XV EUROPEAN WORKSHOP ON EFFICIENCY AND PRODUCTIVITY ANALYSIS (EWEPA)

LONDON, JUNE 12-15 2017

CONFERENCE PROGRAMME

EWEPA LONDON 2017

Loughborough University

CONTENTS

WELCOME TO EWEPA XV!

Dear Colleagues,

Welcome to the Fifteenth European Workshop on Efficiency and Productivity Analysis (EWEPA), hosted by Loughborough University's School of Business and Economics (SBE) at Senate House, a landmark building in the very centre of London.

This year, we are delighted to be welcoming a very lively, international mix of more than 250 participants, coming from 39 different countries and from six continents.

The conference spans four days.

Monday June 12th is the Early Career Research Day giving an excellent opportunity for PhD students and colleagues at the beginning of their academic career to present their work to an interested audience and receive feedback from a nominated experienced discussant.

The three main days of the conference are from Tuesday June 13th to Thursday June 15th. We have 63 parallel sessions over these three days, arranged around particular topics.

On all four days of EWEPA we also have plenary sessions with invited keynote speakers: Jaap Bos (Maastricht University), Per Agrell (Université Catholique de Louvain), Marc Ivaldi (Toulouse School of Economics), and Christopher O'Donnell (University of Queensland).

During the opening session on Tuesday, June 13th, we have the honour of awarding a Lifetime Achievement Award to Peter Schmidt for his seminal contributions to the field.

We are also very pleased to announce two feature sessions. The first is entitled "Can we 'learn' to be efficient?" and is led by Mette Asmild (University of Copenhagen), Jaap Bos (Maastricht University) and Konstantinos Triantis (Virginia Tech) with co-authors. The second is entitled "The UK productivity puzzle" and is led by Jonathan Haskel (Imperial College, London) with Diane Coyle, OBE (University of Manchester) and Rebecca Riley (National Institute of Economic and Social Research).

And finally, we are delighted to be formally announcing the latest research centre to be created at Loughborough's School of Business and Economics: the Centre for Productivity and Performance (CPP). The CPP, directed by Professors David Saal and Victor Podinovski, operates at the methodological interface between economics, management science and operational research. It conducts research that supports both private and public sector decisions and policy makers in evaluating and improving the performance and choices of firms, organisations and individuals.

We look forward to welcoming you to EWEPA XV and London!

Warm regards,

The EWEPA XV Organising Committee

COMMITTEES AND SPONSORS

Organising Committee, Loughborough University, UK

Anthony Glass

Karligash Glass

Victor Podinovski

David Saal

Robin Sickles

Scientific Committee

Jaap Bos	Maastricht University	Netherlands
Cinzia Daraio	Sapienza University of Rome	Italy
Tsu-Tan Fu	Soochow University	Taiwan
William H. Greene	New York University	USA
Emili Griffel-Tatjé	Universitat Autònoma de Barcelona	Spain
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Victor Podinovski	Loughborough University	UK
David Saal	Loughborough University	UK
Vania Sena	University of Essex	UK
Robin Sickles	Rice University (USA) and Loughborough University	UK
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

Cinzia Daraio	Sapienza University of Rome	Italy
Ole Bent Olesen	University of Southern Denmark	Denmark
David Saal	Loughborough University	UK
Valentin Zelenyuk	University of Queensland	Australia

Sponsors

The School of Business and Economics, Loughborough University, UK

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The Operational Research Society, UK

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.

Student participants that have not already confirmed their student status in correspondence with Claire Walker, please remember to bring the required confirmation (official letter from your university) to the conference.

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

Sessions

- All sessions, breaks, lunches and the reception 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 it is 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).

Catering

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

- A light breakfast (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 12th June.
- Welcome Reception on Tuesday 13th June. This includes a light buffet and drinks.

The Conference Dinner on Wednesday 14 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 Grand Connaught Rooms, 61-65 Great Queen Street, London, WC2B 5DA. The pre-booked tickets for the dinner will be available for collection at the EWEPA 2017 registration desk at Senate House. The conference dinner will commence at 19:30 with pre-dinner drinks served from 18:30.

CONFERENCE PROGRAMME AT A GLANCE

Monday 12 June - Early Career Research Day (ECRD)

9:00-10:30 Session
10:30-11:00 Break
11:00-12:00 Plenary Session for ECRD
12:00-13:00 Lunch
13:00-14:30 Session
14:30-15:00 Break
15:00-16:30 Session
16:30-17:00 Break
17:00-18:00 Session
18:00-19:00 Drinks Reception

Tuesday 13 June

9:00-9:45 Opening Session and recognition of the contribution of Peter Schmidt
9:45-10:45 Plenary Session 1
10:45-11:15 Break
11:15-12:45 Parallel Sessions (B)
12:45-14:00 Lunch
14:00-15:30 Parallel Sessions (C), includes feature session “Can we ‘learn’ to be efficient?”
15:30-16:00 Break
16:00-18:00 Parallel Sessions (D)
18:00-19:30 Welcome Reception

Wednesday 14 June

9:00-10:30 Parallel Sessions (A)
10:30-11:00 Break
11:00-12:30 Plenary Session 2
12:30-14:00 Lunch
14:00-15:30 Parallel Sessions (C), includes feature session “UK Productivity Puzzle”
15:30-16:00 Break
16:00-17:30 Parallel Sessions (D)
18:30 - Conference Dinner (additional registration item)

Thursday 15 June

9:00-10:30 Parallel Sessions (A)
10:30-11:00 Break
11:00-12:30 Plenary Session 3
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

SESSIONS ON 13-15 JUNE 2017

	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 13 June

TU-A 9:00-10:45	Opening Session, Special Award to Professor Peter Schmidt Plenary Session 1						
TU-B 11:15-12:45	Agriculture 1	SFA 1	Energy 1	DEA 1	Health 1	Justice	Public sector 1
TU-C 14:00-15:30	Feature Session 1	SFA 2	Energy 2	DEA 2	Health 2	Aggregation 1	Public sector 2
TU-D 16:00-18:00	Non-Parametric	Models 1	Energy 3	Applications 1	Health 3	Aggregation 2	Public sector 3
18:00-19:30	Welcome Reception						

Wednesday 14 June

WE-A 9:00-10:30	Agriculture 2	SFA 3	Profits & Performance	DEA 3	Banking 1	Environment	DEA 4
WE-B 11:00-12:30	Plenary Session 2						
WE-C 14:00-15:30	Feature Session 2	Agriculture 3	Applications 2	DEA 5	Fisheries	Wellbeing 1	Manufacturing 1
WE-D 16:00-17:30	Software	Agriculture 4	Energy 4	DEA 6	Education 1	Productivity change 1	Models 2

Thursday 15 June

TH-A 9:00-10:30	Bad outputs 1	Agriculture 5	Agriculture 6	Banking 2	Education 2	Productivity change 2	Manufacturing 2
TH-B 11:00-12:30	Plenary Session 3						
TH-C 14:00-15:30	Bad outputs 2	Agriculture 7	Agriculture 8	DEA 7	Education 3	Productivity change 3	Models 3
TH-D 16:00-17:30	Bad outputs 3	Agriculture 9	Food	DEA 8	Transportation	Manufacturing 3	Wellbeing 2
17:30-18:00	Closing Session						

MONDAY 12 JUNE
Early Career Research Day

8:00-9:00 Arrival and light breakfast

8:00-17:00 Registration

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

The presenting author is identified by *

9:00-10:30: ESTIMATION
Session Chair: Christopher O'Donnell

Iterative nonparametric S-shape estimation
Daisuke Yagi*, Andrew L. Johnson and Hiroshi Morita
Discussant: Ole Bent Olesen

Robustness to outliers in stochastic frontier analysis: The Student's t-half normal model vs. the normal-half normal model
Alexander Stead*, Phill Wheat and William Greene
Discussant: William Horrace

The impact of labour subsidy on total factor productivity
Pontus Mattsson*
Discussant: Christopher O'Donnell

10:30-11:00 Break

11:00-12:00: PLENARY SESSION

Heterogeneity in efficiency analyses: The good, the bad and the ugly
Jaap Bos*

12:00-13:00 Lunch

13:00-14:30: SECTORAL APPLICATIONS
Session Chair: Vania Sena

The impact of banking reforms on efficiency and competition in Ghana's banking sector
John Dadzie* and Alessandra Ferrari
Discussant: David Tripe

Are Mexican water utilities efficient? A nonparametric answer
Ulises Genis*, Nicolas Gravel and Nicholas P. Sisto
Discussant: David Saal

Stock vs. mutual insurers: Long-term convergence or dominance?
Philipp Schaper*
Discussant: Vania Sena

14:30-15:00 Break

15:00-16:30: REGIONAL APPLICATIONS
Session Chair: Cinzia Daraio

Heterogeneous spillovers among Spanish provinces: A generalized spatial stochastic frontier model
Alberto Gude*, Inmaculada Alvarez and Luis Orea
Discussant: Anthony Glass

The inefficiency of the missing middle
Hien Pham* and Antonio Peyrache
Discussant: Niels Christian Petersen

Size and productivity: A conditional efficiency approach for the Italian pharmaceutical sector
Pierluigi Toma* and Camilla Mastromarco
Discussant: Cinzia Daraio

16:30-17:00 Break

17:00-18:00: ESTIMATION
Session Chair: Valentin Zelenyuk

Adaptive LASSO for stochastic frontier models with many efficient firms
Hyunseok Jung*
Discussant: Christopher Parmeter

Direction selection in stochastic directional distance functions
Kevin Layer*, Andrew Johnson and Robin Sickles
Discussant: Valentin Zelenyuk

DRINKS RECEPTION
18:00-19:00, Senate House

TUESDAY 13 JUNE

8:00-9:00 Arrival and light breakfast

8:00-17:00 Registration

OPENING SESSION
9:00-9:45, Beveridge Hall

Special Award in recognition of the contribution of Professor Peter Schmidt

TU-A: PLENARY SESSION 1
9:45-10:45, Beveridge Hall
Session Chair: Shawna Grosskopf

Twenty years of frontier analysis in the service of regulatory economics: Perspectives and open questions
Per Agrell*
Discussant: Emili Grifell-Tatjé

10:45-11:15 Break

TU-B-1: AGRICULTURE 1
11:15-12:45, Beveridge Hall
Session Chair: Bob Chambers

Spatial regimes in farms' technologies
Cristina Salvioni*, Anna Gloria Billé and Roberto Benedetti

Do productivity convergence approaches converge? A meta-frontier Luenberger-Färe-Primont indicator decomposition in the French agriculture
K. Hervé Dakpo*, Yann Desjeux, Philippe Jeanneaux and Laure Latruffe*

Parsing US agricultural productivity growth: Weather, technology change, efficiency change, and inputs
Bob Chambers* and Simone Pieralli

TU-B-2: SFA 1
11:15-12:45, Woburn Room
Session Chair: Inmaculada Alvarez

Discrete approximation of the stochastic frontier model
Aljar Meesters and Christopher Parmeter*

Measuring spatial competition using efficiency spillovers
Anthony Glass*, Karligash Kenjegalieva and Thomas Weyman-Jones

A new stochastic frontier model with spatial effects in both noise and inefficiency terms
Luis Orea* and Inmaculada Alvarez*

TU-B-3: ENERGY 1
11:15-12:45, Montague Room
Session Chair: Endre Bjørndal

An application of stochastic frontier analysis to measure the influence of weather on electricity distribution businesses: Evidence from developing economies
Karim Anaya Stucchi* and Michael G. Pollitt

Efficiency analysis of electricity distribution by electric cooperative companies in the Philippines
Trishit Bandyopadhyay* and Fernando Roxas

Learning and adaptation under incentive regulation: A survey of Norwegian electricity distribution companies
Edda Nermoen Burheim, Elise Ivara Dahl, Endre Bjørndal* and Mette Bjørndal

TU-B-4: DEA 1
11:15-12:45, Brunswick Room
Session Chair: Joseph Atwood

Efficiency analysis with ratio measures
Ole Ben Olesen*, Niels Christian Petersen and Victor V. Podinovski

DEA models with ratio measures & potential ratio inefficiency
Ole Bent Olesen, Niels Christian Petersen* and Victor V. Podinovski

Radial efficiency metrics using worst-case reference points
Joseph Atwood*, Saleem Shaik and John Walden

TU-B-5: HEALTH 1
11:15-12:45, Bloomsbury Room
Session Chair: Nina Boogen

Spanish hospitals ranking with regard to performance and quality
Sophie Gorgemans*, Enrique Bernal-Delgado, Manuel Ridao-López and Micaela Comendeiro-Maalooe

The contribution of resident physicians to hospital productivity
Maria J. Perez-Villadoniga*, Ana M. Rodriguez-Alvarez and David Roibas

Cost efficiency of the Swiss nursing home sector
Nina Boogen*, Massimo Filippini and William Greene

TU-B-6: JUSTICE
11:15-12:45, Gordon Room
Session Chair: Maria Silva

De lege ferenda, de lege lata: Efficient management structures in legal systems
Samantha Bielen and Jaap Bos*

Network DEA, industry structure, and backlog congestion in the Italian justice sector
Antonio Peyrache and Angelo Zago*

Output-specific inputs in DEA: An application to courts of justice in Portugal
Maria Silva*

TU-B-7: PUBLIC SECTOR 1
11:15-12:45, Room G21A
Session Chair: Finn Førsund

Quality of life shift in Spanish municipalities (2001-2011)
Eduardo Gonzalez*, Ana Carcaba and Juan Ventura

Municipal efficiency, management forms for the waste collection service and the impact of environmental variables
Gemma Perez-Lopez*, Diego Prior and José Luis Zafra-Gómez

Measuring effectiveness of production in the public sector
Finn Førsund*

12:45-14:00 Lunch

TU-C-1: FEATURE SESSION 1
CAN WE "LEARN" TO BE EFFICIENT?
14:00-15:30, Beveridge Hall
Session Chair: Konstantinos Triantis

The space-time continuum (or, at least, movements in space over time)
Mette Asmild* and Dorte Kronborg

Cherry picking in the fall: How banks select takeover candidates
Jaap Bos*

Informing enterprise operational assessment through a complex adaptive systems efficiency measurement approach
Konstantinos Triantis*, Glen Lyddane and Oscar Herrera-Restrepo

TU-C-2: SFA 2
14:00-15:30, Woburn Room
Session Chair: Ian Wright

Endogeneity in panel data stochastic frontier model with determinants of persistent and transient inefficiency
Hung-Pin Lai* and Subal C. Kumbhakar

A flexible estimator for dynamic panel stochastic frontier models
Hung-Jen Wang*, Yu-Fan Huang and Sui Luo

Stationary points for parametric stochastic frontier models
Ian Wright* and William Horrace

TU-C-3: ENERGY 2
14:00-15:30, Montague Room
Session Chair: Gerald Granderson

Objectives and incentives: Evidence from the privatisation of Great Britain's power plants
Thomas Triebs* and Michael Pollitt

Estimation of cost efficiency in restoring biodiversity loss at hydropower plants in Sweden
Wondmagegn Tafesse Tirkaso*

Impact of the 1990 Clean Air Act, RECLAIM program, and ISO membership, on production cost and efficiency in the electric utility industry
Gerald Granderson* and Finn Førsund

TU-C-4: DEA 2
14:00-15:30, Brunswick Room
Session Chair: Paul Rouse

Determination of efficiency scores in a partially negative DEA problem using directional distance model
Subhadip Sarkar*

A DEA-based methodology to determine customer value
Laurens Cherchye, Bram De Rock, Bart Dierynck, Pieter Jan Kerstens* and Filip Roodhooft

A new metric for scale elasticity in data envelopment analysis
Maryam Hasannasab, Dimitris Margaritis, Israfil Roshdi and Paul Rouse*

TU-C-5: HEALTH 2
14:00-15:30: Bloomsbury Room
Session Chair: Sverre A.C. Kittelsen

Technical efficiency in the nursing home sector in Ireland – A stochastic frontier input distance function approach
Marta Zieba, Declan Dineen and Shiovan Ni Luasa*

Evaluating the cost of waiting lists: A primal approach
Ana Rodriguez-Alvarez, David Roibas* and Ana Gonzalez-Vidales

Scale and quality in Nordic hospitals
Sverre A.C. Kittelsen*

TU-C-6: AGGREGATION 1
14:00-15:30, Gordon Room
Session Chair: Valentin Zelenyuk

A family of superlative indexes under Hicks neutral technical change
Hideyuki Mizobuchi* and Valentin Zelenyuk*

Olley-Pakes decomposition with revenue and physical productivity measures
Giannis Karagiannis* and Suzanna-Maria Paleologou

Central limit theorems for aggregate efficiency
Leopold Simar and Valentin Zelenyuk*

TU-C-7: PUBLIC SECTOR 2
14:00-15:30, Room G21A
Session Chair: Pablo Arocena

A conditional directional distance function approach for measuring tax collection efficiency: Evidence from Spanish regional offices
Jose Manuel Cordero, Carlos Díaz*, Francisco Pedraja and Nickolaos Tzeremes

Efficiency measurement of Spanish municipalities: An application of conditional nonparametric frontiers
Jose Manuel Cordero, Carlos Diaz-Caro and Cristina Polo*

