised health care to a given population. Alongside the FHUs there are still units – the Personalised Health Care Units (PHCUs) - that maintain the previous organizational structure and function with a less autonomous model. Although health professionals working in both types of units are paid on a salary basis, the former units also benefit from specific incentive mechanisms based on performance related pay. One of the main objectives of this reform was to improve the efficiency of primary care. Considering that several years have passed since the establishment of the FHUs, it is important to analyse the extent to which the new organizational model has generated efficiency gains in the sector. This study aims to contribute to this analysis by comparing the performance of the FHUs with that of the PHCUs. In order to do so, a performance assessment model was developed and the Data Envelopment Analysis technique used to obtain efficiency scores for each unit. An adjusted Malmquist Index was also used to compare the performance of the different types of units. The results indicate that the organizational model of FHUs appears to be associated with better efficiency levels than that of PHCUs.

A new family of copulas, with application to estimation of a production frontier system
Peter Schmidt*, Christine Amsler and Artem Prokhorov

In this paper we propose a new family of copulas for which the copula arguments are uncorrelated but dependent. Specifically, if w1 and w2 are the uniform random variables in the copula, they are uncorrelated, but w1 is correlated with |w2-½|. We show how this family of copulas can be applied to the error structure in an econometric production frontier model. We also generalize the family of copulas to three or more dimensions, and we give an empirical application.

Measuring the effects of spatial spill-overs on farm-level inefficiency: A semi-parametric approach
Kevin Schneider*, Ioannis Skevas and Alfons Oude Lansink

The environmental consequences associated with crop protection agents are of societal concern (Kohler and Triebskorn, 2013). Various parametric and non-parametric approaches have been conducted to assess whether farmers utilize these inputs efficiently. The need to account for environmental differences in such assessments was acknowledged in earlier studies (Skevas et al., 2012; Skevas and Serra, 2017). However, pest populations are spatial phenomena (Turchin, 2003). In turn, spatial spill-over effects from managerial practices can be expected. No empirical quantification of spatial spill-overs on pesticide inefficiency has been conducted as of now. The objective of this study is to measure the effects of spatial spill-overs on farm-level inefficiency. A particular focus is given to the use of pesticides. First, directional distance functions are computed non-parametrically. Second, a spatial econometric model is defined which measures the influences of neighbors' characteristics on the inefficiency estimates. The data was obtained from the Farm Accountancy Data Network. The panel covers Dutch arable crop farms for the period from 2006 to 2016 and includes information on longitudes and latitudes. Furthermore, data on climate and soil properties was extracted from public databases to account for heterogeneity in time and space. The results are expected to highlight spatial spill-overs among farmers. In particular, our preliminary results suggest statistically significant effects of the neighbors' degree of specialization and intensity. The study aims to contribute to the emerging discussion on spatial interdependence among DMUs.

Price dispersion in thin farmland markets - What is the role of asymmetric information?
Stefan Seifert*, Christoph Kahle and Silke Hüttel

This paper investigates the role of information and search cost in the price formation in thin farmland markets. To separately account for search costs asymmetrically distributed between buyers and sellers, a hedonic pricing model under incomplete information is used. In our empirical application, we estimate a two-tier stochastic frontier to capture the two-sided deviations from the efficient price. Using a comprehensive data set with more than 10,000 transactions between 2014--2017 in the eastern German Federal State Saxony-Anhalt, we find that institutional sellers achieve the lowest losses from being information deficient, which can be explained by their use of public tenders and their high degree of professionalism. On the contrary, we find no evidence of information deficiency for particular buyer groups. In particular, differences for farmers and tenants compared to non-farmers and non-tenants are statistically insignificant despite alleged differences in information and search costs.

Efficiency of Indian coal-based thermal power stations: A nonradial directional distance function approach
Debarun Sengupta*

Coal-based thermal power stations (CTPS) are the primary sources of electricity all over India. However, the thermal power sector is also considered as one of the significant sources of air pollutants in India. The present study tries to calculate the degree of inefficiency of Indian CTPS and identifies the factors which may affect the inefficiency. We employ Data Envelopment Analysis (DEA)

technique and an advanced model involving good and bad outputs. Suspended particular matter (SPM) emissions and electricity generation are treated as bad and good outputs in our model. Adopting the by-production technology model (Murty et al., 2012) we consider the total capacity of CTPS and total coal use as natural input and polluting input respectively. Assuming joint disposability among electricity generation, SPM emissions, and total coal use, we measure inefficiency by using non-radial directional distance function. The study uses station-level data on CTPS distributed all over India for the years 2008-09 and 2014-15. In 2014-15, on an average Indian coal-based TPS can improve its overall performance by 26.8%. To know whether the inefficiency level has changed from 2008-09 to 2014-15 the study uses non-parametric tests. The tests conclude that over time, inefficiency regarding electricity generation has decreased while coal use inefficiency has increased significantly. However, the inefficiency regarding emissions and overall performance of CTPS have remained the same. The second-stage regression finds that public ownership of CTPS has a positive impact on inefficiencies. Operational heat rate affects inefficiency in electricity generation positively, while coal use inefficiency negatively.

Impact of power outages on firms efficiency in Asian emerging and developing countries
Anam Shehzadi* and Heike Wetzel

This study contributes to the empirical literature by analyzing the impact of the number of power outages on manufacturing firm's efficiency for the 14 Asian emerging and developing countries over the period from 2009-2016. we use cross sectional data collected from World Bank enterprise surveys (WBES). The study applies stochastic frontier analysis (SFA) approach, proposed by Aigner et al. (1977), with half normal distribution and truncated normal distribution (Stevenson, 1980) to estimate the impact of power outages on firm's efficiency. Total annual sales are the proxy of efficiency. The vector of inputs is including labor, capital, energy and power outages. Controls variables like country dummies, time dummies, firm size dummies, female owners, generator owners, quality certifications are also used. The parameter estimates indicate highly significant and positive elasticities of labor, capital and energy. The impact of power outages is highly significant and having negative impact on firm output. Furthermore, the results of truncated normal model, power outages have highly significant impact on firm inefficiency in Asian emerging and developing countries in the presence of firm control variables. It emphasizes the importance of good infrastructure quality for a sustainable development in one of the fastest growing regions in the world.

Degree of autonomy and efficiency: An empirical analysis of Russian universities in 2012-2017
Ekaterina Shibanova and Tommaso Agasisti*

Russian higher education system is differentiated in many dimensions, but the majority of comparison angles come from the perspective of governmental control. Russian higher education system includes universities that possess different legal statuses (can be autonomous, budgetary or completely state-owned) and thus enjoy different degrees of freedom.

Firstly, we explore the exact mechanisms of operation that, on the one hand, are provided by the different statuses and, on the other hand, are used by the universities management. We perform analysis of related legal documents, and the development strategies of the universities.

We use semi-structured interviews with universities' management and experts in the field of funding and management of universities (here a comparative analysis is used, we select a balanced sample of both autonomous and non-autonomous universities, 6 in each group). Secondly, in order to test the effects of legal status on HEIs' performance and efficiency, we conduct a semi-parametric dynamic estimation of efficiency, using the Network Data envelopment analysis technique. The data we use comes from the Monitoring of performance of higher education institutions and covers the period of 2012/13-2016/17 academic years. We systematize the official legislation in the field of universities' autonomy to trace the possible mechanisms that can be used to increase the organization's efficiency. The research results contribute to the discussion of universities

management and autonomy of not-for-profit organizations in Russia. We analyze the practices that are used within the universities and trace their relationship with observable measures of efficiency.

Estimating technical efficiency from sample designs using robust nonparametric models
Gabriela Sicilia*, Daniel Santín and Juan Aparicio

In many empirical problems, the comparison of production units, as regions or countries, is done through a representative sample of decision making units to characterize the population. Regardless the sampling design, the use of sample weights is standard in statistics and econometrics for approximating population parameters. However, this issue has been repeatedly ignored in the literature on the estimation of production frontiers. So far, extensions have not been developed to conventional methods that allow to incorporate the sample weights when estimating the production frontier and the efficiency of each evaluated DMU. The aim of this paper is to illustrate this problem together with providing a first methodological strategy to incorporate the sample weights information into the estimation of the production frontier using robust nonparametric models. Finally, we suggest further future directions to face this issue.