Explaining differences in efficiency: the case of local government literature
Francesco Aiello*, Graziella Bonnano and Luigi Capristro Bonanno

Allocating regional funds to local governments using a DEA-based resource allocation model
Pablo Arocena*, Fermín Cabasés and Pedro Pascual

15:30-16:00 Break

TU-D-1: NON-PARAMETRIC METHODS
16:00-18:00, Beveridge Hall
Session Chair: Camilla Mastromarco

Dimension reduction in nonparametric models of production
Paul W. Wilson*

Confidence intervals for efficiency scores in non-convex technologies
Luiza Badin*, Valentin Patilea and Leopold Simar

Nonparametric frontier estimation in the presence of noise: Recent developments
Jean-Pierre Florens, Leopold Simar* and Ingrid Van Keilegom

Predicting recessions in Italy: A nonparametric discrete choice models for time series
Camilla Mastromarco*, Leopold Simar and Valentin Zelenyuk

TU-D-2: MODELS 1
16:00-18:00, Woburn Room
Session Chair: Antonio Peyrache

Measuring capital value: A distance function approach
John Walden*, Rolf Färe and Shawna Grosskopf

Estimating and decomposing optimal shifts of the world technology frontier
Benjamin Hampf* and Jens Krüger

It takes two to tango: The impact of ICT and R&D on efficiency
Fabio Pieri, Ana Rincon Aznar, Francesco Venturini and Michela Vecchi*

A decentralized resource allocation industry model
Antonio Peyrache* and Prasada Rao

TU-D-3: ENERGY 3
16:00-18:00, Montague Room
Session Chair: Tooraj Jamasb

Electricity market reform performance in Sub-Saharan Africa: A parametric distance function approach
Adwoa Asantewaa*, Tooraj Jamasb and Manuel Llorca

Cost efficiency analysis of electric energy distribution sector under model uncertainty
Kamil Makieła and Jacek Osiewalski*

Regional comparisons of energy use efficiency in Indian manufacturing: An index number approach
Kankana Mukherjee*

The effect of institutions on sectoral performance: The case of electricity distribution in Indian states
Tooraj Jamasb*, Pavan Khetrapal, Manuel Llorca and Tripta Thakur

TU-D-4: APPLICATIONS 1
16:00-18:00, Brunswick Room
Session Chair: Daniel Wikström

Estimating efficiency of Italian water utilities by accounting for quality issues
Giovanna D'Inverno*, Laura Carosi, Andrea Guerrini and Giulia Romano

Temporal perception as a source of productivity measure distortion
Fabian von Schéele* and Darek Haftor

Identifying most productive networks derived using unstructured longitudinal data
Arun Bhattacharyya*

Procurement auctions for road resurfacing projects – The efficiency of regional procurement engineers
Jan-Eric Nilsson, Ivan Ridderstedt and Daniel Wikström*

TU-D-5: HEALTH 3
16:00-18:00, Bloomsbury Room
Session Chair: Gary Ferrier

Economies of scale: A meta-analysis on the scale of hospitals
Bart van Hulst* and Jos Blank

Economies of scope in health sector: The case of Portuguese hospitals
Diogo Ferreira*, Rui Marques and Alexandre Morais Nunes

Fuel poverty, health and subjective assessment: A latent class approach and application to the case of Spain
Manuel Llorca*, Tooraj Jamasb and Ana Rodríguez-Álvarez

An expanded decomposition of the Luenberger productivity Indicator with an application to the Chinese healthcare sector
Gary Ferrier*, Hervé Leleu and Zhiyang Shen

TU-D-6: AGGREGATION 2
16:00-18:00, Gordon Room
Session Chair: Kevin Fox

The fourth decomposition of aggregate total factor productivity change
Bert M. Balk*

Parametric decomposition of the input-oriented Malmquist productivity index: With Ethiopian agriculture
Anbes Tenaye Kidane*

Composite Indicators as generalized benefit-of-the-doubt weighted averages
Nicky Rogge*

Decomposing value added growth into explanatory factors
Erwin Diewert and Kevin Fox*

TU-D-7: PUBLIC SECTOR 3
16:00-18:00, Room G21A
Session Chair: Kristof De Witte

Which estimator to measure local governments' cost efficiency? Evidence from Spanish municipalities
Isabel Narbón Perpiñá*, María Teresa Balaguer Coll, Emili Tortosa Ausina and Marko Petrovic

The impact of public funds on firms' technical efficiency of the Italian performing arts sector
Concetta Castiglione, Davide Infante and Marta Zieba*

Overall, allocative and technical efficiency for Swedish district courts 2012–2015
Christian Andersson*, Fredrik Bonander and Jonas Månsson

Direct democracy and local government efficiency
Kristof De Witte* and Zareh Asatryan

WELCOME RECEPTION
18:00-19:30, Senate House

WEDNESDAY 14 JUNE

8:00-9:00 Arrival and light breakfast

8:00-17:00 Registration

WE-A-1: AGRICULTURE 2
9:00-10:30, Beveridge Hall
Session Chair: Jesus T. Pastor

Sustainability and efficiency of dairy sheep production systems in Castilla-La Mancha, Spain
Martiña Morantes, Rafaela Dios-Palomares, David Alcaide-Lopez-De-Pablo*, José Rivas and Antón García

The effect of cow comfort on productive efficiency: An application to Spanish dairy farms
José Antonio Pérez, David Roibás and Alan Wall*

A bounded weighted additive model to assess technical inefficiency: The case of milk production in Canada
Jesus T. Pastor*, Juan Aparicio, Magdalena Kapelko, Lidia Ortiz and Juan F. Monge

WE-A-2: SFA 3
9:00-10:30, Woburn Room
Session Chair: Thomas Weyman-Jones

Allowing for outliers in stochastic frontier models: A mixture noise distribution approach
Phill Wheat*, Alexander D. Stead and William Greene

Heteroscedastic generalized true random effects model (GTRE Het)
Oleg Badunenko, Astrid Cullmann, Subal Kumbhakar and Maria Nieswand*

Energy efficiency and stochastic frontier analysis using the Box-Cox transformation functional form
Thomas Weyman-Jones*, Júlia Mendonça Boucinha and Catarina Feteira Inácio

WE-A-3: PROFITS, PRODUCTIVITY AND BUSINESS PERFORMANCE
9:00-10:30, Montague Room
Session Chair: Jos Blank

Business models interaction: Walmart vs Kmart
Humberto Brea-Solís, Ramon Casadesus-Masanell and Emili Grifell-Tatjé*

An integrated analysis of cash flow, economic costs and economic profitability
David Saal* and Pablo Arocena

The profitability function as an alternative theoretical framework for productivity measurement: An application to the Dutch drinking water sector
Jos Blank*

WE-A-4: DEA 3
9:00-10:30, Brunswick Room
Session Chair: Victor Podinovski

A DEA-based incentive mechanism under central management
Mohsen Afsharian*, Heinz Ahn and Emmanuel Thanassoulis

A DEA-based incentives system under varying degrees of decentralisation
Mohsen Afsharian, Heinz Ahn and Emmanuel Thanassoulis*

DEA models with weight restrictions: What is the meaning of optimal weights?
Victor Podinovski*

WE-A-5: BANKING 1
9:00-10:30, Bloomsbury Room
Session Chair: Joseph Paradi

Risk preference and efficiency in Chinese banking
Ning Zhu*, Yanrui Wu, Bing Wang and Zhiqian Yu*

Achieving a sustainable cost efficient business model in banking: The case of European banks
Oleg Badunenko*, Subal Kumbakhar and Ana Lozano-Vivas*

Improving pension funds' performance by considering an expert's opinions and mutual funds' information using DEA
Joseph Paradi* and Maryam Badrizadeh*

WE-A-6: ENVIRONMENT
9:00-10:30, Gordon Room
Session Chair: Jose L. Zofio

The efficiency and distributional effects of China's carbon mitigation policies: A distance function analysis
Atakelty Hailu* and Chunbo Ma

Operational and environmental performance in wine sector: A unified efficiency DEA-based assessment
Samah Jradi*, Tatiana Bouzdine-Chameeva, Bernard Delhomme and Anicia Jeagler

Environmental productivity change in world air emissions: A new Malmquist-Luenberger index approach
Jose L. Zofio*, Juan Aparicio, Javier Barbero, Magdalena Kapelko and Jesus Pastor

WE-A-7: DEA 4
9:00-10:30, Room G21A
Session Chair: Theodoros Skevas

Evaluating mergers a-priori: The case of European air navigation service providers
Nicole Adler, Ole B. Olesen and Nicola Volta*

Measuring corporate sustainability performance
Tadesse Engida*, Xudong Rao and Alfons G.J.M. Oude Lansink

Derivation of netput shadow prices under different levels of pest pressure
Theodoros Skevas* and Teresa Serra

10:30-11:00 Break

WE-B: PLENARY SESSION 2
11:00-12:30, Beveridge Hall
Session Chair: David Saal

Efficiency analysis in competition and regulation policy
Marc Ivaldi*
Discussant: Robin Sickles

12:30-14:00 Lunch

WE-C-1: FEATURE SESSSION 2
THE UK PRODUTIVITY PUZZLE
14:00-15:30, Beveridge Hall
Session Chair: Jonathan Haskel

The speakers are:

Jonathan Haskel (Imperial College London)

Diane Coyle, OBE (University of Manchester)

Rebecca Riley (National Institute of Economic and Social Research, UK)

WE-C-2: AGRICULTURE 3
14:00-15:30, Woburn Room
Session Chair: Fabian Frick

Productivity change analysis of Polish dairy farms after Poland's accession to the EU – An output growth decomposition approach
Kamil Makieła*, Jerzy Marzec and Andrzej Pisulewski

Efficiency in U.S. farm production and the role of distribution (structure and conduct) of farm programs: Evidence from a national survey
Saleem Shaik* and Hisham El-Osta

Deregulation and productivity: Empirical evidence on dairy production
Fabian Frick* and Johannes Sauer

WE-C-3: APPLICATIONS 2
14:00-15:30, Montague Room
Session Chair: Ørjan Mydland

The efficiency analysis of the shale revolution in the global oilfield market
Binlei Gong*

The opportunity costs of financial fair play regulations in professional football – An efficiency analysis
Ronan Gallagher and Barry Quinn*

Lost economies of scope and merger gains in the Norwegian electricity industry
Ørjan Mydland*

WE-C-4: DEA 5
14:00-15:30, Brunswick Room
Session Chair: Wen-Chih Chen

Sorting items with DEASort in ABC classes
Alessio Ishizaka*, Rita Cavallieri and Francesco Lolli

A stepwise benchmarking method for finding projection points involving returns to scale properties
Akram Dehnokhalaji* and Narges Soltani

Recent updates in DEA computation
Wen-Chih Chen*

WE-C-5: FISHERIES
14:00-15:30, Bloomsbury Room
Session Chair: Antonio Alvarez

Hooked on quotas: Analysis of the performance of the Icelandic small vessel fleet before and after the introduction of ITQs
Arnar Mar Buason and Sveinn Agnarsson*

An evaluation of the Norwegian fisheries management system for the conventional coastal vessels
Ruth Pincinato*, Frank Asche, Andreea Cojocaru and Kristin Roll

Decomposing revenue efficiency into price and technical efficiency. An application to fisheries
Antonio Alvarez*, Lorena Couce and Lourdes Trujillo

WE-C-6: WELLBEING 1
14:00-15:30, Gordon Room
Session Chair: Mikulas Luptacik

The relationship between democracy index and corruption perception index and a nation's innovation efficacy and productivity
Yung-Hsiang Lu and Yi-Chen Lee*

The impact of human capital on technical efficiency: Evidence from Eastern European and Central Asia countries
Salem Gheit*

Measuring income inequalities beyond Gini coefficient
Mikulas Luptacik* and Eduard Nezinsky*

WE-C-7: MANUFACTURING 1
14:00-15:30, Room G21A
Session Chair: Ana Camanho

A green bargain? The impact of an energy saving program on productivity growth in China's iron and steel industry
Thomas Geissmann*, Massimo Filippini, Valerie Karplus and Da Zhang

Export intensity-firm performance nexus: New evidence from basic metals industry in India
Anup Kumar Bhandari* and Vipin Valiyattoor

Manufacturing strategies and operations performance: A frontier approach
Ana Camanho*, Behrouz Arabi, Maria Silva and Rui Sousa

15:30-16:00 Break

WE-D-1: SOFTWARE
16:00-17:30, Beveridge Hall
Session Chair: Ali Emrouznejad

Productivity and efficiency analysis software: A survey of the options
Cinzia Daraio*, Kristiaan Kerstens, Thyago C. Nepomuceno* and Robin C. Sickles

Frontier visualization algorithms for FDH models
Vladimir Krivonozhko* and Andrey Lychev

Measuring efficiency of decision making units: Software update for advanced users
Ali Emrouznejad* and Emmanuel Thanassoulis

WE-D-2: AGRICULTURE 4
16:00-17:30, Woburn Room
Session Chair: Ioannis Skevas

Large and small farms excel in Brazil
Steven Helfand, Nicholas Rada* and Marcelo Magalhaes

Agricultural productivity and farm size in Malawi, Tanzania, and Uganda: A total factor productivity approach
Jacques Julien* and Boris E. Bravo-Ureta

Productivity growth in German dairy farming using a dynamic inefficiency specification: A Bayesian approach
Ioannis Skevas*, Grigorios Emvalomatis and Bernhard Bruemmer

WE-D-3: ENERGY 4
16:00-17:30, Montague Room
Session Chair: Nilkanth Kumar

Efficiency-based system configuration assessment: The case of micro-grids
Taylan Topcu, Konstantinos Triantis* and Matthew Robinson

Equilibrium specification of technology: Implications for energy demand and capacity utilization analysis
Sourour Baccar*

The role of energy and investment literacy for residential electricity demand and end-use efficiency
Julia E. Blasch, Nina Boogen, Massimo Filippini and Nilkanth Kumar*

WE-D-4: DEA 6
16:00-17:30, Brunswick Room
Session Chair: Mette Asmild

The good, the bad and the socially responsible: A production analysis approach to firm's performance ranking
Daniela Puggioni* and Spiro E. Stefanou

Nonparametric production analysis with unobserved heterogeneity
Laurens Cherchye, Thomas Demuynck, Bram De Rock and Marijn Verschelde*

Examining production conditions
Mette Asmild*, Tomas Balezentis and Jens Leth Hougaard

WE-D-5: EDUCATION 1
16:00-17:30, Bloomsbury Room
Session Chair: Jill Johnes

Predicting financial sustainability in a competitive higher education marketplace
Andrew McConnell* and Jill Johnes

Does the governance of the HE system affect the efficiency of universities? A comparison of German and Italian public institutions
Tommaso Agasisti and Sabine Gralka*

Efficiency and VC pay: Exploring the value conundrum
Deborah Allcock, Jill Johnes* and Swati Virmani

WE-D-6: PRODUCTIVITY CHANGE 1
16:00-17:30, Gordon Room
Session Chair: Bernhard Mahlberg

Source of industrial output growth and productivity decomposition analysis for selected Asia countries using DEA Malmquist and KLEMS data bases
Tsu-Tan Fu* and Yih-Ming Lin

Reconsidering non-neutral technical change
Jaap Bos and Ming Li*

Total factor productivity change based on partial productivities
Juan Aparicio, Bernhard Mahlberg* and Jesus T. Pastor

WE-D-7: MODELS 2
16:00-17:30, Room G21A
Session Chair: Kristiaan Kerstens

Computational complexity of shape constrained estimation
Andrew Johnson*

Parsimonious functional forms for multiple-output cost functions: Output-output relationships
Arne Henningsen*

Short- and long-run plant capacity notions: Definitions and comparison
Giovanni Cesaroni, Kristiaan Kerstens* and Ignace Van de Woestyn

THURSDAY 15 JUNE

8:00-9:00 Arrival and light breakfast

8:00-17:00 Registration

TH-A-1: BAD OUTPUTS 1
9:00-10:30, Beveridge Hall
Session Chair: Rolf Färe

Bad outputs
Sushama Murty and R. Robert Russell*

Weak disposability in nonparametric production analysis: Which reference technology is appropriate?
Manh D. Pham* and Valentin Zelenyuk

Employment and pollution abatement: A nonparametric cost function approach
Shawna Grosskopf*, Rolf Färe*, Carl Pasurka and Ron Shadbegian

TH-A-2: AGRICULTURE 5
9:00-10:30, Woburn Room
Session Chair: Supawat Rungsuriyawiboon

How to minimize the production cost of marine cage lobster aquaculture in Vietnam
Au Ton Nu Hai*, The Bui Dung and Stijn Speelman

Short-run and long-run efficiency and their determinants: A study of crop production in Norway
Gudbrand Lien*, Subal C Kumbhakar and Habtamu Alem

Examining the economic performance of Chinese farms: A dynamic efficiency and adjustment cost approach
Supawat Rungsuriyawiboon* and Yanjie Zhang

TH-A-3: AGRICULTURE 6
9:00-10:30, Montague Room
Session Chair: Boris E. Bravo-Ureta

Cross-country comparison of agricultural productivity between the United States, Canada and Australia: The superlative versus the quantity-only based index
Yu Sheng*, Xinpeng Xu and Eldon Ball

Measuring scale efficiency of farms across regions - A Bayesian stochastic metafrontier approach
Stefan Wimmer* and Johannes Sauer

Technology and management gaps using stochastic frontiers with 2-round panel data: Preliminary evidence from an agricultural development project
Boris E. Bravo-Ureta*, William Greene, Mario González-Flores, Lina Salazar and Daniel Solís

TH-A-4: BANKING 2
9:00-10:30, Brunswick Room
Session Chair: David Tripe

Persistent effects in loan loss provisioning concerning Italian banks
Aristeidis Dadoukis*, Giulia Fusi and Richard Simper

The effects of regional differentials in macroeconomic conditions on cost structures of banks
Yuzhu Li* and Richard Simper

Translog cost function estimation: Banking efficiency
Toby Daglish, Oliver Robertson, David Tripe* and Laurent Weill

TH-A-5: EDUCATION 2
9:00-10:30, Bloomsbury Room
Session Chair: Jose M. Cordero

Impact evaluation through frontier methods
Daniel Santín and Gabriela Sicilia*

What is the quality of European universities? Model uncertainty, endogeneity and testing of unobserved heterogeneity
Cinzia Daraio*, Leopold Simar and Paul W. Wilson

Using fuzzy DEA to assess efficiency in education: An application to American schools
Juan Aparicio, Jose M. Cordero* and Lidia Ortiz

TH-A-6: PRODUCTIVITY CHANGE 2
9:00-10:30, Gordon Room
Session Chair: Amparo Sanchis

The productivity puzzle and credit constraints: Is there a cohort effect?
Mustapha Douch*

Misallocation and intersectoral linkages
Latchezar Popov* and Sophie Osotimehin

The effect of the cycle on within-industry productivity convergence: Evidence from the EU
M. Dolores Añón-Higón, Juan A. Máñez, Maria E. Rochina-Barrachina, Amparo Sanchis* and Juan A. Sanchis

TH-A-7: MANUFACTURING 2
9:00-10:30, Room G21A
Session Chair: Tommy Lundgren

Three-step returns to scale analysis using SFA: Russian manufacturing industry
Irina Ipatova*

Internal devaluation versus productivity: Competitiveness of manufacturing across Europe
Charles-Henri Di Maria* and Chiara Peroni

The rebound effect in Swedish heavy industry
Tommy Lundgren*, Golnaz Amjadi and Lars Persson

10:30-11:00 Break

TH-B: PLENARY SESSION 3
11:00-12:30, Beveridge Hall
Session Chair: Kevin Fox

Productivity analysis in the presence of uncertainty
Christopher O'Donnell*
Discussant: Kristiaan Kerstens

12:30-14:00 Lunch

TH-C-1: BAD OUTPUTS 2
14:00-15:30, Beveridge Hall
Session Chair: Shawna Grosskopf

How to integrate material balance issues in productive efficiency analysis: Review of models and practical use
Ludwig Lauwers* and Jef Van Meensel

Do we use fertilizer efficiently? Performance of fertilizer overuse in China's arable agricultural production
Wei Huang* and Li Jiang

Recent developments in modeling technology with unintended outputs
Shawna Grosskopf*, Rolf Färe, Tommy Lundgren and Moriah Bostian

TH-C-2: AGRICULTURE 7
14:00-15:30, Woburn Room
Session Chair: Tomasz Czekaj

Does market information improve technical efficiency? A stochastic frontier analysis for Peruvian farmers
Joanna Kamiche-Zegarra* and Boris Bravo-Ureta

Technical efficiency and household human capital: A data envelopment analysis (DEA)
Emanuele Zucchini*

Multi-output technologies and changing market conditions: Animals' health and dairy farms' efficiency in Denmark
Tomasz Czekaj*, Christine Windfeld Hansen, Jakob Vesterlund Olsen and Anna Plum

TH-C-3: AGRICULTURE 8
14:00-15:30, Montague Room
Session Chair: Timo Sipiläinen

Who is harvesting our grapes? Estimating the impact of the European migrant crisis on vineyard productivity in Southern Italy
Stefan Seifert* and Marica Valente

Input-specific managerial and program inefficiency in the Malaysian dairy industry: A multi-directional efficiency analysis
Nurul Aisyah Mohd Suhaimi*, Yann de Mey and Alfons Oude Lansink

Is there a fair comparison of technical efficiency for conventional and organic dairy farms?
Timo Sipiläinen*

TH-C-4: DEA 7
14:00-15:30, Brunswick Room
Session Chair: Romain Petiot

Size efficiency reconsidered
Kenneth Løvold Rødseth*, Paal Brevik Wangsness, Finn R. Førsund and Halvor Schøyen

The assessment of corporate social responsibility of mining firms
Renata Oliveira*, Andreia Zanella and Ana Camanho

Emphasizing price effects in the US economy sectors 1987-2014
Raluca Parvulescu, Jean-Philippe Boussemart, Hervé Leleu and Karina Shitikova*

Analysis of French logistics services providers performance using data envelopment analysis
Romain Petiot* and Laurent Cavaignac*

TH-C-5: EDUCATION 3
14:00-15:30, Bloomsbury Room
Session Chair: Vania Sena

Measuring performance and productivity growth in education with PISA: The case of Latin-American countries
Sergio Perelman* and Daniel Santin

A multi-level cost model with sub-DMU specific economies of scale: An application to Dutch school boards and schools
Thomas Niaounakis* and Jos Blank

Is less really more? Academic performance of first-year students in Italy in the wake of two institutional reforms
Vania Sena*, Sergio Destefanis, Roberto Zotti and Cristian Barra

TH-C-6: PRODUCTIVITY CHANGE 3
14:00-15:30, Gordon Room
Session Chair: Bill Weber

Biased technological change in the Japanese non-life insurance industry
Takayoshi Nakaoka*, Takuya Urakami and Hiroyuki Inaba

Accounting for Intangible assets in Russia's growth in 1995 – 2014, comparative perspective
Ksenia Bobyleva*

Technical change and von Neumann's coefficient of uniform expansion
Rolf Färe, Daniel Primont and Bill Weber*

TH-C-7: MODELS 3
14:00-15:30, Room G21A
Session Chair: Darek Haftor

Trade friction analysis: Ranking trade barriers in a network model
Flavius Badau*

Socioemotional wealth and productivity differences between family and non-family firms: A distributional analysis
Sarah Creemers, Mark Vancauteren*, Wim Voordeckers and Ludo Peeters

IT complementarities and software programmers' productivity: Results and insights from an online experiment
Natallia Pashkevich and Darek Haftor*

15:30-16:00 Break

TH-D-1: BAD OUTPUTS 3
16:00-17:30, Beveridge Hall
Session Chair: Moriah Bostian

The proof of the pudding is in the eating: Empirical analyses of five environmentally-adjusted efficiency models
K Hervé Dakpo*, Finn Førsund, Ludwig Lauwers* and Jef Van Meensel*

Assessing substitutability among undesirable outputs using parametric directional output distance function: A Monte Carlo analysis
Viktor Khanzhyn*

Prevention or cure? Evaluating the tradeoffs between emissions abatement measures
Moriah Bostian*, Rolf Färe, Shawna Grosskopf and Tommy Lundgren

TH-D-2: AGRICULTURE 9
16:00-17:30, Woburn Room
Session Chair: Suthathip Yaisawarng

Yield gaps and technical efficiency: The case of wheat farmers in Afghanistan
Aziz Karimov* and Rajiv Kumar Sharma

The effects of model specification and assumptions about the nature of inefficiency on cost efficiency scores: A case study of Norwegian cropping farms
Habtamu Alem*, Gudbrand Lien and J. Brian Hardaker

Nerlovian profit efficiency of small-sized, owner-operated sugarcane farms in the Northeastern region of Thailand
Suthathip Yaisawarng* and Thanaporn Athipanyakul

TH-D-3: FOOD
16:00-17:30, Montague Room
Session Chair: Magdalena Kapelko

Measuring price efficiency in infant milk market
Roxani Karagiannis* and Giannis Karagiannis

Industrial concentration and technical inefficiency: A dynamic approach
Maman Setiawan*, Grigorios Emvalomatis and Alfons Oude Lansink

Measuring productivity change accounting for adjustment costs: Evidence from the food industry in the European Union
Magdalena Kapelko*

TH-D-4: DEA 8
16:00-17:30, Brunswick Room
Session Chair: Rafael Leme

A formula for efficiency based on DEA scores
Chris Tofallis*

Facilitating supplier development in construction supply chain: Data envelopment analysis approach
Abdollah Noorizadeh* and Antti Peltokorpi

Efficiency analysis for project portfolio adjustment
Guilherme Marcondes and Rafael Leme*

TH-D-5: TRANSPORTATION
16:00-17:30, Bloomsbury Room
Session Chair: Laurent Cavaignac

Measuring the efficiency of Italian airports: How to counter unexpected shocks
Graziella Bonanno*, Tiziana D'Alfonso and Alberto Nastasi

The relationship between costs and travel time reliability of train operating companies
Andrew Smith* and Manuel Ojeda-Cabral

Airports efficiency over time
Ane Elixabete Ripoll-Zarraga***,** Cecilio Mar-Molinero**,** Fabiola Portillo Pérez de Viñaspre

20 Years of DEA of airports efficiency: A meta-analysis
Laurent Cavaignac* and Romain Petiot*

TH-D-6: MANUFACTURING 3
16:00-17:30, Gordon Room
Session Chair: J.A. Sanchis-Llopis

Credit constraints and technical efficiency: Evidence from Vietnamese manufacturing firms
Chau M. Chu*, Kausik Chaudhuri and Sandra Lancheros

The role of services in enhancing the technical efficiency of Indian manufacturing firms: An analysis using the stochastic production frontier method
Sonia Mukherjee*

Markups, exports and R&D: Evidence for Spanish manufacturing
J.A. Máñez, M.E. Rochina-Barrachina and J.A. Sanchis-Llopis*

TH-D-7: WELLBEING 2
16:00-17:30, Room G21A
Session Chair: Ana Rodríguez-Álvarez

Welfare growth accounting revisited
Tarek Harchaoui* and Paul Willemsen

Regional wage frontiers in pre & post-crisis Spain
Joanna Maria Bashford Fernández*

Fuel poverty and well-being: A consumer theory and stochastic frontier approach
Ana Rodríguez-Álvarez*, Luis Orea and Tooraj Jamasb

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

ABSTRACTS

Evaluating mergers a-priori: The case of European air navigation service providers
Nicole Adler, Ole Bent Olesen and Nicola Volta*

In this research we develop a modified data envelopment analysis model in order to evaluate the a-priori potential efficiency gains resulting from mergers and acquisitions. The model identifies optimal combinations of mergers endogenously in order to maximize the potential efficiency gains from an industry perspective or at the firm level. We also restrict potential merger composition as a function of spatial limitations. The model aims to provide insights for organizations evaluating horizontal mergers and acquisitions and for public authorities regulating public or monopolistic services. We apply the proposed approach to estimate optimal mergers across the European air navigation service provider market and to compare the results to mergers selected by the European regulator (that have yet to be implemented despite laws dating back to 2004).

A DEA-based incentive mechanism under central management
Mohsen Afsharian*, Heinz Ahn and Emmanuel Thanassoulis

This paper proposes a DEA-based incentives mechanism for centrally managed multi-unit organisations. Our approach is embedded within the principal-agent theory when there is asymmetry of information between principal and agent, so the principal needs to apply incentivisation schemes to induce the agents to take desired actions. Here, it is assumed that the central decision maker (the principal) aims to minimize the overall input consumption by the units (the agents) given the aggregated outputs they produce; alternatively, it is desired to maximize the overall output production by all units given the aggregated inputs they use. The existing DEA-based incentive mechanism is modified in order to devise an incentive compensation formula under these circumstances. The proposed approach is centred on computing the super-efficiency of the whole system of operating units with and without the involvement of each unit in turn in order to provide incentives. We extend further the approach to deal with the possibility that in some cases a unit can mask the impact of another unit as a benchmark. We suggest a practical approach for overcoming this problem so that all units that are similarly good performers are rewarded appropriately to incentivize them to better performance. Data from a small German retail bank is used to illustrate our method.

A DEA-based incentives system under varying degrees of decentralisation
Mohsen Afsharian, Heinz Ahn and Emmanuel Thanassoulis*

The paper focuses on hierarchically structured organisations with a large set of operating units. The central body wishes to incentivise the units to operate as efficiently as possible. Using a standard Data Envelopment Analysis (DEA) approach for this purpose, each operating unit could estimate its own targets. However, this decentralized scenario is inappropriate for a centralised organisation in which a central body wishes to optimise the performance of the system of units as a whole, redistributing resources if need be. This paper proposes a DEA-based approach for incentivising the units of a hierarchically structured organisation in order to optimise the performance of the units collectively while at the same time the targets are not too demanding for inefficient units.

Does the governance of the HE system affect the efficiency of universities? A comparison of German and Italian public institutions
Tommaso Agasisti and Sabine Gralka*

Utilizing a novel specification of the stochastic frontier analysis, we assess the impact of the governance system in higher education on the efficiency of the regulated public universities. Conclusions regarding the influence of the centralized versus federal system are drawn by separating short-term (transient) and long-term (persistent) efficiency, while controlling for unobserved

institution specific heterogeneity. While transient efficiency can be interpreted in the context of a chosen year (and conducted to manage short-run actions), persistent efficiency reflects long-term challenges caused by the management on the institutional or state level. When comparing two differently regulated countries the systematic differences in the second term can therefore be judged as an index primarily representing the influence of the governance system on the efficiency of the universities, and/or other structural differences between countries.

It is the first time that persistent inefficiency is considered when evaluating the higher education sector of two countries. The comparison shows which governance systems leads to a generally higher efficiency value and therefore expands the literature regarding the efficiency of universities as well as the governance of them in a fundamental way. We can take advantage of a novel dataset including characteristics of institutions from the Italian higher education sector, as a representative of the central administrative system, and German universities, where education is a responsibility of the federal states, for an exceptional long period of time from 2001 to 2011.

Twenty years of frontier analysis in the service of regulatory economics: Perspectives and open questions
Per Agrell*

Regulators worldwide, in particular in energy network regulation for gas and electricity operators, use the tools of frontier analysis for actual practice. This application area is both a source of inspiration to researchers and (sometimes) a subject of dispute between regulators and their firms. In this talk, we give an overview of the application of efficiency analysis in actual regulation in various jurisdictions, with an emphasis of the key insights that have driven the development forward. Contrary to common belief, there is much more to network regulation than DEA models – the regulators today are integrating stochastic frontiers, outlier detection, service quality models, ex ante merger analysis, partial weight restrictions and subvector efficiency measures in their modelling. However, there are also a number of open questions that wait for solutions, including some surprisingly elementary stages such as model specification tests and calibration of incentive parameters.

Explaining differences in efficiency: the case of local government literature
Francesco Aiello*, Graziella Bonnano and Luigi Capristro Bonanno

One learns two main lessons from the efficiency literature on local governments. 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, dimension, 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 360 efficiency scores retrieved from 54 papers published from 1993 to 2016. The meta-regression 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 a fixed effect unrestricted Weighted Least Squares (WLS) regression.

Due to its main research focus, that is measuring the impact of potential sources of heterogeneity on local governments 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 deregulation in local government, 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 studies focusing on technical efficiency provide higher efficiency scores than works evaluating cost efficiency. Using panel data in primary studies allows researchers to obtain

higher efficiency of local government 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. Furthermore, we find that primary papers evaluating the efficiency of European municipalities provide higher efficiency scores that studies focusing on USA, Africa, Asia and Latina America. We also provide evidence that the estimated efficiency scores in primary papers increase with the level of regulation in local governments. Importantly, MRA results are robust to the potential outliers in efficiency and sample size distributions.

The effects of model specification and assumptions about the nature of inefficiency on cost efficiency scores: A case study of Norwegian cropping farms
Habtamu Alem*, Gudbrand Lien and J. Brian Hardaker

Stochastic frontier (SF) models are used to evaluate the performance of farms and to identify factors that explain differences in performance. Technical evaluations in previous studies have revealed how well farmers operate the physical production processes. However, there is a need to examine the cost efficiency of the farm businesses. The purpose of this study is to compare the performance of various panel data models in estimating cost efficiency. This analysis is based on unbalanced farm-level panel data for 1991-2013 from 455 Norwegian farms specialized in crop production with 3885 observations. We estimated seven SF panel data models grouped into four categories regarding the assumptions used to the nature of inefficiency. The estimated cost efficiency scores varied from 33% to 93%, showing that the results are sensitive to how the inefficiency is modeled and interpreted.

Efficiency and VC pay: Exploring the value conundrum
Deborah Allcock, Jill Johnes* and Swati Virmani

Remuneration packages awarded to top executives have risen sharply in recent years, gaining external criticisms around them being un-deserved, or awarded even where there is evidence of poor performance. The pay of university vice chancellors has also been increasing in recent years, yet the link to university performance or efficiency has not been investigated with such scrutiny as executive pay in the private sector. Arguably, the income flow to universities and the changes to student funding create dynamics in a more complex principal-agent context. In our view, exploring executive pay and efficiency in the higher education context thus become important, where incentives and efficiency should be examined in the context of best value to funders.