The whole and its parts: Inefficiency of production systems and its decomposition
Maria Silva* and Antonio Peyrache*

In this paper we reconcile various strands of the literature dealing with production systems and its internal structure. Such internal structures exist within a firm (composed of varying connecting and interacting processes), but also within an industry composed of different firms. When taking into account the parts that compose the whole it is important to take into account movements of resources or products between the parts – such movements are usually embedded in allocative measures of efficiency. It is also important to consider the various hierarchies that compose the whole: e.g. processes, happen within a firm that happen within an industry that happen within a country, etc.

We propose production models that can be applied to assess the efficiency of the parts and of the whole system, which can be decomposed into the efficiency of the parts and allocative efficiency. Our models can be applied to several situations addressed in the literature such as network models, dynamic models, output-specific input models, industry models or hierarchical models. As a result we reconcile previous literature that has been developed independently, but addressing very similar and related issues. We apply the models to a health setting analysing service efficiency within an hospital, and then comparing hospitals and aggregating their efficiency into an aggregate measure of 'industry' efficiency.

Nonparametric stochastic frontier models with multiple inputs and outputs
Léopold Simar* and Paul W. Wilson*

Stochastic frontier models are widely used to analyze productivity and efficiency of firms, and are attractive because they allow for noise in the data generating process (DGP). The models are typically fully-parametric, with functional form specifications for the frontier as well as both the noise and the inefficiency processes along the lines of Aigner, Lovell and Schmidt (1977, JoE). Several attempts have be made to move toward nonparametric models by relaxing some of these parametric hypotheses which are often unrealistic and rejected by data when tested. However, a fully nonparametric approach raises problems of identification of the specified model as discussed by Hall and Simar (2002, JASA). Generally all of these approaches are limited to a univariate response variable where, if working in output (or input) orientation, the single output (or input) is regressed on the inputs (or outputs) (e.g., see Hall and Simar, 2002, JASA; Kneip, Simar and Van Keilegom, 2015, JoE; and Simar, Van Keilegom and Zelenyuk, 2017, JPA, hereafter SVKZ). Some of these approaches have been extended the full multivariate setup (e.g, Simar and Zelenyuk, 2011, JPA; Kuosmanen and Johnson, 2017, EJOR), raising endogeneity issues. These are either ignored or addressed, requiring additional, restrictive and implausible assumptions. This paper extends the

multivariate framework to provide a flexible, almost fully non-parametric model which avoids endogeneity problems. We use directional distance measures of efficiencies in a novel and original way. We discuss identification issues and the properties of the resulting estimators. We examine finite-sample performance of the estimators through Monte-Carlo experiments. Practical implementation of the method is illustrated in an empirical example with real data.

Improving finite sample approximation by central limit theorems for DEA and FDH efficiency scores

Léopold Simar* and Valentin Zelenyuk*

We propose an improvement of the finite sample approximation of the central limit theorems (CLTs) that were recently derived for statistics involving production efficiency scores estimated via Data Envelopment Analysis (DEA) or Free Disposal Hull (FDH) approaches. The improvement is very easy to implement since it involves a simple correction of the variance estimator with an estimate of the bias of the already employed statistics without any additional computational burden and preserves the original asymptotic results such as consistency and asymptotic normality. The proposed approach persistently showed improvement in all the scenarios that we tried in various Monte-Carlo experiments, especially for relatively small samples or relatively large dimensions (measured by total number of inputs and outputs) of the underlying production model. This approach therefore is expected to produce more accurate estimates of confidence intervals of aggregates of individual efficiency scores in empirical research using DEA or FDH approaches and so must be valuable for practitioners. We also illustrate this method using a popular real data set to confirm that the difference in the estimated confidence intervals can be substantial. A step-by-step implementation algorithm of the proposed approach is included in the Appendix.

Effect of environmental regulations on efficiency of Kanpur leather industry: A DEA and directional distance function approach

Aparajita Singh* and Haripriya Gundimeda

This paper examines the effect of environmental regulation on productive efficiency taking the case of Kanpur leather industry in India. Kanpur is one of the major foreign exchange earners among the Indian leather clusters however it is also cited for its environmental pollution. Standard limits on effluents discharge are imposed on leather tanneries to reduce pollution. But in the presence of resource constraints, these regulations are seen as an opportunity cost in the form of reduced output. We use data of 61 Kanpur tanneries for the year 2016 to measure the environmental efficiency and the cost of regulation on the Indian leather industry. Using traditional data envelopment analysis models and extending the approach to directional distance function, we evaluate the efficiency of the leather firms in the absence and presence of undesirable factors. We find that the leather firms in the sample are 63% efficient in utilizing the inputs to produce their given level of good outputs without accounting for undesirable factors. Once the undesirable factors are taken into consideration, we find that their efficiency is higher by 12% as they are credited not only for utilizing the conventional inputs efficiently but also reducing the environmentally detrimental inputs. Our results show that under strong disposability (unregulated scenario) of undesirable outputs, the firms in the sample could increase the aggregate output by 27% while when we assume weak disposability (regulated scenario) of undesirable output, the aggregate output could only be increased by 17%. This implies that environmental regulations have an opportunity cost in terms of smaller feasible expansion of good output and on an average, this regulatory cost equals a 10 percent loss in the ability of the firms to potentially expand their good output. We conclude that undesirable factors significantly influence the efficiency of the leather firms and therefore should not be avoided in the efficiency analysis.

Drawing inference in the context of spatial stochastic frontier analysis
Ioannis Skevas*

This paper specifies a stochastic frontier model that takes into account spatial spillovers among producers. The hypothesized spillovers are justified based on the similar environmental conditions under which neighboring farmers operate and the potential communication between them in making their production decisions. Technically-wise, efficiency is modeled as a function of neighbors' efficiency levels and a set of farm-specific characteristics. Estimation proceeds using Bayesian techniques. Subsequently, inference is drawn based on the derivation and interpretation of marginal effects of the utilized farm-specific covariates on efficiency. The derived marginal effects are decomposed into direct and indirect ones with the latter revealing the strength of spatial spillovers. The case study concerns specialized Dutch dairy farms observed over the period 2009-2016. Exact information on farms' latitude and longitude are available and are used to construct the spatial weights matrix. The empirical findings suggest that farmers' efficiency scores are spatially dependent. The direct and indirect marginal effects are negative and significant for subsidies and positive and significant for farmers' age adding credibility to the hypothesized existence of spatial spillovers between farmers.

What does drive efficiency of urban railway operators in Japan? Focusing on time-invariant and time-varying effect
Yeon-Jung Song*

This paper aims to evaluate performance of urban railway operators in Japan and compare technical efficiency of operators. We apply stochastic frontier analysis and decompose efficiency into persistent and transient part to examine how time-invariant and time-varying factors influence operators' efficiency. While transient inefficiency reflects problems caused by short-run management, persistent inefficiency can be considered the long-term problems caused by institutional level. Given that the firm's production technology is holistic and availability of changes in some technologies or strategic factors are likely to depend on the time, decomposing efficiency enables us to consider all of perspectives for estimating inefficiency under the same context to provide detailed and integrated implications of strategy of railway service by companies.

Panel data of 34 Japanese urban railway operators from 2000 to 2015 is used for the estimation. Our preliminary results show that large private operators (called major private companies) tend to show larger overall efficiency than small operators (called minor private companies). In addition, while all operators show comparatively high transient efficiency and there are little differences among them, we find persistent efficiency of each operators vary considerably and small operators tend to have smaller persistent efficiency than large operators. We consider that differences in persistent efficiency give us perspectives to understand the influence of the factors which are not likely to change over time such as ownership, governance and operation scale and discuss policy implication in this paper.

Network utilities performance and institutional quality: Evidence from the Italian electricity sector
Golnoush Soroush*, Tooraj Jamasb, Carlo Cambini and Manuel Llorca

In addition to the firm-level structural, environmental, and managerial differences, institutions impact quality of the business environment and ultimately how firms use their resources. However, whether the performance of regulated network utilities in a country is affected by the quality of regional institutions is yet to be investigated thoroughly. We aim to close this gap by analysing how the quality of these institutions impact performance of Italian electricity distribution utilities. We apply a stochastic frontier analysis approach to estimate cost functions and examine the performance of 108 electricity distribution utilities from 2011 to 2015. For this time span, the overall efficiency score of the Italian electricity distribution utilities is 58% and our estimates indicate that utilities in regions with better institutions tend to be more efficient. In addition, regional economic development measures including Gross Value Added and Employment Rate significantly impact

performance of utilities. Furthermore, of the four governance indicators that we considered as institutional quality measures, control of corruption shows the highest impact on utilities' performance. The results also suggest that national regulators need to take regional institutional diversity into account in incentive regulation and efficiency benchmarking.

On hypothesis testing in latent class and finite mixture stochastic frontier models
Alexander D. Stead*, Phill Wheat and William H. Greene

Latent class and finite mixture (LCFM) stochastic frontier (SF) models have been proposed in in recent years as a way of allowing for technological heterogeneity or alternative distributions for the error components. This raises the issue of testing down to simpler models, such as the standard SF model. However, the standard results on the distribution of test statistics cannot be applied due to boundary problems and issues with identification. Previous studies have used information criteria; however, this does not constitute a hypothesis test, and Monte Carlo evidence from the LCFM literature suggests that likelihood-based tests outperform information criteria in terms of selecting the correct number of classes. In the wider literature, use of a modified likelihood ratio (MLR), in which a penalty term is incorporated into the likelihood, has been shown to simplify the problem. This paper explores the use of MLR tests in the context of LCFM SF models. We review the literature on the distribution of MLR statistics and discuss how these results apply in three relevant SF contexts. We provide Monte Carlo evidence on the sampling distributions of the MLR statistic in each of these contexts, and compare this to the asymptotic distributions from the literature.

Industrial eco-efficiency performance and dynamics in Europe. The existence of technological spillovers within a metafrontier framework
Eirini Stergiou* and Konstantinos Kounetas

EU policies concerning global warming have been outspread the last few decades as air pollution consists the largest environmental problem. Initiatives for air quality's improvement has been added in the agenda of environmental directives on the grounds that the prolonged economic growth intensified the environmental issues rapidly and made the link that connects them even more solid. The manufacturing production process is one of the responsible sources of the poor environmental performance as undesirable outputs are produced simultaneously with the produced output. We model the eco-efficiency performance under a meta-frontier framework for 14 industries from the manufacturing sector from 27 European countries over the 1995-2011 period. The utilization of NOx, SOx, CO2, CH4, N2O, CO, NMVOC and NH3 as undesirable outputs and GVA as the desirable help us to understand better this concept. In the first stage, we estimate the efficiency measure using the conventional Directional Distance Function (DDF) as well as the non-radial DDF approach by embodying slacks under different technology regimes to examine if technological heterogeneity and differences in the infrastructure could influence the eco-efficiency scores. In the second stage of analysis, we investigate the existence of conditional and unconditional convergence and distribution dynamics on different types of eco-efficiency and technology gap. The estimated results will indicate whether industries will move towards the meta-technology frontier and if opportunities for abatement procedures are present.

Wine hedonic pricing using the two-tier stochastic model
Loren Tauer* and Harold Fried

The two-tier stochastic frontier model is used to estimate a hedonic wine price model for U.S. Rieslings. Separate exponential distributions above and below the expected function represents overpricing and underpricing of wine given the attributes used to determine the expected price of wine. U.S. Rieslings with vintages between the years 2000 and 2016 were used with prices converted into 2016 prices using the CPI for food and beverages, and converted into natural log form for estimation. A model was estimated where the only independent variables were the score ranking of the wine between 0 and 100, as determined by tastings conducted by Wine Spectator, and the score squared to allow a non-linear relationship. This model specifies consumers as buying wine based

strictly on the tasting score, believing all quality attributes are inherent in the tasting score. We find that some wines are overpriced while other wines are underpriced for these consumers. However, when we add U.S. wine regions into the two-tier regression no solution is obtained, suggesting that there is not simultaneously over and underpricing. Then to determine the existence of either only overpricing or underpricing, two separate one-tier models are estimated. We then find no underpricing and very minor overpricing. The implication is that wineries correctly price their Rieslings given the region conditional upon the tasting score. This means that wines from some regions command a premium or discount for any given tasting score.

The efficiency implications of political donations
Vitezslav Titl*, Kristof De Witte and Benny Geys

Firms' political donations can induce distortions in the allocation of public procurement contracts. In this article, we employ an advanced non-parametric efficiency model to study the public sector (cost) efficiency implications of such distortions. Using a unique dataset covering the Czech regions over the 2007-2014 period, we find that the efficiency of public good provision is lower when a larger share of public procurement contracts is awarded to firms donating to the party in power ('party donors'). We then link this efficiency difference to two underlying mechanisms: i.e. shifts in procurement contract allocations from firms with previous procurement experience to party donors, and the use of less restrictive allocation procedures that tend to benefit party donors.

Does inefficiency affect firm crisis? Evidence from Italian agri-food industry
Pierluigi Toma*

Firm survival is one of the main issues in the field of research related to entrepreneurship, organizations and business management resulting in a large and heterogeneous body of scholarly literature. In the last decades scientific efforts concentrated on the determinants related to the survival of firms. Earlier research has faced this issue by arguing that the success and survival are potentially driven by very different conditions. The present study represents an advance in the firm survival research field by examining the role of efficiency and productivity in the context of surviving attitude of firms in specific industries, and testing if it could be considered as a predictive symptom. The agri-food industry, particularly in Italy, is an example of an industry that has experienced a notable growth during the last years in terms of economic significance, number of dedicated firms and geographical scope of activities. However, commonly due to their small size, the main goal, for a large number of agri-food firms is to ensure their survival. If agri-food firms seek to ensure their survival and Italian public institutions wish to support a vivid agri-food industry, identifying the conditions that specifically help firm survival is crucial. The paper explores the effects of some scientifically established determinants on Italian agri-food firm survival, adding another factor that is the production efficiency, testing if the latter affect or not the probability of firm default. Our results provide important policy relevant knowledge of what institutional, industry- and firm-level factors should be developed in order to keep the firms alive.

Estimation of the workload boundary in socio-technical infrastructure management systems
Taylan Topcu, Kostas Triantis* and Bart Roets

Despite its academic popularity, applications of DEA to engineering and engineering management problems of real complexity have been limited. We believe that the solid theoretical foundation of efficiency measurement creates value for the heuristics based discipline of systems engineering with the provision that: (i) the normative roots of DEA are preserved and (ii) a proper mapping of the operational realities into the DEA model formulation is achieved. This paper, through an industry-academia collaboration between Virginia Tech and INFRABAEL, presents a novel interdisciplinary DEA application for infrastructure management systems by bringing together the domains of systems engineering, safety science, macro-ergonomics, and efficiency measurement. We compute the workload boundary of safe operation envelope for railroad Controllers. First, we identify organizational, socio-economic, and technical factors that describe the performance environments

in which Controllers operate. Then, we design and implement on-site a measurement framework based on a disaggregate dataset. We apply a two-stage clustering approach to generate statistically relatively homogeneous groups and calculate meta - and in-cluster efficiency scores. Validation of results indicate two primary insights: (i) disregarding performance environment heterogeneity leads to over estimation in target setting and (ii) system improvement strategies could be informed by DEA, provided that, domain expertise is used in the model formulation.