This research extends previous studies by estimating the relationship between vice chancellors' pay and various explanatory variables including an array of measures of 'performance'. Performance can be interpreted as: effectiveness, i.e. achievement of outcomes; efficiency i.e. the ability to achieve the best possible output from given inputs (measured using data envelopment analysis); or financial stability, measured using HEFCE's financial security index.

We use a comprehensive data set covering the period from 2009 to 2015 and control for other factors such as vice chancellor's human capital, university mission and local and other institutional aspects.

Decomposing revenue efficiency into price and technical efficiency. An application to fisheries
Antonio Alvarez*, Lorena Couce and Lourdes Trujillo

The policies intended to limit fishing effort need a better understanding of the fishing technology. In particular, these policies should be based on the marginal productivity of the different inputs which vary greatly across time and boats. Additionally, the efficiency with which fishermen operate the technology is an important variable to take into account. For these reasons, in recent years, there has been an increasing interest in studying the performance of fishing fleets.

This paper uses a panel data set of fishing boats in order to estimate the technology and the technical efficiency of the artisanal fleet in the island of Gran Canaria. Since we are interested in

finding which variables explain the differences in technical efficiency across boats, we estimate a model that allows technical inefficiency to be a function of some explanatory variables. While some papers have recently applied these types of models, we use the Hadri (1999) model. To the best of our knowledge, this is the first attempt to apply this model to fisheries data.

One of the main interests of our research is to analyze the effect on catch landings of the variables that can be easily modified by the fishermen. In particular, we are interested in analyzing the role of days spent fishing. In Gran Canaria there is a great variability in the number of fishing trips per month across boats and we would like to assess the possible effect of regulating days at sea in order to reduce fishing effort.

Overall, allocative and technical efficiency for Swedish district courts 2012–2015
Christian Andersson*, Fredrik Bonander and Jonas Månsson

This paper investigates overall efficiency for Swedish district courts between 2012 and 2015. Previous research has studied technical efficiency of district courts, however, overall efficiency has not, to our knowledge, been studied. To measure overall efficiency we follow Färe (1989). Cost efficiency is decomposed into allocative or price efficiency and technical efficiency. Allocative efficiency captures overspending on inputs that either could be due to input prices or to input mix, while technical efficiency target excess use of inputs. Very detailed data from the Swedish National Courts Administration (SNCA) is used. Outputs of courts are multi-dimensional and to analyse a limited number of courts (in our case 48 per year) some aggregation is needed and heterogeneity within groups of outputs has to be handled. A common problem in previous research is that outputs from courts are used without any weighting of different types of cases and matters. As pointed out by Santos & Amado (2014) the average duration of different types of proceedings could be one option to minimise aggregation problems. We have access to average hearing times for both cases and matters and use that information to aggregate subgroups of cases and matters within all output dimensions. To select the final model the strategy presented in Wagner & Shimshak (2007) is followed. The final model has four inputs (judges, lawyers, other personnel and court space) and its prices and four outputs (criminal cases, civil cases, other cases and matters).

The results indicate that most of the overall inefficiency is due to allocative inefficiency. Allocative efficiency could either be due to paying more than necessary or having a non-optimal mix of inputs. The policy conclusions that can be reached from the research is, however, far from trivial. For example it is a common knowledge that wage heterogeneity exist: personnel in large cities earn on average more due to higher cost of living and rent for office space is higher so to some extent our analysis just confirm this. On the other hand, our research gives an estimate on how much extra it cost to allocate courts in large cities. Re-location into less costly cities or areas would reduce costs, but it might also have less favourable consequences such as transport costs for clients and problems recruiting qualified staff.

The effect of the cycle on within-industry productivity convergence: Evidence from the EU
M. Dolores Añón-Higón, Juan A. Máñez, Maria E. Rochina-Barrachina, Amparo Sanchis* and Juan A. Sanchis

In this paper we analyze within-industry TFP convergence in the European Union during the period 2003-2014. We first identify the frontier firms and explore the determinants of the distance to the frontier. We find that, relative to non-frontier firms, frontier firms, both at the European level and at national level, are larger, have higher mean value added, earnings and profits, and pay higher average wages per employee. Regarding persistence of firms in the frontier/non-frontier status, we observe first that, generally, persistence is higher among frontier manufacturing firms than among frontier firms in non-financial market services. The analysis of the determinants of the TFP gap between frontier and non-frontier firms within industries suggests that, in general, larger and more labor skilled firms are closer to the frontier. In contrast, the older and more capital-intensive firms are further away from the frontier. These results differ when analyzing separately manufacturing,

non-financial market services and other production, and also when considering the pre- and the post-crisis periods.

Using fuzzy DEA to assess efficiency in education: An application to American schools
Juan Aparicio, Jose M. Cordero* and Lidia Ortiz

Many studies devoted to efficiency performance evaluation in the education sector are based on data aggregated at school level (measures of central tendency) calculated from the average values of students belonging to the same school. Although this is a common way of summarizing data from the original observations (students), it is not less true that this approach neglects the existing dispersion of data, which may become a serious problem if variability across schools is high. In order to overcome this drawback, we resort to fuzzy Data Envelopment Analysis (DEA). This approach allows us to deal with imprecise data and the notion of fuzziness. In particular, this paper applies the methodology proposed by Kao and Liu (2000) ["Fuzzy efficiency measures in data envelopment analysis", Fuzzy Sets and Systems, 113: 427-437] to measure the efficiencies of a sample of American schools participating in PISA 2012 with some fuzzy information (the socio-economic status of students together with their test scores in reading and maths). The idea is to transform a fuzzy radial DEA model to a family of conventional crisp radial DEA models by applying the α-cut approach. Since the efficiency measures are expressed by membership functions rather than by crisp values (the means), more information is provided from the point of view of management.

Total factor productivity change based on partial productivities
Juan Aparicio, Bernhard Mahlberg* and Jesus T. Pastor

In contexts where monetary prices for commodities do not exist or the observed prices differ from the economic prices due to market failures or governmental interferences, usual approaches to estimate productivity change over time rely on the Malmquist index and the Luenberger indicator, which are both based on distance functions. In contrast to these two approaches, Portela and Thanassoulis (2006) introduced a total factor productivity index based upon observed values only, showing its easy interpretation, its properties and how it can be decomposed into the traditional efficiency change, technical change and an 'unusual' residual term. In this paper, we endow Portela and Thanassoulis' index with a new decomposition without resorting to a residual component. Additionally, we characterize the index through the satisfaction of several specific index tests.

Allocating regional funds to local governments using a DEA-based resource allocation model
Pablo Arocena*, Fermín Cabasés and Pedro Pascual

This paper presents an application of a DEA-based model of resource allocation to determine the distribution of the funds by a regional government among the municipalities under its jurisdiction. Such grants, together with the local taxes collected by the local governments, are the two main income sources to support the provision of services by the municipalities. The idea behind our formulation is the optimization of the allocation of the global regional budget, while taking into account efficiency, effectiveness and equity considerations across municipalities. We apply this model to the allocation of the current transfers to the municipalities within the autonomous community of Navarre in northern Spain.

Electricity market reform performance in Sub-Saharan Africa: A parametric distance function approach
Adwoa Asantewaa*, Tooraj Jamasb and Manuel Llorca

Electricity Sector Reforms (ESR) are multi-faceted technical, economic and structural changes seeking to achieve simultaneously a set of diverse but interrelated objectives. The original 'textbook' models implemented by earlier reformers including Chile, Argentina and the United Kingdom in the 1990's pursued operational efficiency on the presumption that market mechanisms would also improve social welfare and environmental quality.

However, the initial adverse outcomes of reforms seemed to re-affirm the pejorative views of critics that reforms are in the rent-seeking interests of private capital over considerations of social welfare as manifest in their negative distributional impacts. This was coincident with a period where the environmental agenda emerged with full force further and the transition to a low carbon economy became a global priority. Consequently, reforms began to actively pursue efficiency, sustainability and welfare objectives simultaneously with the result been the transformation of a previously unidimensional program into a multi-objective one. These new models present new Pareto optimality challenges as the set objectives are interdependent and requires trade-offs to ensure balance. Consequently, there seem to be an intellectual basis to re-visit the theoretical rationale of ESR and re-specify the models and techniques accordingly. It is time to move away from the unidimensional modelling approach of evaluating ESR performance to one that captures the multi-faceted nature of the reform outcomes.

This study utilizes a multi-output, multi-input distance function approach to evaluate the performance of a multi-objective ESR program for a set of 40 Sub-Saharan African (SSA) countries from 2000 to 2012. Plant load factor , transmission and distribution losses, installed generation capacity per capita, consumption per capita and percentage of renewables in the generation mix are the performance indicators observed while a set of seven reform steps which are scored using an extension of the Besant- Jones (2002) scorecard approach are used as inputs. The inefficiency term 'u' modelled using the stochastic frontier approach is explained using the six dimensions of the World Bank governance indicator.

Preliminary results show no correlation between the extent of ESR and performance in most countries. However, country level endowment played a role in performance but the type of resource mattered. Countries with wide availability of fossil fuels such as coal and natural gas performed better than those with renewable resources except for geothermal. It also shows that institutional factors have a significant impact on electricity market reform performance. Specifically, countries that are more politically stable, a strong judiciary are perceived to be less corrupt performed better in the program.

Examining production conditions
Mette Asmild*, Tomas Balezentis and Jens Leth Hougaard

In this paper we argue that one element of the competitiveness of an industry is its production conditions, and that these can be represented by the frontier of the production possibility set as estimated by Data Envelopment Analysis and related methods.

Having access to a large dataset of dairy farms across Europe from the Farm Accountancy Data Network, enables us to empirically estimate the differences in the production conditions for milk producers in Denmark, and those encountered by their competitors across Europe. The results are surprising, since the Danish milk producers, renowned for their high technical efficiency based on KPIs like milk/cow, are actually facing some of the worst production conditions when the costs of production are considered.

The space-time continuum (or, at least, movements in space over time)
Mette Asmild* and Dorte Kronborg

In a large dataset of American banks observed over a long period of time, we investigate the units' movements over time within a six-dimensional production space. The aim is to identify global- or club convergence, or possible divergence, not only in size but also with respect to the input- or output mixes. This enables us to answer questions like whether (all) the banks are becoming more similar over time or whether it appears like some of them are becoming more specialized than others. Besides examining the observations' actual locations, we also investigate the movements of an estimated production frontier over time, in order to determine which dimensions any frontier movements are mainly occurring in.

Radial efficiency metrics using worst-case reference points
Joseph Atwood*, Saleem Shaik and John Walden

We present a radial efficiency metric whereby firm efficiency is measured relative to a "worst-case" performance level or norm termed the "worst-case reference point" (WCRP). Worst case reference points may result from regulatory requirements or may be estimated using firm level input/output data. In either case, the resulting efficiency metric is a radial measure that can be estimated using conventional directional DEA (DDEA) linear programming. Figure 1 plots a set of example data in addition to two WCRF qDDEA-alpha efficiency frontiers. The WCRF efficiency metric is computed as the distance from the blue WCRF point to the firm's input-output observation divided by the distance from the WCRP to the quantile-efficient frontier's starred points. The resulting efficiency metric is unit-less with a value of less than one, one, or greater than one respectively indicating "inefficiency", "efficiency", or "super-efficiency". We examine the statistical properties of the WCRP efficiency metrics using nCm subsample bootstrapping. The paper concludes with an application examining the use of WCRP efficiency metrics in a fisheries management problem.

Equilibrium specification of technology: Implications for energy demand and capacity utilization analysis
Sourour Baccar*

In this paper we attempt to provide evidence on the structure of technology, when capital is treated as quasi-fixed input. However instead of choosing a single functional form as an approximation to the variable cost function, modified versions of three commonly used flexible functional forms are estimated: (i) the Translog, (ii) the Generalized Leontief and (iii) the Symmetric Generalized McFadden. While maintaining the same data set and the same assumptions about technology, an empirical comparison of alternative flexible models is attempted. A theoretical framework is developed which allows for derivation and estimation of long run elasticities, capacity utilization and their derivatives in situations where full static equilibrium is not a tenable assumption. This original method holds for either single or multiple fixed input models. A specification test is proposed and conducted to assess the adequacy of the full equilibrium model and find that the long run equilibrium hypothesis is rejected. The derivatives of long run elasticities with respect to energy price give insight on the evolution of technological parameters in response to fluctuations of energy prices. The issues analyzed in this paper are not merely of theoretical interest, but are also of practical concern.

Trade friction analysis: Ranking trade barriers in a network model
Flavius Badau*

This study extends the trade resistance model developed in Badau [Ranking Trade Barriers Using Data Envelopment Analysis. European Journal of Operational Research, 247 (3), 978–986, (2015)] in order to achieve a more comprehensive view of trade. Badau (2015) modeled the interaction between trade costs and trade barriers in a Johansen's Capacity Utilization production framework with trade barriers as (variable/fixed) inputs and trade costs as outputs. With additional data on trade volumes and trade barriers (non-tariff barriers and trade facilitation), the framework of that model is extended to a two-stage network model for a more comprehensive view of trade that captures the simultaneous interaction between trade barriers, trade costs, and trade volumes. The first stage (sub-technology) of the network includes trade costs as a function of trade barriers, while the second stage (final technology) includes trade volumes as a function of trade costs. Overall, the production network consists of trade barriers as primary inputs, trade costs as intermediate inputs, and trade volumes as final outputs. Estimation of the network model through Data Envelopment Analysis allows trade barriers to vary to any level, and more specifically to those optimal levels that allow for the greatest simultaneous reduction in trade costs and increase in trade volumes. In order of impact, the results suggest that trade facilitation and port-related factors impact trade the most, followed by non-tariff trade barriers, transportation-related factors, and lastly tariffs.

Confidence intervals for efficiency scores in non-convex technologies
Luiza Badin*, Valentin Patilea and Leopold Simar

The envelopment estimators popular in efficiency analysis rely on the assumption that all the observations fall on the same side of the frontier. The nonparametric Free Disposal Hull (FDH) estimator introduced by Deprins et al. (1984) represents the smallest free disposal set covering all the observations and the technical efficiency of an arbitrary producer is measured with respect to the boundary of the free disposal hull of the whole sample. The asymptotic sampling distribution of the FDH estimator derived in Park et al. (2000) is of Weibull type, depending on the dimension of the input x output space and an unknown parameter, which has to be estimated. Park et al. (2000) propose a consistent estimator, but their Monte-Carlo experiments show rather poor performances of the estimator in terms of accuracy.

The objective of our paper is to provide alternative estimators for the parameter of asymptotic Weibull distribution, easy to implement and fast to compute in practical situations. The behavior of the resulting estimators and their effect on the achieved coverage of the confidence intervals for the efficiency scores are investigated and compared through a Monte-Carlo simulation study.

Heteroscedastic generalized true random effects model (GTRE Het)
Oleg Badunenko, Astrid Cullmann, Subal Kumbhakar and Maria Nieswand*

In this paper, we develop a stochastic frontier model, which allows for heteroscedastic error terms (GTRE). This approach controls for systematic and non-systematic differences in the production process through estimating their impact on persistent and transient inefficiency directly. Although, conceptually GTRE models relate persistent inefficiency to some sort of systematic issue and transient to non-systematic managerial shortcomings (Filippini and Greene, 2016), yet they technically do not involve this. We extend the existing GTRE models by introducing heteroscedasticity of the error terms and refer to it as a heteroscedastic GTRE (hetGTRE).

We apply the model to a newly created and rich dataset of German electricity distribution operators between 2006 and 2012 with a total number of about 1200 observations. Germany provides an interesting case to analyze given its political history, which notably affected the electricity sector. After the reunification of Germany a substantial restructuring process of Eastern German firms took place in the early 1990'ies whereas firms in Western Germany remained unconcerned. Given that the restructuring process involved a large amount of investments, we hypothesize that this intervention has long-term impacts on the efficiency of this capital-intensive firms. More precisely, we expect that firms located in Eastern Germany exhibit a higher persistent efficiency on average due to systematic impact on production that has been induced by the reunification process. Whereas we expect the transient efficiency of Eastern German firms too be rather similar to the transient efficiency of firms located in Western Germany because managerial inefficiency is assumed to be non-systematic.

Our preliminary results show that the location of firms, i.e. being either located in Eastern or Western Germany, affects persistent inefficiency such that firms in Eastern Germany appear to perform better. Further, the variance in persistent efficiency is much smaller for East than for West German firms. From this we conclude that firms in Eastern Germany have benefited from the massive intervention in terms of persistent efficiency. We further find no significant differences in transient efficiency between the electricity distributors, which supports our hypothesis. The results also imply that the generally increasingly ramshackled infrastructure in Western parts of Germany could be boosted by restructuring and investments.

Achieving a sustainable cost efficient business model in banking: The case of European banks
Oleg Badunenko*, Subal Kumbakhar and Ana Lozano-Vivas*

Although the business model (BM) is the most fundamental task of the bank's management to ensure sustained operation and profitability of a bank, it has become a subject of supervisor's

scrutiny due to the recent financial crisis when failing banks were rescued with public funds and supervisors were criticized around the world. Since one of the reasons for the financial crisis was that some banks had (and still have) unsustainable BMs, sustainable BMs are, for example, on the top of the ECB's agenda.