Workload quantification and distribution in socio-technical infrastructure management systems: Human vs. autonomous systems
Taylan Topcu, Kostas Triantis* and Bart Roets

Infrastructures are complex socio-technical systems that progressively depend on the cooperation between humans and autonomous systems for their management. Socio-technical systems have many internal stakeholders on various levels of the organization and their individual value maximization attempts could drive the enterprise towards undesirable trade-offs. Traditionally in such systems, safety critical decision-making activities are allocated to a group of humans that are usually denoted as Controllers. Rapidly improving data measurement and artificial intelligence technology, along with increasing financial pressure on such organizations, incentivize high-level managers to increase the role allocated to automation in control and management activities. While increasing automation allows for the centralization of the system, leading to long-term cost reduction, uncontrollable and dynamic characteristics of the network, such as traffic complexity or density, render the use of automation sub-optimal and require manual control in certain instances. In this paper, we investigate real-world operational data from Belgian Railways and use microeconomic production theory to quantify the workload allocation between humans and autonomous decision-making systems, and study which uncontrollable network characteristics influence the workload distribution. We use machine-learning techniques to establish a relationship between Controller preferences regarding the use of automation and contextual network characteristics. We believe this initial step to capture revealed preferences regarding use of automation would lead to an improved understanding of: (i) workload distribution between human and autonomous systems, (ii) misalignments between Controller and organizational preferences, and (iii) design of high performing infrastructure management systems.

The shadow price of management
Thomas Triebs*, Kai Sun and Robin Sickles

Despite the fact that management is considered an important factor in production we know surprisingly little about its optimal use. One important reason for this lack of understanding is that neither the quantity nor the price of management is generally observed. In this paper we estimate management's shadow price, its price efficiency, and its ease of substitution. We are able to estimate a shadow price using the management practice measures provided by Bloom and Van Reenen (2007). When estimating observation specific shadow prices we also obtain Morishima elasticities of complementarity. These show how easily management substitutes with capital, labor, and materials. Finally, we can contrast management's shadow price with the salaries of top managers to learn about its allocative efficiency.

Know what you sow: The cost of seed type misidentification in Tanzania
Federico Trindade*, Ayala Wineman, C. Leigh Anderson and Timothy Njagi

Most studies of the impact of improved seed adoption have relied on self-reported household surveys. Results from a recent DNA fingerprinting study find that 15.27% of surveyed maize farmers incorrectly identify their seed as improved ("false positives"), while 13.21% incorrectly identify their seeds as not being improved ("false negatives"). Changes in input use, including fertilizer and labor allocations, suggest that farmers treat seed differently according to whether or not it is perceived improved, hence misidentification may lead them to choose suboptimal management practices, decreasing their potential profits.

This study uses DNA fingerprinting data of 820 households in Northern Tanzania to quantify this efficiency loss. We combine a maize yield production function with a stochastic frontier approach to compare efficiency scores of households that correctly report their seed type with those that do not. By comparing the average values of "false positive" and "true negative" households, and "false negative" and "true positive" households, we estimate the technical and allocative efficiency loss associated with seed type misidentification.

The average efficiency of both improved and unimproved samples is approximately 0.55. Preliminary findings do not support the hypothesis that "false positive" households are less efficient than "true negatives". We do, however, find that "true positive" households are more efficient than "false negatives", with an average efficiency premium of 0.16. Quantifying this efficiency loss could provide valuable information on the productivity gains to investments in information, labeling and certification that promote the likelihood of correct improved seed identification.

The effect of merger to Vietnamese bank efficiency: A two-step DEA window analysis approach
David Tripe*, Trang Tran and Jing Liao

The study examines the role of mergers and acquisitions (M&As) on bank efficiency over the 2008-2016 period, using a balanced panel dataset from 22 commercial banks in Vietnam. The study employs the two-stage DEA window analysis approach. In the first stage, DEA window analysis is used to estimate the technical efficiency of the Vietnamese banks. In the second stage, the efficiency is regressed on the merger dummy and other control variables using tobit, truncated and bootstrap methods as robustness checks. Our findings suggest that, the efficiency of Vietnamese banks decreases after M&As. There are two possible explanations for this finding: first, the M&As are not driven by profit-maximizing incentives; second, it may due to the intervention by the government to rescue weak banks. In addition, the newly-formed entities need to spend additional resources on resolving the bad debts transferred from the weak, targeted banks. The results are robust in all specifications employing tobit, truncated, and bootstrap methods.

Productivity trends in Russian industries: Firm-level evidence
Anna Tsvetkova* and Evguenia Bessonova

The paper focuses on convergence of labor and multifactor productivity in Russia. Using firm-level data over 2011-2016 period we obtain the following result: low-productivity firms grow faster, than high-productivity firms. Despite this fact, the initial gap between the most and the least productive firms in the Russian economy is so wide, that it is hardly possible to overcome it in the short run. Moreover we find that this gap has increased during 2011-2016 period, suggesting productivity divergence in Russia. In order to examine divergence at industry level we also apply stochastic frontier analysis. Our estimates confirm divergence in most industries.

Immigrant wage gaps and determinants: A stochastic wage frontier approach using linked employer-employee data
Ragnar Tveteras* and Subal C. Kumbhakar

This paper estimates wage frontiers using a rich linked employer-employee panel data set with two million Norwegian private sector employee observations linked to their respective firms. Norway has a substantial immigrant population, with around a quarter of the workforce having immigrant status. As in many other OECD countries there is an ongoing debate on the economic integration and contribution of immigrants, with implications for policies for integrating immigrants to increase their productivity. We explain individuals' wage gap and catching up using both employee and firm characteristics. One of our objectives is to test how rapidly and through which mechanisms immigrants reduce the wage gap. By interacting the immigrant status with own individual characteristics (education, age, sex etc.) and employer characteristics (e.g. firm size, firm productivity) we estimate how different factors influence the wage gap. We also distinguish between immigrants from countries which are socio-economically more distant (e.g. Asia and Africa)

and close (e.g. Europe), and provide separate estimates of wage gaps and determinants for these groups. Our estimates provides new empirical evidence on immigration wage gaps and their determinants, which may be useful in the design of different policy measures related to immigrant integration. We use state-of-the-art stochastic frontier model in which we control for both worker and firm heterogeneity in estimating the wage gap and its behavior over time, testing the assimilation hypothesis.

A novel approach for measuring conditional efficiency in non-parametric models: An application to European banking

Panagiotis Tziogkidis*, Mike Tsionas and Dionisis Philippas

The paper proposes a new approach for measuring conditional efficiency in non-parametric models. In a multidimensional efficiency analysis framework, we use an iterative process which determines the reference set for each decision making unit, by identifying its nearest neighbours within a set of exogenous variables. In each step of the process, seemingly unrelated regressions are run between the input and output variables of the units within each reference set. The optimal number of nearest neighbours is then obtained by minimising the total sum of squared errors, of all seemingly unrelated regressions for any given number of nearest neighbours. We apply our approach on the list of significant financial institutions supervised under the framework of the single supervision mechanism of the European Central Bank.

Modelling quality in data envelopment analysis (DEA) for the Brazilian electric power sector

Wadaed Uturbey*, Ana Lopes and Heinz Ahn

The Brazilian regulator of the electricity sector, ANEEL, has adopted a benchmark model for efficiency assessment of electricity utilities that is based on Data Envelopment Analysis (DEA) and Corrected Ordinary Least Squares (COLS). The adopted model considers operational indicators of quality of service that are related to service interruptions. However, the results showed evidences of inconsistencies in the model adopted by the regulator. Notice that there are different forms of defining quality proxies to properly capture the level of the service provided by Distribution and Transmission System Operators (DSOs and TSOs), like system outages, amount of energy not served, number of consumers involved, just to mention a few. Moreover, quality of service has a strong dependence on the amount invested in the network, and incentives must be related with the target quality level set by the regulator and with the actual level attained by the operators. This work addresses the definition of quality indices adequate to the DEA analysis for the calculation of efficiency scores of Brazilian DSOs and TSOs. A discussion and comparison with the approach of the regulator is presented.

Computing nonparametric measures with R. A critical surveys and future recommendation

Philippe Vanden Eeckaut*, Eliegbo Amouzou and Mohamed Charhbili

Nowadays, we have numerous solutions for computing efficiency measurement as illustrated in Daraio et al. 2019. The first set of solutions are dedicated software like OnFront or Frontier. The second set of tools are based on generic software like general solver (AMPL or GAMS) or econometric software. The third set is to use a software environment (R or STATA) and use dedicated packages for efficiency measurement (Benchmarking for R is a well know example). We believe that the third path is probably the best option for the future and we advocate the use of R for several practical reasons. In the second part of this paper, we propose a critical review of existing and missing packages for nonparametric measurement in R. We conclude by some recommendation for optimal use of R in term of data structure and speed of computation.

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Competitiveness and nonparametric efficiency measurement

Philippe Vanden Eeckaut*, Anne-Laure Levet and Eliegbo Amouzou

The literature on Competitiveness and Efficiency as proposed in Latruffe 2010 or Nivievsky 2010 exposes the difficulties to define, identify and measure the link between these indicators. In this paper, we analyse in this context the recent development in directional profit analysis. One of the objectives of the paper is to propose several decomposition of profit efficiency which include the notion of competitiveness. We restrict ourselves in this first step to a nonparametric and static analysis framework.

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Evaluation of DEA models with multiple environmental variables for cost regulation of transmission service operators

Aline Veronese da Silva*, Marcelo Azevedo Costa, Mohsen Afsharian and Ana Lúcia Miranda Lopes

Second Stage Data Envelopment Analysis (DEA) refers to the family of are techniques that incorporate the effect of contextual variables on the DEA scores. The most common approaches have at their center the regression-based techniques, which capture the average behavior of the efficiency regarding a limited set of environmental variables.

This study evaluates alternatives to deal with multiple contextual variables that affect DEA scores. Concerning the limited degrees of freedom of a multivariate regression-based model, one approach comprises the aggregation of the results of multiple univariate models. Different aggregation techniques are tested. In addition, adjustments of the DEA input variable regarding the contextual variables are also evaluated, and compared with standard second stage procedures. In particular, two approaches are examined: (a) an empirical alternative, where an equivalent input variable is created, and (b) a statistical approach, which is based on the properties of the sum of squares decomposition for regression models.

These two approaches are applied on the data set of the Brazilian Transmission System Operators (TSOs), which comprises a small number of companies compared to a large number of contextual variables. It is demonstrated how the Brazilian energy regulator estimates the efficient operational cost of the companies applying a second stage procedure. It is also shown regulator's results do not reveal an appropriate fitness of the adjustment to the environmental effect. Under these circumstances, however, the proposed approaches reveal promising results.

Revenue decoupling and energy consumption: Empirical evidence form the U.S. electric utilities sector

Victor von Loessl* and Heike Wetzel

Energy efficiency marks a substantial resource to tackle increasing greenhouse gas emissions. However, in traditionally regulated energy markets, energy providers maximize their profits by selling electricity or heat as long as their marginal revenue exceeds their marginal costs of production. This so called 'throughput incentive' fundamentally restricts the motivation of utilities to invest in energy efficiency. This paper therefore investigates the relation between the regulatory policy revenue decoupling, that separates utilities' revenue from sales fluctuations, and electricity customers' energy demand and efficiency in the U.S. To process the research question at hand, we follow recent developments in energy demand function modeling and Stochastic Frontier Analysis (SFA) estimation techniques that allow to account for persistent as well as transient efficiency. The estimation results show a significant negative correlation between revenue decoupling and electricity consumption patterns. Furthermore, we identify only little transient inefficiency of electricity customers. However, results indicate an underlying persistent inefficiency across the entire electric sector.

Impact of conservation agricultural practices on irrigation performance: The case of smallholders in India

Maria Vrachioli* and Johannes Sauer

Sustainable and efficient water management constitutes one of the greatest 21st century challenges facing the agricultural sector. Population growth, increasing food demand and the sustainability of the resources to meet these challenges have driven the agricultural sector to engage in significant conservation strategies. In this study, we assess the impact of using different conservation agricultural practices associated with irrigation cost within the stochastic production frontier framework. More specifically, an input distance function is estimated to measure farmers' irrigation-specific technical efficiency. An input distance function provides the amount by which an input vector can be radially contracted, irrigation cost in our case, while it is still feasible the output vector to be produced. This analysis is augmented by accounting for farmers' perception of climate change and also correcting for selectivity bias. Deciding to adopt or not a conservation technology is not necessarily a random determination. Unobserved heterogeneity across the farms, including farmers' climate change perception among other factors, can have an impact on farmer's decision to adopt or not conservation practices. This study focuses on the Bihar region of India for the cropping year of 2016-2017. A farm-level survey acquires production-related data (including irrigation cost) and farmers' perception on climate change. Current discussions on agricultural water management issues, due to irrigation water scarcity, have resulted in many policy recommendations aiming to enhance effective water usage through the adoption of conservation agricultural practices. The magnitude of gains from the more effective use of agricultural water imply that water policy can aim toward conservation agricultural practices that promote efficient use of water for irrigation purposes. However, the effectiveness of these policies depends on the proper measurement of irrigation performance at the farm level.

Productivity, price and profit change in a common pool industry

John Walden* and Min-Yang Lee

Productivity and profit change are key economic performance measures for virtually all industries, and are particularly important when the industry of interest is heavily regulated. Changes in profits help inform decision makers whether policies which they have enacted impacted the regulated industries positively, or negatively. In this paper, we estimate productivity, price and profitability change using the index number decomposition approach shown in O'Donnell (2012), combined with the meta-frontier concept of O'Donnell, Rao and Battese (2008) and O'Donnell, Fallah-Fini and Triantis (2017), for a common pool fishery over a 20 year time period. We focus on the northeast U.S. scallop fishery because it has been managed through a unique system of rotational closures with strict limits placed on harvests from each area. Surprisingly, this approach has resulted in a very profitable fishery, with profits doubling since 2004. Results show that profitability has increased mainly due to increasing output prices. Productivity improved slightly during the time period, and productivity growth was driven largely by changing environmental conditions. Output prices improved substantially due to the growth of higher valued large scallops brought about by the rotational management scheme.

Financial inclusion, financial technology, and economic development: A composite index approach

Barnabe Walheer*

Financial inclusion is recognized by policy-makers as one of the main tools of global economic development. Recently, increasing attention has been attached to propose reliable indicators to quantify financial inclusion of countries. In this paper, we adopt a composite index approach for that purpose. The main distinguished feature of our empirical exercise is its data-driven spirit. In particular, we make very few assumptions about the nature of the composite index. Moreover, we define financial inclusion from three main dimensions making used of both demand- and supply-side data, and recognize that financial technology is playing a growing role in boosting financial inclusion.

Next, we analyze financial inclusion changes over time by distinguishing a catching-up and an environmental change effects. The latter allows us to define the scope for policy interventions. Finally, we take the heterogeneity between countries into consideration by partitioning countries into income per capita categories. Our empirical exercise reveals important patterns useful to understand financial inclusion differences and to design future policy implementations.

Efficiency, technological advancement, and spillovers of hotels in China
Barnabé Walheer, Linjia Zhang* and Yingchan Luo

The prosperity of China's economy has benefited from the rapid development of the tourism industry. In this paper, we develop a new economic model to capture both inter- and intra-heterogeneity aspects of firm operation into consideration and extend the concept of meta-technology, specially designed to evaluate performances in the presence of heterogeneity and rely on a robust nonparametric estimation method. Our model is applied to evaluate two performance dimensions of the Chinese star-rated hotel sector: efficiency and technological advancement; and spillovers. Our findings reveal important patterns useful for both hotel managers and policy-makers. The result shows that the Chinese star-rated hotel sector is relatively efficient and technically advanced; there are incoming and outgoing spillover effects; but results vary importantly in terms of the number of stars and the services.