Given its relevance, it is important to understand implication that BM characteristics have for bank performance in general and for cost efficiency in particular. Optimizing operating efficiency has become a necessity for the survival of bank. This is one of the top priorities for a bank, especially during times when revenue-generating opportunities are sub-optimal.

This paper uses the Herfindahl index to measure how concentrate the bank is in items of the asset, funding or income portfolio. We analyze efficiency of bank BM along three business dimensions, viz., assets, funding and income, for the European Banking Industry. We apply recently developed four component heteroskedastic cost model to investigate effects of three business dimensions to time-varying bank cost inefficiency while controlling for bank effects and persistent cost inefficiency. In the proposed model we assume bank-specific effects and persistent cost inefficiency random and distributed independently and identically across banks but time-varying cost inefficiency and noise terms are made heteroscedastic in terms of assets, funding and income diversification for each bank. Note that we are interpreting heteroscedasticity of the noise term as risk thereby meaning whether different forms of diversifications are risk enhancing or risk reducing.

The fourth decomposition of aggregate total factor productivity change
Bert M. Balk*

An industry is an ensemble of individual firms (decision making units) which may or may not interact with each other. Similarly, an economy is an ensemble of industries. In National Accounts terms this is symbolized by the fact that the nominal value added produced by an industry or an economy is the simple sum of firm-, or industry-specific nominal value added. From this viewpoint it is natural to expect there to be a relation between (aggregate) industry or economy productivity and the (disaggregate) firm- or industry-specific productivities.

In an earlier paper (Statistica Neerlandica 2015) three (time-) symmetric decompositions of aggregate value-added-based total factor productivity change were developed. In the present paper a fourth decomposition will be developed. A notable difference with the earlier paper is that the development is cast in terms of levels rather than indices. Various aspects of this new decomposition will be discussed and links with decompositions found in the literature unveiled.

Efficiency analysis of electricity distribution by electric cooperative companies in the Philippines
Trishit Bandyopadhyay* and Fernando Roxas

Unlike most of its neighbors in Asia, the Philippines followed a dissimilar path to developing its distribution networks all throughout the island nation. Whereas other countries, even an archipelago like Indonesia used the power of big government to develop their distribution networks, the Philippines followed the US model and employed the Electric Cooperative (EC) model to electrify the rural areas, resulting in a highly fragmented industry structure. This research looks at whether the excessive fragmentation is detrimental to efficient EC operations and whether the ECs contend with constant or variable returns to scale. A double bootstrapping procedure in a two-stage (Simar & Wilson, 2007) process where non-parametric estimates of efficiencies from a Data Envelopment Analysis (DEA) model are subjected to regression analysis in order to account for exogenous factors that might affect the performance of 90 ECs using data from National Electricity Administration, Philippines. The data set indicates that efficiency is unrelated to the relative size classifications used to categorize ECs. Regression models which included both technical and non-technical parameters shows that gender, the seniority (age in years) of the GM, length of tenure as GM and the number of languages spoken in the workplace show significant statistical relationship with derived efficiency measures.

Export intensity-firm performance nexus: New evidence from basic metals industry in India
Anup Kumar Bhandari* and Vipin Valiyattoor

Technological advancement nowadays, in general and that in the communication system, in particular, coupled with extremely intensive integration of the different economies across the globe makes today's world as if a 'global village'. Given this backdrop, we pose the question whether participation of a firm in the global market (in the form of export of its finished produces into the world-wide end points) has any effect on its performance or not? We have studied basic metal industry in India during 2000-01 to 2014-15. To justify a bit about our selection, basic metal industry not only occupies an important position in Indian economy, its prosperity has further crucial implications as well on the growth of the entire Indian economy, in general and few of her sectors like agriculture, transportation, communication and infrastructure, and others, in particular. We follow a two-stage methods to do our empirical analyses. Data Envelopment Analysis (DEA) methodology is used at the first stage to analyse input-output data of 147 companies of Indian basic metal industry, collected from Centre for Monitoring Indian Economy (CMIE) of Prowess data base to have their technical efficiency scores as a by-product. We have also done some allied analyses, in this connection, to have an understanding on the possibility of technological heterogeneity, if any, across different of its sub-sectors and five such sub-groups have been chosen for this purpose, namely (a) aluminium and aluminium products; (b) castings and forgings; (c) metal products; (d) steel; and (e) steel pipes and tubes. And, therefore, we have Technology Closeness Ratio (TCR), a measure indicating how close a sub-sectoral technology is towards the overall technology defined/estimated for the entire sector as a whole, for each of these five chosen sub-sectors. In fact, we do observe some evidence of such technological heterogeneity across the chosen sub-sectors of the industry. To analyze the impact of the export intensity of a firm on its performance, econometric techniques are used at the second stage, considering technical efficiency scores of a firm (obtained at the first stage) as explained variable with its export intensity as an explanatory variable. To maintain the standard ceteris paribus condition, other factors (that may also influence performance) like transport and communication infrastructure, credit intensity, age and size of a firm, total technology expenditures intensity and marketing intensity are used as control variables. Unfortunately, however, we observe some evidence of significant negative nexus between export intensity and firm performance, which is in contrast to the 'learning by exporting' proposition anticipated in the earlier literature and we thus conjecture that it may probably be termed as a 'sunset industry' and that even applies more prominently for the more recent years. For other variables, firm size has a significant positive effect on its performance throughout.

Identifying most productive networks derived using unstructured longitudinal data
Arun Bhattacharyya*

With the progress of Social Network Analysis (SNA) business applications of social networks has been growing leaps and bounds. In this context identifying networks, classification of networks, targeting based on networks, statistical modeling of networks have made significant progress. Formation, stability and robustness of networks also gaining momentum in business applications. However, two important aspects of SNA have not received much traction in business application yet are Dynamic (Social) Network Analysis (DNA) and the Productivity aspect of networks, i.e., identification of most productive networks. Networks are by default dynamic. It evolves and dissolves over time. Science around dynamic network formation is in progress. This paper focuses on productivity aspect, which is crucial for business, when networks are Dynamic. Given a 'Big-Data' (16.5M records) and a set of business rules, a DNA can generate a large number of networks. With limited resources, only a subset of that can (should) be targeted; and this subset should contain the ones that would maximize the objective function of the business. Business objective could be Profit, Revenue, Output maximization or Cost Minimization; constrained or non-. From business perspective not all networks are target-worthy. The proposed paper addresses this particular issue - how to find the best set or most productive set of networks, given business objective.

De lege ferenda, de lege lata: Efficient management structures in legal systems
Samantha Bielen and Jaap Bos*

Many Western countries struggle with large inefficiencies in their legal systems, leading to very long lead times in legal decision making. In this paper, we attempt to compare a legal system as it is (de lege lata) with the same legal system as it should be (de lege ferenda). For the latter, we use two approaches, that allow us to assess the extent to which a legal system - under ideal conditions - can be expected to self organize. The first approach consists of assessing the impact of a number of policy proposals on efficiency in the legal system. The second approach consists of an approach where we use an evolutionary computing algorithm the let the system self organize. For our empirical analysis, we make use of a unique data set of Belgian courts.

The profitability function as an alternative theoretical framework for productivity measurement: An application to the Dutch drinking water sector
Jos Blank*

Profit efficiency is generally regarded as the ultimate measure of efficiency (Färe & Primont, 1995). Aside from technical inefficiencies the measure also includes inefficiencies that arise from misallocations in the output and input mix. However, it is questionable whether profit efficiency is the most suitable approach from a social perspective. In the public sector a more appropriate benchmark is the one that delivers the highest social value for every (tax) dollar spent on a public service. A more suitable efficiency measure therefore follows from the profitability function that describes the relation between profitability – the ratio of revenue over cost – and input and output prices. This function – indicated by Kumbhakar (2011) as "the return to the outlay" function is a more suitable approach from a social perspective. Whereas in a profit maximizing framework firms expand production until marginal cost equals marginal revenue, in a profitability framework firms expand production until the cost elasticity equals the revenue elasticity (both with respect to production).

In this (rather theoretical) paper we will present the profitability function and derive its optimal input and output demand equations, similar to Hotelling's Lemma (Hotelling, 1932). The system of a profitability function and its demand functions will be empirically applied to the drinking water services in the Netherlands. Based on a data set on the time period 2005-2014 it is shown that the estimated model fits the data well.

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The role of energy and investment literacy for residential electricity demand and end-use efficiency
Julia E. Blasch, Nina Boogen, Massimo Filippini and Nilkanth Kumar*

This paper estimates the level of transient and persistent efficiency in the use of electricity in Swiss households using the generalized true random effects model (GTREM). A panel dataset of 1,994 Swiss households from 2010 to 2014 collected via a household survey is used to estimate an electricity demand frontier function. We further investigate whether energy and investment literacy have an influence on the household electricity consumption. The results show significant inefficiencies in the use of electricity among Swiss households, both transient (11%) and persistent (22%). We note that the high persistent inefficiency is indicative of structural problems faced by

households and systematic behavioural shortcomings in residential electricity consumption. These results indicate a considerable potential for electricity savings and thus reaching the reduction targets defined by the Swiss federal council as part of the Energy Strategy 2050, wherein end-use efficiency improvement is one of the main pillars. The results support a positive role of energy and, in particular, investment literacy in reducing household electricity consumption. Policies targeting an improvement of these attributes could help to improve efficiency in the use of energy within households.

Accounting for Intangible assets in Russia's growth in 1995 – 2014, comparative perspective
Ksenia Bobyleva*

In recent decades, long-term economic growth in major developed economies is determined by factors of production that are most susceptible to new technologies - form the basis of the knowledge economy. But ICT alone could not be identified as the main driver of cross-industry productivity growth. Even more often we can see evidence of the importance of intangible assets in determining productivity and economic growth. In a broad sense, the intangibles are defined as objects with no physical meaning, but income-generating or creating the conditions for its receipt.

One of the key questions that we dealt with is what role intangible assets play in explaining the gap in productivity between Russia and OECD countries. In this case we pay attention to industry level analysis. Which industries are driven by intangible assets most of all? Which of these industries in Russia and how they relate to the other developed and transition economies?

Accounting for intangible assets as a factor of economic growth is possible using neoclassical approach of building economic growth accounts, for the first time introduced by Solow (1957) and further developed for the level of industries by Jorgenson et al (Jorgenson, Gollop, Fraumeni 1987). Using this framework, measures of output growth can be decomposed into the contributions of inputs and productivity within a consistent accounting framework. This approach allows to assess the relative importance of labor, capital, and intermediate inputs to growth, and to derive measures of multifactor productivity growth (MFP). The output contribution of an input is measured by the growth rate of the input, weighted by that input's income shares.

For the main we proceed from the fact that the component of intangible assets incorporated in capital, but also we try to better understand the factors hidden behind MFP in the light of intangibles. For capital as a whole the paper applies the concept of capital services along with traditional capital stocks, taking into account intellectual property product, which under SNA 2008 includes more assets (computer software and databases; research and development; mineral exploration; artistic originals).

This paper examines component of Intangible Assets in growth accounting during 10 years period since 1995. We have analyzed the trends taking place before and after the 2008 crisis. The growth accounting results for Russia we gain from Russian KLEMS and they are directly comparable to those of other countries that participate in the World KLEMS project.

Rapid growth in Russia since the end of 1990-s has been mainly driven by investment and productivity growth was limited to a handful of services industries. Extensive sectors attracted labour and capital away from efficient sectors, that provides an important potential source of catch up growth in many industries by reallocation of factor inputs. It appears that increasing of intangible assets in the growth will be an indicator of a positive trend, even if they did not yet.

Measuring the efficiency of Italian airports: How to counter unexpected shocks
Graziella Bonanno*, Tiziana D'Alfonso and Alberto Nastasi

This paper investigates the efficiency of Italian airports. It uses a sample of 45 airports and covers the period from 2007 to 2016. The contributions of the analysis are twofold. The first novelty comes from the consideration of low cost flights operated to/from Italian airports. To the best of our

knowledge, this aspect has been considered in the case of American airports. Since American airports are mostly public, while Italian airports are mostly private, we expect different findings as to the efficiency of vertical relationship between airports and airlines. Secondly, the estimations of efficiency refer to some recent methodological advances in the Stochastic Frontier approach (SFA) which relax the hypothesis of independence between the two error terms of a stochastic frontier, that is, the erratic and the inefficiency components (Bonanno et al., 2017). In a context like the airport industry current managerial decisions are influenced by past natural shocks, thereby rendering the assumption of independence too stringent. A shock may impact on the random error component and, at the same time, may affect future decisions, influencing the inefficiency component. This makes the random noise and the inefficiency of airport two dependent variables rather than independent as assumed in standard SFA models. Our findings provide airport managers with a robust tool to suitably deal with unexpected frequent shocks and increase efficiency.

Cost efficiency of the Swiss nursing home sector
Nina Boogen*, Massimo Filippini and William Greene

In this paper, we estimate an empirical cost function in order to analyse the efficiency in the production of elderly care services in Swiss nursing homes. We analyse whether the total number of elderly care services at the cantonal level are produced using minimal costs. Therefore, in a first step, we estimate a frontier cost function for the nursing home sector at the level of the cantons. In a second step, we examine factors that influence the level of cost efficiency in the production of elderly care services at the cantonal level. We use a panel dataset from 25 Swiss cantons over the years from 2006 to 2014 that includes information on outputs, input price, and output characteristics. The econometric estimation is mainly based on the Generalized True Random Effects (GTRE) model, which was proposed by Filippini & Greene (2016). This model allows us to estimate the persistent inefficiency (more long-term and structural effects e.g. regulations or investment in non-efficient capital) and also the transient inefficiency (more short term effects, e.g. the non-optimal use of capital) in the Swiss elderly care system.

The results of the cost efficiency estimation for the nursing homes services in the cantons indicate a significant potential for cost savings. In addition, we find the ratio of transient to persistent inefficiency to be rather balanced. Keeping constant the quantity of health care services the cost saving potential for these services lies around 15-20%.

In the second step of this analysis we will try to identify the factors that influence the level of efficiency in the production of elderly care services in the Swiss nursing home sector using a non-parametric Kruskal-Wallis tests.

Cherry picking in the fall: How banks select takeover candidates
Jaap Bos*

Banks merge for many different reasons: to avoid failure, to escape competition, to build empires. One reason why a bank may opt to take over another bank is particularly hard to test: cherry picking. The cherry picking hypothesis itself is straightforward: the take over candidate is selected because she is a classic underpriced asset. One reason why testing the hypothesis is difficult, is because it requires a good counterfactual. In this paper, I show how with a proper counterfactual, we can indeed test the cherry picking hypothesis.

Heterogeneity in efficiency analyses: The good, the bad and the ugly
Jaap Bos*

A recurrent theme in many efficiency studies, is broadly captured by the term "heterogeneity." Another, related theme is "where to put the Zs." In this talk, I will give my perspective of the role of heterogeneity in efficiency analyses, and the different ways of dealing with it.

Reconsidering non-neutral technical change
Jaap Bos and Ming Li*

These days, understanding the drivers of changes in inequality is the key to effective policy making. One of those drivers can be non-neutral technical change, especially when technology favors high-skilled labor over low(er)-skilled labor. Technical change can be said to be especially biased if it is wrongly measured, in which case a presumed equality between a marginal rate of technical substitution and the relative price of inputs actually reflects an overpayment of one input compared to at least one other input, thus contributing to a rise in inequality that is not reflected in changes in productivity.

In this paper, we tackle this issue. We start from the premise that old units of input – through experience – are more efficient than new units. We then show, first in a simple two-firm setting, and then in a more generalized model, how this can result in a bias in the measurement of non-neutral technical change. Subsequent simulations demonstrate that this bias is significant, both statistically and economically. When we apply our approach to industry data covering 40 countries over the period 1995-2009, we indeed find evidence that non-neutral technical change is biased in line with our theoretical model. These findings allow us to assess to what extent this bias has contributed to rising inequality over the sample period, as well as the conditions that made this bias particularly strong in certain industries.

Prevention or cure? Evaluating the tradeoffs between emissions abatement measures
Moriah Bostian*, Rolf Färe, Shawna Grosskopf and Tommy Lundgren

Abatement activities can be classified as either preventive or treatment of pollution. Preventive activities directly affect the production process for intended outputs (e.g., electricity, manufacturing goods), by reducing the quantity of emissions generated. Treatment occurs ex post, and thus, does not directly enter into the production process. Of course, these two forms of abatement are linked, in that more of the first entails less of the second. However, increasing prevention may also entail less of the intended output. To evaluate the tradeoffs between pollution prevention and treatment, we must consider both of these effects. Moreover, the associated costs of these effects derive from separate production technologies. Prevention enters into the joint technology for intended output and generated emissions. The generated emissions then enter into a second abatement technology where treatment determines the final level of pollution. We model this relationship as a network of production and abatement activities, solving for the optimal allocation between prevention and treatment. We apply this framework to firms in the Swedish manufacturing sector.