Factors determining differences in organic agricultural production across Spanish regions: A stochastic frontier approach
Alan Wall* and Luis Orea

Organic agricultural production in the European Union (EU) is relatively low compared to conventional production, though it has been significantly increasing in recent years. Indeed, official data show that the percentage of agricultural land in the EU dedicated to organic production has increased by well over 20% since 2010. Moreover, concerns at EU level with the adverse effects of conventional production has led to substantial support for organic production though the Common Agricultural Policy, with at least 30% of the budgets of Rural Development Plans earmarked for agri-environmental measures, support for organic production and investment projects associated with environmental innovation.

Spain has experienced similar increases in organic production over the last decade, though large differences exist across regions. The focus of this research is to try to identify factors that determine differences in the adoption of organic production across Spanish regions. Recent studies have identified three main categories of factors influencing regional adoption of organic production: physical factors (including population density, distance from population centres, land characteristics and size of farms), structural characteristics (distribution and logistic infrastructure, marketing channels, etc) and socio-cultural factors (including institutional support). Using a stochastic frontier approach, we test for the relevance of these factors in explaining differences in organic production across Spanish regions, paying special attention to differences in prices of certification and in regional financial aid for organic production, which are controlled by regional authorities.

Impacts of climate change on future U.S. agricultural productivity
Nicholas Rada*

We first employ a stochastic frontier approach to examine how climate change could have affected U.S. agricultural productivity based on a state panel of weather and productivity data. We then forecast state-level temperature and precipitation in the 2050s based on the assumptions of major climate change models. We construct THI load and Oury indices accordingly to estimate the potential heat stress- and drought-related production losses for scenario analysis purpose. The results show that the same degree changes in temperature or precipitation will result in diverse impacts on regional productivities.

Scale and scope economies of German electricity and gas distribution networks
Heike Wetzel*

The German electricity and gas distribution sectors are characterized by an exceptionally fragmented structure. There are currently 1076 network operators distributing electricity or gas in Germany. This number contrasts sharply with other European countries which feature a significantly smaller number of network operators. The question arises whether or not this highly fragmented structure with a lot of small distributors is cost efficient. A suboptimal, and therefore cost inefficient sector structure induces welfare losses in the form of too high network charges for end consumers. It is therefore the aim of this paper to analyze the cost structure of German electricity and gas distribution. The focus lies on the estimation of scale and scope economies as these determine the cost efficient configuration of the industry.

Measuring efficiency in residential electrical energy: A microdata case study
Tom Weyman-Jones*, Júlia Mendonça Boucinha* and Catarina Feteira Inácio*

The traditional measure of energy efficiency simply examines the ratio of energy consumed to economic activity in a sector, while efficiency and productivity analysis measures the inefficiency component of the error term in a behavioural regression function. Many factors determine the demand for energy besides the level of sectoral economic activity, and unless these are accounted for by frontier analysis, energy efficiency change is overestimated.

The sector examined here is residential electrical energy consumption in Portugal 2008-14. The innovation is the availability of a microdata sample of residential consumers. Microdata at the level of the individual consumer offers richness in studying the variability of economic behaviour. In 2008, almost 3500 households with common electricity tariffs were interviewed and details recorded about their electrical energy consumption, applicable consumption bands, appliance ownership and monthly income. This was repeated in 2014 with another similar group of households. These microdata can be used to measure electrical energy efficiency in the light of the government's drive to foster energy efficiency improvement. In this paper we make use of the two microdata samples from 2008 and 2014 to investigate stochastic energy demand functions which will differentiate between the traditional and the stochastic frontier analysis approaches by deriving energy efficiency measurement from the inefficiency component of the regression error. This is critical when environmental policy must co-exist with significant macroeconomic restructuring as occurred in Portugal during this period. The availability of two microdata sets allows the estimation of efficiency change over time.

Robust stochastic frontier analysis: A panel data model with Student's t errors
Phill Wheat, Alex Stead* and William Greene*

Wheat, Stead and Greene [J. Prod. Anal., (2019)] proposed a Student's t-half normal stochastic frontier model. This altered the standard stochastic frontier specification to allow for heavy tails in the noise distribution, enabling the model to satisfactorily handle outliers with respect to parameter estimation and the decomposition of residuals into noise and inefficiency, which was found to be significantly altered at the tails of the residual distribution. In this paper, we extend this work to a panel data context and consider a generalised true random effects model with Student's t distributed symmetric noise components. We discuss estimation via a multi-stage approach, and provide applications to real data, comparing the outputs to the standard generalised true random effects model.

Benchmarking the efficiency of water companies' retail businesses
Sam Williams, Christopher Pickard, Karli Glass and Anthony Glass*

The Water Services Regulatory Authority (Ofwat) is the economic regulator of the privatised water and sewerage industry in England and Wales. Ofwat imposes caps on the prices that water companies can charge their customers, at price reviews that occur every five years, the next being in

2019 (PR19). These caps are set in part based on an assessment of the companies' cost efficiency, using econometric cost models. In a recent development, Ofwat decided to require separate econometric cost benchmarking of the companies' domestic retail businesses at PR19. The lack of precedent in econometric efficiency benchmarking in the water retail sector presents a material challenge for those seeking to generate econometric estimates, but it also presents an opportunity to gain a deeper understanding of efficiency of firms' retail businesses. This paper develops a practical methodology for generating econometric retail efficiency estimates using available data. We estimate different model specifications for total retail (operating) costs, and bad debt and non-bad debt costs. Among other things, we find that the variables associated with bad debt (i.e., bill size and the deprivation measures) are often important determinants across the different model specifications.

The impact of British Columbia's carbon tax on manufacturers: A bi-production approach to estimate environmental and production efficiencies

Michael Willox*, Subal Kumbhakar and Oleg Badunenko

In this paper, we evaluate the impact of the British Columbia carbon tax on the production and environmental efficiency. Existing models lump these two types of efficiency together to estimate production technology that includes both good and bad outputs. However, this specification fails to satisfy the axioms of production technology and also confounds production and environmental efficiency. To address these shortcomings we model good and bad outputs as a bi-production technology which separates the production of good output as a function of good inputs from the bad outputs, which are a function of pollution-producing inputs. We demonstrate how bi-production technology establishes the link between good and bad outputs and allows for the determinants of both persistent and transient inefficiency to be estimated. We present an empirical example using establishment-level data for the manufacturing sector in British Columbia, Canada from 2004 to 2012. The findings suggest that British Columbia's carbon tax improved manufacturers' production efficiency, but for environmental efficiency the results were mixed. The carbon tax improved environmental efficiency in terms of greenhouse gas (GHG) and carbon monoxide (CO) emissions. However, the carbon tax had the opposite impact on environmental efficiency with respect to emissions of nitrogen oxides (NOx).

Does environmental safety production technique reduce farmers' profit efficiency? Evidence from small chili farms in Thailand

Suthathip Yaisawarng* and Wirat Krasachat

Conventional agriculture uses chemical fertilizers and pesticides that are harmful to environments and farmers' health whilst consumption of food with chemical residues may damage certain organs. A growing concern about food safety, health and environment have led Thai government to initiate the voluntary "Good Agricultural Practices" (GAP) program in 2003 in order to reduce the use of chemical fertilizers and pesticides, and chemical residues. GAP technology is more labor intensive than conventional farming and perhaps results in higher production costs. However, GAP farmers could command higher price for their product. Adopting GAP technology may dampen farmers' profit efficiency.

This paper uses DEA to calculate Nerlovian profit efficiency indicator and decompose it into directional technical efficiency and allocative efficiency. Our sample consists of 60 GAP and 40 conventional small chili farms in Thailand for the 2018 crop year. Inputs are cultivated land, labor, fertilizers, and other inputs such as seeds, pesticides, land preparation, and water irrigation. Output is fresh chili. We hypothesize that GAP farms, on average, are more profit efficient than conventional farms and that GAP farms, on average, would have higher maximum potential profit than conventional counterparts. If evidence supports our hypothesis, our results could motivate farmers who may be hesitated to adopt the GAP technology for financial reason.

Stock performance measurement based on data envelopment analysis approach with bounded variables

Patcharaporn Yanpirat* and Sajika Thammanukitcharoen

Financial investment of stock securities represents a portfolio selection problem. An extension from the single criterion has been employed by the multiple criteria decision making (MCDM) as an alternative approach in evaluating and selecting the stock securities. In MCDM, fixed weights are assigned to the particular criteria by the decision maker(s) and then all multiple criteria are aggregated into a single criterion by the selected appropriate method to make the decision. Data envelopment analysis (DEA) could be considered as a variant of MCDM. The importance weight are the decision variables in DEA generated by the linear programming model with the optimal values. The applications of the DEA in stock portfolio selection have the limited number of research papers. This paper is a new variant of DEA in making the decision in stock performance measurement when the data of input and output performance measures are bounded. Financial and nonfinancial performances in terms of quantitative and qualitative data are determined and based on the opinions of the group of decision makers via the empirical survey. A case based application is conducted on the selected stock securities in the Stock Exchange of Thailand based on financial data availability during the years of 2010 – 2017. For qualitative measures, they are used in terms of an average preference score. In determination of input and output factors for the DEA, step-wise regression analysis is conducted. Dealing with the risk of the stock performance during the relevant period, the interval estimation with lower and upper bounded of those financial measures are employed. The higher the variance, the higher the risk they are. Therefore, the lower-bound data for outputs and upper-bound data for inputs are used. The BCC output-oriented DEA model with bounded variable is implemented to rank the stock securities. The average relative efficiency scores revealed an effective and practical in measuring the reliable ranking of those stocks and act as enriched information for selecting stock portfolio in the broaden perspectives.

The relationship between technology transfer and skill-upgrading in developing countries: Evidence from plant-level data

Mahmut Yasar*

This article examines whether technology transfer (through importing and foreign direct investments) influence the skill-upgrading behavior of plants in developing countries. Using a variety of specifications, estimators, and robustness checks (including fixed effects quantile regression, correlated random effects Probit, and an Instrumental Variable (IV) approach based on the higher moments of the data), we find that importing and foreign direct investments likely facilitate transfer of technologies from advanced nations, which then results in skill-biased technological change and increased demand for skilled labor. These results indicate that, contrary to standard trade theory predictions, international linkages can lead to increased skilled labor demand and a widening of the skilled-unskilled labor wage gap in a developing country. Our findings support the theoretical explanation provided by Acemoglu (2003). Since the firms in developing countries mainly rely on the technologies developed in advanced nations, trade is expected to increase, rather than decrease, the skilled-unskilled labor wage gap in developing countries as well.

Integrating spatial spillover into stochastic frontier analysis for total factor productivity in China's agriculture

Fang Yin* and Wei Huang

Agriculture is human activity based on environment, which is driven by spatial processes, so total factor productivity indices vary spatially and temporally. When measuring the long-term agricultural growth, we incorporate spatial dependence into total factor productivity using stochastic frontier approach with an autoregressive specification of the inefficiency component of a compound error term. Based on the county-level data in China from 1980 to 2011, we use five major crops (rice, wheat, maize, soybean and potato) production as output, and input with agricultural labor,

machinery and sown area, fertilizer and pesticide. The first order of contiguity weight is selected for regression after investigating the effect of those alternative spatial weight matrix on the results. We found the total factor productivity from these crops grew rapidly during 1980 to 2011, with the efficiency of fertilizer and pesticide decreasing but the machinery using increasing. Moreover, there are drivers behind technical efficiency are correlated with where the crops are located, such as lower technical in northeast China, so that identify these drivers can have major impact on designing policies aimed at improving crops patterns.

Judicial efficiency in EU countries: A dynamic network model approach
Osman Zaim*

With the increased congestion in judicial systems of the EU countries, efficiency of justice delivery has become a major concern for the European Commission, which in turn prompted the establishment of "The European Commission for the Efficiency of Justice" (CEPEJ). In fact, a closer look at the indicators of efficiency (i.e., length of proceedings; number of incoming cases; pending cases; clearance rates every year) annually published by CEPEJ show a wide variability in the efficiency of justice provision among EU countries. A causal examination of the functioning of the judicial machinery, with increasing number of pending cases rolling over from one year to the next, in addition to settled disputes each year, suggests that efficiency analysis of the judicial system should be conducted within a dynamic network model framework. Although analysis of the judicial efficiency using Data Envelopment Analysis dates back to year 1982, a network modelling approach seem to have been neglected. Hence, this study, after formulating a dynamic network model for the operation of the judicial system, defines the reference technology and applies a variety of efficiency estimations for the EU countries (i.e., efficiency in the provision of resolved disputes; efficiency with respect to the optimal allocation of resolved and pending cases with the objective of achieving maximum number of resolved cases over a period of time).

Dynamics of total factor productivity change: An empirical analysis of Indian commercial banks
Mohammad Shahid Zaman* and Anup Kumar Bhandari

Since the inception of the financial deregulation programme, the Indian banking sector has undergone gradual but notable reforms. A key objective of these reforms was to create more diversified, profitable and productive banking system by limiting state interventions and fostering competition among banks. This study employs the data envelopment analysis (DEA) based Malmquist productivity index (MPI) to measure total factor productivity (TFP) change among Indian commercial banks and to evaluate the effect of bank specific determinants on their performance over the period of 1998-2015. To achieve this a two stage empirical analysis has been employed. In the first stage, we calculated efficiency scores in terms of TFP change and its components. Double bootstrap procedure of Simar and Wilson (2007) is applied to obtain bias corrected efficiency scores for each of the TFP components and to draw consistent inferences. The second stage regression analysis seeks to explain the variation in calculated efficiency scores to the set of bank specific variables like bank size, priority sector lending, other income to asset ratio, ownership and capital adequacy ratio. We hypothesize that the heightened competitive pressures after these reforms accompanied by the shift of banking business from traditional to non-traditional activities created good incentives for Indian banks to optimise their operations, thereby resulting in the increase in productivity.

Does it pay to be green? Investigating the relationship between firm economic performance and the EU ETS
Maja Zarkovic*

A persistent concern in the literature on climate policy is that the emissions abatement, achieved through the environmental regulation, in turn potentially adversely affects firms' economics performance. I investigate these issues in the context of the European Union Emissions Trading Scheme (EU ETS) and the German manufacturing sector, based on confidential administrative firm-

level production census data. As a measure of the economic performance, I estimate cost efficiencies and its determinants for narrowly defined industries, by means of the Stochastic Cost Frontier Analysis (SFA). In order to directly compare cost efficiencies across industries and treatment groups, I employ Meta Frontier Analysis (MFA). Using a Primal System Approach, I decompose cost efficiency into its two sources- allocative and technical efficiency. I analyze the causal impact of the EU ETS on cost-efficiencies in a difference-in-differences (DD) framework. Finally, I explore potential endogeneity issues in my SFA model. My results suggest that there is still potential to increase cost efficiency in most industries of the German manufacturing sector. The analysis of the cost efficiency drivers confirms that in most industries, exporting firms are more cost-efficient than their counterparts. In contrast, innovating firms and firms, which are regulated by the EU ETS, are found to be less cost-efficient than non-regulated firms. A subsample DD analysis cannot confirm that the EU ETS affected the cost efficiency of treated firms in a significant way. Allocative efficiency represents a much smaller source of higher costs than technical efficiency in most of the industries.

Dependence of the technical efficiency on the uncertainty of the inefficiency error
Anatoly Peresetsky, Yevhenii Shchetynin*, Alexey Zaytsev* and Subal C. Kumbhakar

Stochastic frontier analysis (SFA) production models usually imply heteroscedasticity of the inefficiency. The dependence of the technical efficiency (TE) on the uncertainty of the inefficiency error is unclear, as the functional relations between them are complex. We obtain the sign and the value of the dependence between the TE and the heteroscedasticity factors and the uncertainty of inefficiency error for the most used exponential and half normal distributions of the inefficiency error. For these distributions, more uncertainty leads to smaller TE, while our results suggest, that it can be the case that the marginal effect has a different sign for different meaningful uncertainty distributions. We accompany our theoretical findings with analysis of Russian manufacturing industry. The experiments support the evidence that the effect of the uncertainty of the inefficiency error on the technical efficiency is negative and significant for the exponential and the half normal distributions of inefficiency error.