Technology and management gaps using stochastic frontiers with 2-round panel data: Preliminary evidence from an agricultural development project
Boris E. Bravo-Ureta*, William Greene, Mario González-Flores, Lina Salazar and Daniel Solís

The objective of this paper is to develop and apply a methodological framework designed to disentangle the technology effect (shift in the frontier) from the managerial effect (average change in technical efficiency) associated with development projects. The motivation stems from the fact that agricultural development interventions often endeavor to promote output growth by encouraging technological improvements accompanied by activities designed to enhance managerial performance. The indicator of impact frequently used to evaluate these projects is change in household income attributable to the intervention. This study seeks to extend the methodology developed by Greene (2010) and adapted by Bravo-Ureta, Greene and Solís (2012) to evaluate the impact of development projects to cases where 2-round panel data sets are available. For this study, balanced panel data with a total of 2,152 observations is available from 2-rounds; the first corresponds to the agricultural cycle going from July 2012 to June 2013, and the second for the 2014-2015 cycle. The method relies on a quasi-experimental framework along with an SPF with baseline and endline data for beneficiaries that self-select to become treated along with data for a suitable control group. The data comes from the Direct Supports for the Adoption of Rural Agrifood

Initiatives (or CRIAR) Program implemented in Bolivia with funding from the Inter-American Development Bank. CRIAR targeted smallholder farmers from native and indigenous areas in Bolivia, with the objective of enhancing food security and income through increases resulting from the adoption of improved technologies.

Business models interaction: Walmart vs Kmart
Humberto Brea-Solís, Ramon Casadesus-Masanell and Emili Grifell-Tatjé*

Most of the business model literature has focused on studying business models in isolation. Our study is one of the few that analyze how business models interact and compete between each other; being a relevant antecedent Casadesus-Masanell and Zhou (2013). In particular, we look at the interaction between two giants of the retailing business: Walmart and Kmart. Although both companies are in the same industry, they employed similar but different business models. Our main goal is to capture the elements that explain Walmart's overtake of Kmart's hegemony in the discount retailing industry and to explain how a prominent incumbent collapse.

The departing point of our quantitative analysis is the Economics of Business Performance (Grifell-Tatjé and Lovell, 2015). We construct a benchmark procedure based on information collected from different companies in the industry for the period 1970 to 2002. This framework allows us to measure the impact of the interactions between Kmart and Walmart while at the same time considering the industry's influence.

The empirical methodology allows us to identify three drivers that affect financial performance differences between Kmart and Walmart (measured as differences in profits). These drivers are technological change, improvements in efficiency and changes due to variations in scale and scope (activity effect). A fourth element taken into consideration is the use of market power through variation in prices.

Our preliminary results show a detailed portray of the interaction between these two companies. In the first years of the analyzed period, price and size effects were the main drivers behind Kmart's dominance of the industry. In contrast Walmart used technological progress to reduce distance with its main rival. The dynamics changed in 1977 when Kmart switched to a leadership in differentiation strategy. Walmart exploited this decision by boosting its efficiency levels as well as continuing improving its technology. By being more productive, Walmart was able to counter Kmart's apparently unsurmountable advantage. In 1986, Walmart's profits coming from improvements in productivity completely offset Kmart's lead due to its size. Finally, in 1991, Kmart's supremacy was gone.

Our study is a tale about the importance of technological innovation. Furthermore, it emphasizes the importance of carefully considering rivals' strategic decisions before making any major policy change. Has Kmart kept is cost leadership strategy in the late 70's; Walmart would have had much more difficulty to catch up.

Hooked on quotas: Analysis of the performance of the Icelandic small vessel fleet before and after the introduction of ITQs
Arnar Mar Buason and Sveinn Agnarsson*

In 1990, a comprehensive ITQ system was introduced into the Icelandic fisheries. Boats smaller than 6 gross registered tonnes, were though exempt from the quota system, and during the next decade various measures were employed to manage the small boat fleet. In 2001, a special quota system was set up for these small vessels and the effort restrictions previously in place slowly phased out in the ensuing years. In this paper, data on the small boat fleet covering the period before and after the quota system came into effect, is used to analyse the development of productivity and efficiency of the fleet during the period 1995-2015. Using stochastic frontier methods, the aim is to study if the introduction of a quota system improved the performance of the fisheries, as theory teaches should

happen in an overcapitalized fishery, and whether the boats that first exited the industry were the least efficient ones.

Learning and adaptation under incentive regulation: A survey of Norwegian electricity distribution companies

Edda Nermoen Burheim, Elise Ivara Dahl, Endre Bjørndal* and Mette Bjørndal

Since the deregulation of the Norwegian electricity market in the early 1990s, the electricity network companies have been regulated by the Norwegian Water Resources and Energy Directorate (NVE). Incentive regulation was implemented from 1997, and the incentives for cost efficiency were substantially strengthened with the overhaul of the regulation scheme in 2007. The current yardstick model consists of a revenue cap, based on actual costs as well as a norm cost derived from DEA efficiency estimates. These efficiency estimates are updated yearly, based on cost and output data for year t-2. The DEA model used by the regulator is an input-based cost efficiency model with constant returns to scale (CRS). There are different models for distribution (up to 22 kV) and regional transmission (22 kV – 132 kV). Adjustment for exogenous environmental factors is done with a two-stage approach, and noise is handled by using five-year averages in the specification of cost and output variables. The efficiency estimates are calibrated so that the aggregate (industry) return on capital, based on book values for year t-2, is equal to a predetermined rate of return consistent with the perceived risk level of the industry.

Our paper focuses on how companies learn and adapt under such an incentive regulation scheme, and we base our discussion on a survey of Norwegian electricity distribution companies. The main research question is to what extent, and how, the companies take into account the effect on their regulated revenue when making decisions on various operational and strategic issues. We have also asked them about how well they understand different aspects of the regulation / benchmarking models, and how they evaluate the regulation regime. One of the main findings is that the companies tend to be positive to the changes made to the regulation model in 2007, when the efficiency incentives were substantially strengthened. A majority of the companies see the changes as beneficial, especially when asked to take a system perspective. Another main finding is that the companies to a greater extent take the regulation model into account when considering strategic decisions, than when the decisions are about operational issues. Finally, we find that large companies are more likely than small companies to be involved in restructuring / merger projects. The latter observation is interesting, since several previous studies have found that most of the companies in this industry tend to be below the optimal size.

Manufacturing strategies and operations performance: A frontier approach

Ana Camanho*, Behrouz Arabi, Maria Silva and Rui Sousa

In operations management, exploring the effects of investments on assets and best practices implementation on firm performance is a topic that has attracted increased attention. This paper explores the use of Data Envelopment Analysis to construct operating practice frontiers, in order to evaluate manufacturing firms' performance. For plants that share the same asset frontier, which can be high or low depending on firms' investments on assets, we investigate whether the adoption of best practices in new product development, lean management and total quality management leads to improved performance simultaneously across several performance dimensions. The performance dimensions considered are cost, quality, flexibility and delivery of the products. We also test the law of cumulative capabilities and the law of trade-offs, taking into account the relative position between the asset frontier and operating practice frontier. This analysis, based on the International Manufacturing Strategy Survey 2013 (IMSS VI), can provide guidelines for the design of manufacturing strategies at firm level.

The impact of public funds on firms' technical efficiency of the Italian performing arts sector
Concetta Castiglione, Davide Infante and Marta Zieba*

In Italy, as in many other European countries, the performing arts are publicly subsidised. Italian subsidisation is ensured by a Parliamentary Law that in 1985 established the Fund for the Performing Arts (FUS). The main aim of this research is to measure the impact of the FUS allocation on the technical efficiency of Italian performing arts firms, since firms that received less or no public funds can be either more or less efficient. In the first case in order to stay in the market, in the second case because public funds guarantee more income to them. Data are derived from the ORBIS dataset carried out by Bureau van Dijk over the period 2005-2014. Preliminary results are obtained by applying the recent stochastic production frontier techniques for panel data and they confirm our hypotheses. Although our primary efficiency determinant of interest is the public funding, other efficiency determining variables are also examined such as immaterial assets, labour cost, firm characteristics (legal status, size, group affiliation and age), local environment (rule of law and crimes) and localization area. The impact of public funds on the technical efficiency of performing arts firms, as predicted, is relevant for what concerns the whole sample of the performing arts companies, whilst gives differentiated results at the four territorial areas level.

20 Years of DEA of airports efficiency: A meta-analysis
Laurent Cavaignac* and Romain Petiot*

The steady growth of airport traffic caused by deregulation and observed during the last thirty years generated tensions on airports management and raised the question of airports efficiency. Take as proof the constant increase of research articles on airports efficiency in the literature (Bezerra and Gomes, 2016).

Some of the main questions are that of the impact of public/private governance and that of airport size on efficiency and on the quality of service provided to users (passengers, shippers and airlines). More specifically, what are the consequences of public subsidies, public service delegation or privatization?

The most commonly used efficiency analysis tools are Stochastic Frontiers Analysis (SFA) and Data Envelopment Analysis (DEA). Over the last 20 years, 116 articles focused on airport efficiency using the DEA method (Cavaignac and Petiot, 2017). In this paper, we present the results of a meta-analysis (Tobit regression) conducted on 55 comparable articles published during this time span.

Our aim is twofold. First, we evidence the influence of the data year, the data geographic origin, the number of airports, the returns to scale assumption, the model orientation and the type of input and output on efficiency results. Second, we outline the most robust results in order to inform public policy and practices.

Bezerra, G.C.L and Gomes, C.F. (2016) Performance measurement in airport settings: a systematic literature review. Benchmarking: An International Journal, 23 (4), 1027-1050.

Cavaignac, L. and Petiot, R. (2017) A Quarter Century of Data Envelopment Analysis Applied to the Transport Sector: A Bibliometric Analysis. Socio-Economic Planning Sciences. In Press.

Short- and long-run plant capacity notions: Definitions and comparison
Giovanni Cesaroni, Kristiaan Kerstens* and Ignace Van de Woestyne

Starting from the existing input- and output-oriented plant capacity measures, this paper proposes new long-run input- and output-oriented plant capacity measures. While the former leave fixed inputs unchanged, the latter allow for changes in all input dimensions to gauge either a maximal plant capacity output or a minimal input combination at which non-zero production starts. The paper also establishes a formal relation between the existing short-run and the new long-run plant capacity measures. Furthermore, for a standard nonparametric frontier technology, all linear programs as well as their variations are specified to compute all efficiency measures defining these

short- and long-run plant capacity concepts. Finally, we numerically illustrate this basic relationship between these short-run and long-run technical concepts of capacity utilisation.

Parsing US agricultural productivity growth: Weather, technology change, efficiency change, and inputs

Bob Chambers* and Simone Pieralli

This paper attempts to examine the interaction between US state-level agricultural TFP growth and weather outcomes. The focus is on determining whether that interaction was different at the end of the 20th century than it had been in the 1960s. To pursue this goal, we combine official United States Department of Agriculture (USDA) state-level productivity data for the 48 contiguous states for 1960-2004 with matching data on growing degree days and moisture drawn from Schlenker and Roberts (2008, 2009). Those combined data are used to construct an aggregate agricultural production frontier that incorporates both aggregate input use and observed weather. The constructed frontier is used to decompose observed state-level agricultural TFP growth into four components: technical change, weather-related shifts in the frontier, aggregate input growth, and movement towards or away from the frontier. The first and second components attempt to measure changes in the frontier that can be attributed to technical improvements made within US agriculture and changes in measurable weather variates. The fourth component reflects state-level adjustments either towards the productivity frontier or away from it as the states adopt or adapt existing technical advances.

Recent updates in DEA computation

Wen-Chih Chen*

DEA is a linear program (LP) based method to determine the relative efficiency of a point representing the input-output transformation process of a firm. Although solving an LP can be done in polynomial time and is considered an “easy” task, solving a large number of full-size LPs becomes computationally burdensome when the data set is massive.

This talk focuses some recent updates in DEA computation. A new approach proactively searching the critical reference points is introduced. The proposed method enhances the computational performance significantly comparing to the state of the art, particularly for the problems with high dimension (number of inputs and outputs) and high density (percentage of efficient points). The method provides the flexibility to fulfil the requirements based on different DEA assumptions and to integrate with the computation methods in the literature. An algebraic modeling language package is also developed based on the approached developed.

A DEA-based methodology to determine customer value

Laurens Cherchye, Bram De Rock, Bart Dierynck, Pieter Jan Kerstens* and Filip Roodhooft

During the last decade, firms have become increasingly customer centric, implying that customers, rather than products, are treated as the most important asset of a firm and that acquiring and retaining profitable customers is the main strategic focus. The switch to customer-centric strategies also implies that firms are collecting an enormous amount of customer-related data. Currently, these customer-related data are analyzed by means of techniques such as customer profitability analysis (CPA) and/or customer lifetime value (CLV). Although both techniques differ on some important aspects, both techniques aim to determine the contribution of individual customers or customer groups to firm value based on data about past customer behavior.

The purpose of this paper is 1) to propose an alternative methodology to determine the contribution of customer segments to firm value and 2) to illustrate the practical usefulness of our newly developed methodology by using data from a large European telecom provider. The methodology is based on the multi-output methodology developed by Cherchye et al.(2013) which explicitly includes information about output-specific inputs and joint inputs in the efficiency evaluation. We also demonstrate the usefulness of heat maps to communicate the results of our analysis.

We show the practical usefulness of our DEA-based methodology on Activity Based Costing data collected from a large European telecom provider, which offers fixed telephone, mobile telephone, digital television, and internet subscriptions. Our analysis reveals that the average cost reduction potential across all customer segments amounts to 1.26% of the total controllable costs or approximately EUR 5 million. As expected, there is substantial variation in the cost reduction potential across the customer segments as the average cost reduction potential of the ten segments with the highest cost reduction potential amounts to 28.19% of the total controllable costs.

Nonparametric production analysis with unobserved heterogeneity
Laurens Cherchye, Thomas Demuynck, Bram De Rock and Marijn Verschelde*

We propose a novel nonparametric method for the identification of production functions with unobserved technological heterogeneity. We assume cost minimization as the firms' behavioral objective, and we model unobserved heterogeneity as an unobserved productivity factor on which we condition the input demand of the observed inputs. Our model of unobserved technological differences can equivalently be represented in terms of unobserved input levels that guarantee data consistency with our behavioral assumption, and we argue that this avoids the so-called transmission bias in a natural way. Our empirical application to Belgian manufacturing data shows that our method allows for drawing strong and robust conclusions, despite its nonparametric orientation. For example, our results show how input cost shares (including unobserved input costs) vary over time and pinpoint a clear link between outsourcing and technology.

Credit constraints and technical efficiency: Evidence from Vietnamese manufacturing firms
Chau M. Chu*, Kausik Chaudhuri and Sandra Lancheros

This paper investigates the impact of credit constraints on productivity and efficiency for an unbalanced panel of over 13,000 Vietnamese manufacturing firms during the 2005-2013 period. A fixed effect stochastic frontier approach is employed to control for unobserved heterogeneity that can easily be identified in general stochastic frontier models. This paper, to our knowledge, is first application of this approach in measuring technical efficiency of firms in Vietnam, which is a Southeast Asian middle-income country and necessitates productivity improvement for long-term economic growth. The other contribution is to explore the role of credit constraints in improving technical efficiency using the translog production function. As a number of Vietnamese firms, especially micro and small ones, find difficulty in having access to external finance, internal cash flow plays an important role in explaining their capital expenditures. Our results reveal that financial constraints do not constitute impediments to firms' productivity and efficiency. Interestingly, when considering the ability of having access to external financing in terms of firm size, we find that micro and small firms are likely to have hindrances in their access to external finance, larger firms are reported to have fewer credit constraints.

A conditional directional distance function approach for measuring tax collection efficiency: Evidence from Spanish regional offices
Jose Manuel Cordero, Carlos Díaz*, Francisco Pedraja and Nickolaos Tzeremes

This paper analyses the evolution of the technical efficiency of Spanish regional tax offices in respect of the main devolved taxes for the period 2005-2014. We apply the conditional directional distance function methodology, which allows us to incorporate undesirable outputs into the production function. Those variables are represented by economic/administrative complaints lodged by taxpayers as an (inverse) measure of the quality of service provision. Moreover, by using this methodological approach we also account for the influence of so-called exogenous or environmental variables when estimating efficiency scores. Those variables are represented by the socioeconomic context in which these offices operate. This methodology has been adapted for application in a dynamic context in order to analyse how the behaviour of these units has evolved over a period that includes different stages of the economic cycle. The main results show that efficiency levels have fallen over the period, especially since the start of the economic recession. Likewise, we identify that

the influence of per capita income and, towards the end of the period, fiscal capacity are especially significant explanatory factors of this evolution.

Efficiency measurement of Spanish municipalities: An application of conditional nonparametric frontiers

Jose Manuel Cordero, Carlos Diaz-Caro and Cristina Polo*

Measuring local government efficiency is a complex task that has to take into account that they usually operate in a heterogeneous context. Therefore, the estimation of relative efficiency measures of their performance needs to account for the effect of contextual and exogenous variables on the production process. This should assure that the respective measures adequately reflect the portion of inefficiency that may be attributable to local authorities. In this paper, we apply time-dependent conditional frontier estimators to evaluate a sample of Spanish municipalities for the 2005-2012 period, thus we can explore the effect of the economic crisis on the performance of those municipalities. By applying this nonparametric approach, we can avoid the strong assumptions on the specification of the estimated production function required by traditional two-stage methods. Furthermore, we examine the effect of contextual and exogenous variables on municipal efficiency levels and technological change. The results reveal that the levels of efficiency decrease during the expansionary phase of the economic cycle, especially for the local governments with a greater size, although this trend has been reversed since 2010.