Axiomatic aspects of productivity indexes with fixed weights and relevance of transitivity
Valentin Zelenyuk*

We discuss axiomatic aspects of productivity indexes with fixed weights and a relevance of transitivity for such indexes. In particular, we discuss several general versions of transitivity property inherent in the fundamental concepts of the production theory in the neo-classical economics. We also discuss the transitivity property for the index numbers, its relevance for some contexts and its serious problems for other contexts. In particular, we show serious problems of the so-proclaimed “proper” indexes and explain why Frisch (1936), in his Econometrica review-article on indexes, called such (and other) indexes as “absurd”.

A Bayesian data envelopment analysis approach for correcting bias of efficiency estimators: Evidence from the EU banking sector
Panagiotis Zervopoulos* and Konstantinos Triantis*

A two-stage Bayesian data envelopment analysis (DEA) method is developed to correct bias of efficiency estimators. Unlike existing Bayesian DEA methods, which provide statistical inference only to chance-constrained DEA models, this approach is appropriate for conventional DEA models yielding scores between zero and one. The validity of the new method’s estimators is supported by formal statistical justification, simulations and results obtained from scaled real-world data sets with a size ranging from 50 to 200 firms. Emphasizing simulations and real-world data sets, the bias-corrected Bayesian DEA estimators yielded by the new method have the closest proximity to their corresponding DEA scores even for samples with as few as 50 firms. These two types of estimators (i.e., Bayesian DEA and conventional DEA) resemble each other for sample sizes of 200 firms. The length of the confidence intervals of the Bayesian DEA efficiency estimators is deemed reasonable while preventing ambiguity in the interpretation of the results. The real-world data sets are drawn

from the European Union banking sector, and the variables are found in the sample firms' balance sheets (source: BankFocus).

Stochastic nonparametric estimation of productivity growth
Yu Zhao* and Hiroshi Morita*

The Malmquist index has been widely estimated in productivity literature with both deterministic nonparametric and stochastic parametric approaches. It is well known that the deterministic nonparametric approach commonly assumes away stochastic noise, while the stochastic parametric approach requires specific functional forms. To account for the impact of stochastic noise in a nonparametric setting, we suggest a consistent estimator of Malmquist index based on stochastic nonparametric envelopment of data (StoNED). To allow for a multiple-input multiple-output setting, we further adopt stochastic directional distance functions to estimate the Malmquist index. For an illustrative application, we investigate the productive performance of Japanese regional banks with a balanced panel over periods 2008 to 2017. Based on the results of the decomposition of the Malmquist index, we identify the main drivers of productivity change for each observation. We further discuss the policy implications of the empirical results.

Performance of Chinese banks over 2007–2015
Shirong Zhao* and Paul Wilson

This paper examines the performance of Chinese commercial banks before, during, and after the 2008 global financial crisis and the 2008-2010 China's 4 trillion RMB stimulus plan. Fully nonparametric methods are used to estimate technical efficiencies. Recently-developed statistical results are used to test for changes in efficiencies as well as productivity over time, and to test for changes in technology over time. We also test for differences in efficiency and productivity between big and small banks, and between domestic and foreign banks. We find evidence of the non-convexity of banks' production set. The data reveal that technical efficiency declined at the start of the global financial crisis (2007-2008) and after the China's stimulus plan (2010-2012), but recovered in the years later (2014-2015), ending higher in 2015 than in 2007. We find that productivity declined during and just after the China's stimulus plan (2009-2011), but recovered in the years later (2014-2015). However, there was no improvement in productivity from 2007 to 2015. We also find that the technology shifted downward from 2012 to 2013, and then shifted upward from 2013 to 2015. We provide evidence that in general big banks were more efficient and productive than small banks. Finally, foreign banks had higher efficiency and productivity than domestic banks only in 2008.

Efficiency contribution patterns in Chinese commercial banks
Ning Zhu*, Jens Leth Hougaard, Zhiqian Yu and Qian Niu

Apart from conventional DEA-based efficiency approach which is self-benchmark to assess individual bank's efficiency, in this paper, we employ a new approach based on each firm's marginal efficiency contribution by peer-benchmark, and effectively overcomes several drawbacks in conventional DEA approach to re-evaluate, not only levels, but also patterns, of performance of Chinese commercial banks. Specifically, we extend initial efficiency contribution approach by Zhu et al. (2018) with respect to a disaggregation into input and output specific efficiency contribution. We take large state-owned commercial banks and small-medium commercial banks in China into account, and are able to empirically test efficiency contribution gap in both levels and patterns between the two types of banks. Due to specific input and output efficiency contribution, we further explore the source of efficiency contribution, and target for structure optimization in the Chinese banking sector. Moreover, there are arguable differences between conventional DEA-based efficiency score and efficiency contribution index, but it finds reasonable supports for the latter one according to key performance indicators.

Assessing firm market power non parametrically: An example of the GB residential mortgage market

Minyan Zhu* and Antonio Peyrache*

Theory (Bresnahan and Reiss 1990,1991a,b) suggests we can use the observed relationship between the number of firms (N) and market size (S) to infer firms' market power: if we establish the minimum S required to support the incumbents and an entrant respectively, we learn how quickly incumbents' profitability erodes with firm entry. As margins per customer drops with N, the minimum S required to support each additional entrant has to be larger. It can be shown when margins per customer drops sufficiently fast with N, the observed N will be a concave function of the S. Based on this prediction, we derive the theoretical relationship between market output (more informative than N) and S depending on the intensity of competition, and empirically test it across thousands of geographic residential mortgage markets in Great Britain. To do so we estimate the relationship non parametrically to determine its shape at different quartiles instead of assuming one unique relationship across different geographic regions. To infer market power, a measure of output loss against the predicted maximum output given S is obtained. We then relate this measure of potential output loss in each region to the market share distribution of individual banks in the same region to explore the role of market power as well as firm heterogeneity in explaining the observed relationship between market output and market size.

The labour management factors and nursing homes efficiency: A semi-parametric approach

Marta Zieba*, Declan Dineen and Shiovan Niluasa*

The examination of efficiency and its determinants in relation to the nursing home industry is an important research area due to the fact that the population is aging increasingly rapidly while the labour force continues to decline. This study uses a rich primary data set comprised of 38 public and 72 private nursing homes in Ireland for the period 2008-2009, and applies alternative semi-parametric two-stage methods, such as Tobit regression with bootstrap DEA and double bootstrap DEA, to obtain unbiased estimates of technical efficiency and the efficiency determinants. Output is measured as total patient days, while inputs are measured as medical staff, non-medical staff and the number of beds in a nursing home unit. Various labour management factors related to medical staff, staffing levels and staff flexibility, together with other nursing home characteristics and environmental variables (e.g. size, ownership, case mix, location, age and chain status of the nursing unit) are included as efficiency determining variables. We find notable differences in the results between the conventional DEA and the semi-parametric DEA methods. Our findings suggest that nursing homes in Ireland are only 54% technically efficient on average, and that private or for-profit nursing homes are more technically efficient than the public units. Moreover, while the medical to non-medical staff ratio, and the labour to capital ratio have a positive effect on technical efficiency, there is a trade-off between efficiency and other labour management indicators such as staffing levels and staff flexibility.

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CONFERENCE SCHEDULE

MONDAY 10 JUNE 2019
Early career researcher day

TUESDAY 11 – THURSDAY 13 JUNE 2019
The main conference

CONFERENCE VENUE

Senate House, Malet Street,
London, WC1E 7HU

SOCIAL EVENTS

TUESDAY 11 JUNE 2019
Welcome evening reception at Senate House

WEDNESDAY 12 JUNE 2019
Conference dinner*
The Honourable Society of Gray's Inn
8 South Square London WC1R 5ET
**conference dinner is an additional registration item*

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