Socioemotional wealth and productivity differences between family and non-family firms: A distributional analysis

Sarah Creemers, Mark Vancauteren*, Wim Voordeckers and Ludo Peeters

We use a micro-level approach to study the role of family ownership in shaping firms' productivity distributions. Specifically, we examine the distributional differences in labor productivity between family and nonfamily firms. To achieve this goal, we use a dataset containing information on 1,802 firms located in the Netherlands during the period 2010–2013. The identification of distributional differences is accomplished by using the nonparametric (instrumental-variable) quantile regression estimator proposed by Fröhlich and Melly (2013). Allowing productivity differences among family and nonfamily firms to vary at different points of the unconditional (marginal) productivity distribution, our main finding is that the best-performing (least-performing) family firms show a productivity discount (premium) as compared to their nonfamily counterparts. Stated differently, the nonfamily firms' productivity distribution shows considerably longer tails (higher dispersion and kurtosis), while the family firms' distribution exhibits less extreme productivity outcomes at both its lower and upper tail (lower dispersion and kurtosis). We contend that this empirical finding is broadly consistent with the socioemotional-wealth perspective on productivity, as described in Firfiray, Larraza-Kintana, and Gomez-Mejia (2016).

Multi-output technologies and changing market conditions: Animals' health and dairy farms' efficiency in Denmark

Tomasz Czekaj*, Christine Windfeld Hansen, Jakob Vesterlund Olsen and Anna Plum

We analyse the relationship between animal health and milk quality indicators and the economic performance of dairy farms in Denmark using multi-output multi-input technologies. Recently in the European Union (EU) the market conditions for dairy producers has substantially changed due to abolition of the milk quota system in the Common Agricultural Policy of the EU. For the empirical research on the performance of dairy farms in EU the existence of this market regulation called for appropriate model specifications, and the choice of input oriented models could have been based on the argument that there is output quota regulation. Since the regulation has changed the choice of the proper orientation of the models describing the production process is a vital question for applied research in this field.

We address this problem empirically testing different model specifications (input-, output- and hyperbolic- distance functions) using a panel data of dairy farms in Denmark. Our data contains economic data from farm accounts merged with data on livestock health and milk quality indicators allowing us to assess whether the better performing farmers are utilising the production potential in the quota abolition differently than other farmers when simultaneously for the livestock health and milk quality.

Persistent effects in loan loss provisioning concerning Italian banks
Aristeidis Dadoukis*, Giulia Fusi and Richard Simper

This paper concerns Loan Loss Provisioning (LLP) behaviour of Italian banks after the recent Global Financial Crisis. We apply Stochastic Frontier Analysis (SFA) and we disentangle firm effects from permanent (time-invariant) and residual (time-varying) efficiency for a panel data set of commercial banks for the period 2008-2015. The focus of the paper is not the standard cost frontier but an innovative and original approach to find a provisioning frontier – giving best practice institutions. To that end, we identify and estimate a stochastic frontier model that examines the efficiency of the provisioning strategies of bank managers, identifying in the process the persistent effect which varies across banks but remains invariant over time. In that way, we allow persistent and transient managerial effects in our estimation, capturing management's innate abilities and skills with respect to optimal Loan Loss Provisioning practises.

The findings indicate that Italian banks show increased levels of LLP inefficiency after the Global Financial Crisis. In particular inefficiency for commercial financial institutions is more pronounced, showing higher levels of, time-invariant, residual and overall inefficiency relative to their cooperative counterparts. In addition, we identify that large commercial banks' management under-performs with respect to their Loan Loss Provisioning levels as they operate below the industry's median, lending support the too big to fail argument and herding behaviour.

The impact of banking reforms on efficiency and competition in Ghana's banking sector
John K Dadzie* and Alessandra Ferrari

The aim of this paper is to shed light on the effectiveness that deregulation reforms have at improving the efficiency and competitiveness of banks in underdeveloped financial markets. We use Ghana as a case study and collect an unbalanced panel dataset of commercial banks over the period 2000-2014 which both precedes and follows its major deregulation reform of the mid-2000s. Using Battese and Coelli (1995) stochastic frontier model, in its panel data set-up, we first analyse the dynamics and the determinants of efficiency by separately looking at the effects of different policy changes and differences in banks ownership. We then estimate two separate models of competition: the persistence of profitability (POP) model and the Boone indicator. This allows us to get more robust results and to look in detail into the dynamics of competition, with a specific focus on the loans market. Our results show that while efficiency improved throughout the sample period, deregulation policies have a different effect due to the lack of skills and differentiation abilities of banking in a developing country. In particular the most effective policy at reducing costs appears to be the removal of entry restrictions, via the beneficial spill-over effects brought in by better-skilled foreign new entrants.

While deregulation has some positive effects on efficiency we find that its potential positive effects on competition are not exploited, and that macroeconomic and institutional weaknesses continue to exert a negative counterbalancing effect. Reforms need to be anchored on stronger macroeconomic fundamentals, institutional initiatives and generally stronger credit environments for their full potential to be revealed in the context of underdeveloped financial markets.

Translog cost function estimation: Banking efficiency
Toby Daglish, Oliver Robertson, David Tripe* and Laurent Weill

This paper examines the selection of data source and econometric technique for studies of banking efficiency using translog cost functions. We examine the use of Seemingly Unrelated Regression estimation for a cost function, as against estimation using Ordinary Least Squares. Choice of cost data to feed to the estimation is also important, and we find that use of wage and interest data may sometimes be superior to cost data inferred from bank accounting information. Lastly, we discuss filtering of data, where some observations may contain erroneous or noisy data.

Do productivity convergence approaches converge? A meta-frontier Luenberger-Färe-Primont indicator decomposition in the French agriculture
K. Hervé Dakpo*, Yann Desjeux, Philippe Jeanneaux and Laure Latruffe*

This paper investigates five ways to assess convergence of productivity and its components in a large sample of different sub-samples of French farms over the period 2002-2014: 57,075 observations distributed among six sub-samples depending on the main production specialization of farms: field crop farms, dairy farms, beef farms, sheep/goat farms, pig/poultry farms and mixed crop-livestock farms. First total factor productivity (TFP) results indicate that beef farms had the highest productivity progress during the period studied while pig and poultry farms the lowest. The objective is therefore to understand whether the absolute or conditional convergence hypothesis holds during the period studied (Miller and Upadhyay, 2002). In other words, the question is whether sub-samples of farms converge to a steady-state of productivity irrespective of their main production specialization or whether there is specialization-specific convergence.

For this sigma, gamma, stochastic and club convergences are estimated using several econometrics techniques (OLS, random effects and coefficients, system-GMM). We develop a Luenberger-Färe-Primont (LFP) indicator to measure productivity and decompose it into technical and several efficiency components (technical, scale, mix, residual). The new LFP indicator is additively complete, because it is expressed in a difference form, and inherits the properties of its multiplicative (ratio) counterpart. Among those properties, the transitivity axiom is very important for multi-lateral and multi-temporal comparisons as in the case of most databases. LFP uses the directional (shortage) distance function (Luenberger, 1992) and in terms of construction it is similar to the Bennet's indicator. A crucial advantage of the difference-type productivity measurement lies in the ease of interpretation as in the case of a profit indicator.

To compare the different farm sub-samples, the LFP indicator is further extended to a meta-frontier estimation in order to evaluate the technology gap ratio convergence. Preliminary results indicate that crop field farms have the lowest gap and actually define the meta-frontier. Besides, mixed and beef farms exhibit the highest convergence rates in terms of technology gap decrease.

The proof of the pudding is in the eating: Empirical analyses of five environmentally-adjusted efficiency models
K Hervé Dakpo*, Finn Førsund, Ludwig Lauwers* and Jef Van Meensel*

The surge in modelling pollution-generating technologies has issued several approaches and techniques that mainly differ in the way undesirable outputs are included in the models (disposability assumptions) but also on the structure of those models. Theoretical discussions have been provided on many of these approaches (Dakpo et al., 2016). Our aim in this article is therefore to perform empirically analyses of an almost exhaustive bunch of existing environmentally-adjusted efficiency models (EAEM) on four types of data sets and critically assess their "informative value". These data sets have been discussed in Ball et al. (1994); Färe et al. (1989); Hampf and Rødseth (2015); Lauwers et al. (1999) and cover different areas. Among the different approaches, we have considered, the input-oriented models (Hailu and Veeman, 2001), the weak disposability assumption (Färe et al., 1986), the materials balance based approaches - iso-environmental lines estimation

(Coelli et al., 2007), the weak G-disposability (Rødseth, 2015), and multi-equation modelling: the by-production approach (Førsund, 2017; Murty et al., 2012). These models cover almost all the existing approaches in modelling pollution-generating technologies and are compared using the nonparametric data envelopment analysis (DEA). In terms of structure, the different models are compared given the nature of the efficiency scores (hyperbolic, radial/non-radial, directional, sub-vector…), the nature of the technology (constant, variable returns to scale), the primal or dual nature of the production technology; the latter being useful to derive shadow prices. Finally, we extend this discussion to the emission factors (constant or non-constant) and also how abatement outputs can be handled in these models.

Productivity and efficiency analysis software: A survey of the options
Cinzia Daraio*, Kristiaan Kerstens, Thyago C. Nepomuceno* and Robin C. Sickles

The software available to implement and carry out efficiency analysis is crucial for the diffusion of efficiency frontier techniques among applied researchers and policy makers. The implementation of up-to-date productivity and efficiency analysis is indeed important to advance our knowledge in many fields, ranging from the public and regulated sectors to the private ones. This contribution fills a gap in the existing literature and surveys the currently available options to estimate a variety of frontier methodologies using either general or dedicated programs. We present a conceptual mapping of the key terms associated to the surveyed software and outline directions for future research.

What is the quality of European universities? Model uncertainty, endogeneity and testing of unobserved heterogeneity
Cinzia Daraio*, Leopold Simar and Paul W. Wilson

We develop up-to-date econometric techniques to test for the relevance of latent heterogeneity factors and to assess their impact on the efficient boundary of the production set. We extend the framework of Daraio, Simar and Wilson (2016) to account for endogeneity and latent heterogeneity.

Our approach is implemented in the context of the quantitative assessment of European Higher Education systems. Higher Education Institutions (HEIs) carry out a complex production process. Multiple activities, such as teaching, research and third mission are realized by combining different inputs (or resources): human capital, financial stocks and infrastructures; to produce heterogeneous outputs, such as: undergraduate degrees, PhD degrees, scientific publications, citations, service contracts, patents, spin off and so on, within an heterogeneous environment in which size and subject mix play also an important role. Within this process, the quality of HEIs, which is an unobserved factor, play a crucial role. The main objective of the paper is to estimate this latent factor and assess its impact on the European Higher Education system.

Direct democracy and local government efficiency
Kristof De Witte* and Zareh Asatryan

This paper studies the role of direct democracy in ensuring efficient and cost-effective provision of goods and services in the public sector. The sample consists of the population of municipalities in the German State of Bavaria, where in the mid-1990s considerable direct democratic reforms granted citizens with wide opportunities to directly participate in local affairs through binding initiatives. Using information on the municipal resources and the municipal provision of public goods, and applying a fully non-parametric approach to estimate local government overall efficiency, the analysis shows that more direct democratic activity is associated with higher government efficiency. This result suggests that more inclusive governance through direct decision-making mechanisms may induce more accountable and less inefficient governments.

A stepwise benchmarking method for finding projection points involving returns to scale properties
Akram Dehnokhalaji* and Narges Soltani

A famous problem in Data Envelopment Analysis (DEA) is finding projection points or target units for inefficient Decision Making Units (DMUs). These reference points provide information about inputs/outputs improvements that are necessary for an inefficient unit to become efficient. The target unit is located on the efficient frontier and possibly far from the unit under evaluation. In this regard, the inputs reduction or output increments seems disappointing or even impossible to achieve in short-term. In this regard, finding intermediate targets is of great importance in benchmarking literature.

In this paper, we suggest a stepwise benchmarking procedure for each inefficient unit and improve its performance gradually at several steps, which is more realistic in practice. The advantage of our method to other existing methods is that we select the closest target unit based on a new similarity criterion. The RTS category of all targets in the sequence is the same as the inefficient units based on our similarity criteria and consequently the intermediate targets, final projection point and the unit under evaluation are all similar in size which is more meaningful in applications comparing to other existing similarity criteria considering l_p-norm-based metrics which find the closest target geometrically. The numerical and empirical example illustrates the performance of our proposed target setting algorithm.

Internal devaluation versus productivity: Competitiveness of manufacturing across Europe
Charles-Henri Di Maria* and Chiara Peroni

Since the global crisis of 2008, growth has been anaemic in most countries. Among the possible way out international organisations such as the OECD, IMF or the European Commission suggest to boast exports. Beside currency devaluation (that are inefficient when countries belongs to the same monetary union such as the EURO zone) these international organisation have advocated for internal devaluation – wage moderation. To assess competitiveness of countries unit labour costs (ULC) are often monitored. In short monitoring ULC is usually restricted to compare wage evolutions to labour productivity changes. Using a decomposition proposed by Kumar and Russel (2002) assuming constant returns to scale it is shown that ULC evolution can be decomposed in wage evolutions, change in exchange rate, efficiency change, technical change and capital deepening. Departing from Kumar and Russel and subsequent authors it is shown that this decomposition holds for any returns to scale (increasing, decreasing, variable,…) and then the decomposition includes a new element: scale efficiency change. This new decomposition is applied to ULC evolutions of manufacturing industries.

Decomposing value added growth into explanatory factors
Erwin Diewert and Kevin Fox*

A method for decomposing nominal value added growth is presented, which identifies the contributions from efficiency change, growth of primary inputs, changes in output and input prices, technical progress and returns to scale. In order to implement the decomposition, an estimate of the relevant cost constrained value added function for the two periods under consideration is required. This is taken to be the free disposal hull of past observations. Aggregation over sectors is also considered. The methodology is illustrated using U.S. data for two sectors over the years 1960-2014.

Estimating efficiency of Italian water utilities by accounting for quality issues
Giovanna D'Inverno*, Laura Carosi, Andrea Guerrini and Giulia Romano

This paper compares the efficiency of Italian water utilities and includes in efficiency assessments both quantity and quality variables. Unaccounted-for water and environmental impact, measured as environmental infringements made by the municipalities served, are included in the estimation as undesirable outputs. The determinants of performance trends are then assessed, by linking the

specific features of each firm (such as ownership, size, geographical location and degree of diversification) to the trend of its efficiency.

The productivity puzzle and credit constraints: Is there a cohort effect?
Mustapha Douch*

This paper provides empirical evidence of how the 2008 crisis affected firms' productivity and firm survival in the UK. We first show how heterogeneities help us to explain the shortfall in productivity in the 2008- 2009 crisis. While on aggregate we indeed find a shortfall in productivity, once we distinguish between firms according to cohort and ownership status, we find that the young (post 2008) cohort was the main group affected by recent crisis. One hypothesis is that this reflects a lack of access to credit. To test this, we use firm-specific and time-varying credit scores, which capture firms' ability to obtain credit. This compares to previous studies, which derive a measure of credit vulnerability by indirect means (i.e. Manova et al. (2009)). In fact, the results suggest that the older (pre-2008) cohorts of both domestic and foreign firms were relatively less affected and had more or less similar responses to the crisis. Similar results were found at a disaggregate level -i.e. services, manufacturing and construction sectors - that is, unconstrained firms tend to have a high level of productivity performance even during the recent global recession. However, while these older cohorts tend to be relatively productive, they have drastically increased their savings, leading to less investment. In other words, the recession and general level of economic uncertainty may well have distorted firms' behaviour in dealing with resource allocation -i.e. capital. Thus, the combined effects of low investment by the old cohort and a general poor productivity (TFP) performance of the new cohort suggest a new insight on the productivity puzzle. On the other side, from the standpoint of firm survival, foreign firms have been more affected than their domestic counterparts. Thus, we analyse whether there exists a heterogeneous response among cohorts and how access to credit had an important implication for firms' survival. This shows that while it is generally the case that unconstrained firms have lower failure rates, post-recession this has changed -i.e. there has been an increase in the failure among less constrained firms.

Measuring efficiency of decision making units: Software update for advanced users
Ali Emrouznejad* and Emmanuel Thanassoulis

This paper presents software that takes its features closer to the latest developments in the DEA literature. The updated software includes features such as: assessments under a variety of possible assumptions of returns to scale including NIRS and NDRS; truly unlimited number of assessment units (DMUs); Analysis of groups of data by estimating automatically separate boundaries by group; Malmquist Index and its decompositions; Super efficiency; automated removal of super-efficient outliers under user-specified criteria; cross efficiency; bootstrapping and models that deal with congestion. Advanced feature including slack-based measures of efficiency and Network DEA will also be presented.

Measuring corporate sustainability performance
Tadesse Engida*, Xudong Rao and Alfons G.J.M. Oude Lansink

Measuring corporate sustainability performance is crucial for guiding sustainability improvements. Although extensive assessments and indicators exist that reflect the different aspects of sustainability, because of the relatively large number of measures and interactions among them, a composite indicator that integrates over all variables is particularly useful. This paper discusses and empirically assesses a method for constructing a composite sustainability indicator. The method first uses principal component analysis to reduce the number of variables and to remove correlation among variables. Next, the method applies data envelope analysis with bootstrapping procedure to these principal components (factors) to individually score each company. The method solves weights endogenously. An empirical application is made on companies in European Food sector using data from Sustainalytics. Our research results could have important implications for stakeholders aimed at enhancing corporate sustainability.

Technical change and von Neumann's coefficient of uniform expansion
Rolf Färe, Daniel Primont and Bill Weber*

Technical progress allows a given amount of inputs to produce more output(s) which in turn tends to enhance welfare through lower prices or new and higher quality products. Brozen (1951 a,b) argued that the technology may change if what is technologically possible changes, if what the technological leaders are capable of changes, or if "The spread of a new, efficient technique by imitation changes the average technology (Brozen 1951a, p.279)." In this paper we study several measures of technical change. First, we review how technical change is measured by the Malmquist index. Then, we introduce the idea of the angle of the average technology as a way to operationalize Brozen's (1951a) notion of an average technology. This measure of technical change compares the angle formed by the average inputs and outputs over time. As the angle steepens, technological progress occurs. Finally we make use of von Neumann's (1938, 1945) coefficient of uniform expansion to measure technical change. This measure compares the observed convex technology derived from the observed DMUs between two periods. Solow's (1957) residual measure of technical change can be derived from the coefficient of uniform expansion and from the Malmquist productivity index. An empirical example is used to understand how the three measures—Malmquist index, change in the angle of the average technology derived from the technology matrix, and the coefficient of uniform expansion—quantify technical change.

Regional wage frontiers in pre & post-crisis Spain
Joanna Maria Bashford Fernández*

This paper explores the evolution of wages in Spain on a regional basis. The methodology proposed uses stochastic frontier analysis (SFA) to estimate the wage frontiers of workers in different regions of Spain as a function of their human capital (education and experience), different aspects of their occupation, economic activity/sector, type of working day, etc. Once the wage frontier has been estimated an analysis is made of the determinants which may contribute to the workers having difficulties in achieving their maximum attainable potential salary.

For this purpose a panel data model (Greene, 2005) is used to estimate the stochastic frontier. The data is obtained from the Spanish Living Conditions Survey [Encuesta de condiciones de vida (ECV)], a harmonized survey conducted on a yearly basis by all the Member States of the European Union. Specifically an analysis is made of the period between 2006 and 2015 focusing on salary differences at regional level. Given the high heterogeneity of production structures and labour markets across regions in Spain, the regional aspect is of particular interest to policy makers given the indirect implications for re-location of industries and jobs within and outside Spain on a more global scale. Moreover more than 60% of covered workers have their wages set by regional agreements. Additionally, the period analysed encompasses differing business cycles, the aftermath of Spain´s entry to the Eurozone and serves to throw some light on the potential and real salaries available to Spanish workers before and after the onset of the economic crisis.

The author formed part of the Spanish employment market in the parallel period and this paper is motivated by her own observations and perception of the evolution of salaries in the country at the time.

Economies of scope in health sector: The case of Portuguese hospitals
Diogo Ferreira*, Rui Marques and Alexandre Morais Nunes

Background: Economies of scope are defined as the potential cost savings arising from the joint production of two or more outputs, rather than their separate production. Given the importance of the health sector for the community, measuring the existence of potential economies of scope clearly contributes to the improvement of this sector sustainability.

Objective(s): To search for the existence of economies of scope in Portuguese hospitals through some frontier-based methods.

Methods: This paper develops (1) a generalized algorithm to get locally convex frontiers from the bidirectional conditional order-a frontier method, as well as (2) a generalized economies of scope-based ratio, to be possible the introduction of all inefficiency sources.

Data: This paper makes use of the 2002-2009 Portuguese hospitals' dataset, concerning the provision of obstetrics & gynecology & pediatrics and psychiatric services.

Results: Considerable economies and diseconomies of scope were found in the Portuguese public hospitals. A strong dependence on the production line and on the merging status of the hospital was observed. Diseconomies of scope are more likely for large hospitals, i.e. more than 6,000 inpatient discharges and/or 7,500 medical appointments (values per year).

Conclusions: Even merged hospitals can exploit economies of scope; however, when they become outsized entities, such an exercise turns out to be a hard task.

An expanded decomposition of the Luenberger productivity Indicator with an application to the Chinese healthcare sector
Gary Ferrier*, Hervé Leleu and Zhiyang Shen

To isolate specific sources of productivity change, productivity measures are often decomposed into constituent pieces. The objective of this research is to present a new decomposition of the Luenberger productivity indicator. The expanded decomposition sheds light on more dimensions of productivity growth, which may facilitate policy development. We begin with the standard decomposition of the Luenberger productivity indicator into its technical change and efficiency change components. The efficiency change component is then further decomposed into technical efficiency and structural efficiency components. Finally, the structural efficiency component is decomposed into mix efficiency and scale efficiency components. We illustrate the decomposition using data from the health care sector of the Chinese economy over the period 2008-2014. Given the rapid growth in the Chinese health care sector in recent years and the health care reforms initiated by the government, a deeper understanding of productivity in this sector is warranted.

Nonparametric frontier estimation in the presence of noise: Recent developments
Jean-Pierre Florens, Leopold Simar* and Ingrid Van Keilegom

Deterministic nonparametric frontier estimation has been popularized by the use of envelopment estimators in the family of FDH/DEA estimators. In the presence of noise, these estimators are not more consistent because they envelop noisy data points. Their robust versions (order-m or order-α quantiles frontier) are robust to extreme and outlying data points and so are certainly an improvement, but still they are deterministic in nature, the DGP does not explicit the presence of noise. Therefore stochastic versions have been suggested. They are standard in fully parametric setups but there the models rely on too much restrictive assumptions. In a nonparametric approach, we know from Hall and Simar (JASA, 2002) that there are some identification issues when trying to keep the model purely nonparametric. Several attempts have been proposed but so far, most of them are based on some more or less restrictive parametric assumptions. In the less restrictive one, suggested by Kneip, Simar and Van Keilegom (Journal of Econometrics, 2015), the frontier is nonparametric, the inefficiency distribution is nonparametric and it is only assumed that the noise has a normal distribution with unknown variance. The model is quite general, with no homoskedastic restrictions, neither for the inefficiency, nor for noise. Some recent developments try to relax this normal assumption, but then introducing other assumptions to insure identifiability. These are based on preliminary research on the boundary estimation of a variable observed with symmetric noise. To obtain the identification we restrict the inefficiency distribution to some very flexible parametric density that can be viewed as an approximation of any continuous density on the positive real line. The extension to the estimation of a production frontier is then the next step, which is more easy to handle even in a nonparametric way.

Measuring effectiveness of production in the public sector
Finn Førsund*

Key concepts in efficiency analyses are efficiency and effectiveness. Efficiency is popularly connected to 'doing the things right' and effectiveness to 'doing the right things'. The paper elaborates upon the latter concept within a setting where resources are transformed into outputs under the control of a public provider, while outcomes with outputs as inputs represent higher social goals, but this production is outside the public provider's direct control. A new measure of overall preference effectiveness is introduced and its decomposition into output-oriented efficiency and output-mix efficiency is shown. The monumental task of getting the necessary information for calculating effectiveness is highlighted.

Deregulation and productivity: Empirical evidence on dairy production
Fabian Frick* and Johannes Sauer

We investigate productivity development and its relation to resource reallocation effects in the dairy sector in southeast Germany during the phasing-out of the European Union milk quota. We hypothesize that both extreme price levels and market deregulation fostered efficient reallocation of production resources. We use a farm-level dataset containing financial accounting data for a period of 15 years. Farm-level productivity is estimated by a proxy variable approach which is robust to endogenous input choice (Wooldridge 2009). We compare this approach to conventional stochastic frontier analyses, a panel data fixed effects regression as well as an index based analysis. After aggregation we decompose sector productivity into unweighted mean productivity and a covariance term measuring the allocation of resources toward more productive farms following Olley and Pakes (1996). The method of analyzing reallocative efficiency introduced by Petrin and Levinsohn (2012) is included as a robustness check. We observe an increase in the covariance term coinciding with a period of deregulation efforts and rather volatile milk prices. We seek to find support for our hypotheses by a regression analysis linking the measure for the potential covariance between resource reallocation and productivity on the one hand and deregulation as well as price variability on the other. In this analysis we find some empirical evidence for the hypotheses.

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Source of industrial output growth and productivity decomposition analysis for selected Asia countries using DEA Malmquist and KLEMS data bases
Tsu-Tan Fu* and Yih-Ming Lin

The industrial level source of growth analysis using the KLEMS data base has recently been widely adopted for cross-country productivity comparisons. However, this method fails to decompose the total factor productivity into the components of technical change and efficiency change, which may cause inaccurate measures of productivity and thus mislead the policy implication. The purpose of this research is to integrate panel data production frontier model (DEA Malmquist) with the Asia KLEMS data base (with 32 industries for each country) for measuring source of output growth and productivity components in selected countries such as Taiwan and South Korea. Japan and India are planned to be included. We also identify the major drivers of output growth for each industry of each country investigated and for each time period in 1980-2010. Cross-country and cross-period comparisons on industrial structure and growth pattern for manufacturing and service industries, as

well as results of source of growth and productivity change analysis, are investigated in this paper. Preliminary results have shown that Korea has performed better than Taiwan on TFP growth in manufacturing industries, whereas Taiwan's TFP growth has dominated Korea in services industries. The cross-country results on technical change and technical efficiency at industry-level will be further investigated and to be completed soon. Until now, there is limited paper which attempts to integrate the KLEMS data with production frontier models. Therefore, research results in this research could provide academic value and useful references to policy makers.

The opportunity costs of financial fair play regulations in professional football – An efficiency analysis

Ronan Gallagher and Barry Quinn*

This paper analyses the implications of Financial Fair Play regulations as enforced by UEFA, the Premier League and the Football League on the joint financial and sporting efficiency of English football clubs. Using a stochastic non-parametric efficiency model, we analyse an unbalanced panel of 54 clubs over the 2003-2004 to 2013-2014 seasons. We document that the breakeven provisions of the extant regulations serve to reduce the overall efficiency of clubs while shifting the relative balance of importance from sporting outputs to financial outputs leading to unintended consequences which may reduce competitive intensity. We discuss the implications of our findings for regulators and club management.

A green bargain? The impact of an energy saving program on productivity growth in China's iron and steel industry

Thomas Geissmann*, Massimo Filippini, Valerie Karplus and Da Zhang

The impact of environmental regulation on firm productivity has been long been debated, however, mainly for western economies and with limited firm-level evidence. This study presents the first empirical evaluation of the effects of an environmental regulation on the total factor productivity (TFP) of Chinese industrial firms using parametric methods. Furthermore, this is the first contribution analyzing such effects with respect to TFP change subcomponents of technical change and scale efficiency change, and one of the first empirical applications estimating TFP change via a cost function. We study the impact of a large-scale national energy saving program (the Top 1000 Energy-Consuming Enterprises Program, or T1000P, 2006-2010) in China on firm productivity in the iron and steel industry. The T1000P assigned targets for reducing energy consumption, and thereby direct and indirect pollutant and greenhouse gas emissions, of the 1000 most energy-consuming industrial firms. Using detailed data from the China Industrial Census on 5,340 firms for the period of 2003 to 2008, we estimate a positive effect of the T1000P on firms in the iron and steel industry. Specifically, the T1000P is found to have significantly increased annualized TFP change, and thereby competitiveness of treated firms, by 3.1 percent on average. Effects on technical change and scale efficiency change are positive and statistically significant, and contribute about equally to the overall treatment effect. Results are robust to instrumenting for policy exposure and other alternative specifications. Private benefits to firms from the policy likely reflect the combination of incentives and targets applied under the program.

Are Mexican water utilities efficient? A nonparametric answer

Ulises Genis*, Nicolas Gravel and Nicholas P. Sisto

A well-known difficulty encountered when comparing firms according to their efficiency is that the technology they use may be affected by several exogenous factors that are beyond managers control. This is particularly the case for water utility firms whose production process depends significantly upon climatic or hydrologic parameters that vary significantly across locations. In this paper, we evaluate, for the years 1998 and 2008, the productive and cost-efficiency of 341 large Mexican water utility companies defined to be those serving more than 12,500 customers in 2008. While most empirical rankings of firms based on efficiency that we are aware of are based on the Debreu-Farrell efficiency index, we choose to focus on the Additive Index, which is the unique known

index that is strictly monotonic with respect to efficiency gain and that indicates perfectly efficiency (Russell and Schworm (J Prod Anal, 2011, 36:143-156)). We provide a non-parametric estimate of the relationship between this index and a bunch of external factors in such a way as to neutralize the effects of those factors on the comparisons of firms based on their efficiency. Comparisons with the ranking of firms provided by the Debreu-Farrell index as well as with indices based on the more restrictive cost-minimization hypothesis are also provided.

The impact of human capital on technical efficiency: Evidence from Eastern European and Central Asia countries
Salem Gheit*

This paper principally aims to investigate and examine the contribution of human capital represented by a number of proxies (different levels of education) to technical efficiency using firm level data. The data is sourced from the Business Environment and Enterprise Performance Survey (BEEPS) in 2013, conducted by the European Bank for Reconstruction and Development jointly with the World Bank Enterprise Survey, and spanning more than 9000 firms from different industries (low-tech, medium-tech, high-tech, and services) with different sizes and ages in 28 countries across the Eastern European and Central Asia region.

The empirical results suggest that highly-educated labour (workers with tertiary education and those with university degrees) appear to have a positive impact on firms' efficiency. In other words, firms with higher levels of human capital proxied by the proportion of highly-skilled workers tend to be more efficient compared to those firms with intermediate workers whose their educational attainment lies at the level of high school and college. In fact, the impact of the latter (intermediate workers) seems to be negative in most cases. The results also indicate that years of education have no significant effect on efficiency and therefore productivity in these countries. In addition, firms' size factor (micro, small, medium, or large) tends to play a role in encouraging firms to be more efficient, meaning that the larger the firm is, the more efficient it is anticipated to be. It is also found that, factors such as; funds received from different kinds of financial institutions (Private commercial banks, State-owned banks or government agency, or Non-bank financial institution) in the form of loans, becoming a member of the European Union organisation in 2004 and 2007, and the percentage of foreign ownership of the firm (whether it is a complete or partial ownership) have their significant positive influences on efficiency. Last but not least, it is noted that the top manager's cumulative experience in the firm measured in the average years of experience plays its part in promoting efficiency levels and positively affecting the firms' productivity.

Measuring spatial competition using efficiency spillovers
Anthony Glass*, Karligash Kenjegalieva and Thomas Weyman-Jones

This paper suggests the methodology for implementing the theoretical relative profit difference test as in Boone (2008) to test the intensity of spatial competition. We also provide an empirical application to demonstrate the steps involved in the practical implementation of the test. We use a panel data set of U.S. banks over the period 1998-2015, which is an interesting study period as it includes the period pertaining to the financial crisis. Among other things, we examine impact of the geographical expansion of a bank across U.S. states on the banking performance and competition intensity.

The efficiency analysis of the shale revolution in the global oilfield market
Binlei Gong*

The shale technical revolution has reshaped the oil and gas industry dramatically and achieves commercial success in the US. This paper evaluates the effect of the revolution on efficiency of global oilfield companies that have footprints in up to five segments. Firstly, a semiparametric model with shape constraint is introduced to estimate firm-level technical efficiencies with multi-segment concern but in absence of functional form assumption. In the second step, this study evaluates the

change in efficiency after companies acquiring different techniques innovated from the revolution (such as directional drilling and hydraulic fracturing). The empirical results show that practicing just one of the techniques may decrease efficiency. However, combining multiple techniques can produce significant spillover effects and improve efficiency. Therefore, innovation and integration are both crucial for the oilfield market.

Quality of life shift in Spanish municipalities (2001-2011)
Eduardo Gonzalez*, Ana Carcaba and Juan Ventura

We use a list of 16 social indicators covering 8 QoL domains in 400 Spanish municipalities in 2001 and 2011 to compute a composite indicator, using weight constrained DEA. These dimensions cover all the relevant aspects of QoL: living conditions, housing, education, health, safety, personal activities, environment. We compute a Malmquist index comparing both periods to track the changes occurred during the decade. The Malmquist index is then decomposed into a catching-up effect and a frontier shift component, showing joint social progress. This allows interpreting the global evolution of QoL for these municipalities and also to assess which of them have moved towards the frontier (catching-up). The results show that the Mediterranear area has been the most affected by negative catching-up, while the central-northern regions still dominate the QoL frontier. The Southern regions show poor QoL scores, but some positive catching-up is observed. Overall there has been advance in QoL conditions as represented by frontier shifts.

Spanish hospitals ranking with regard to performance and quality
Sophie Gorgemans*, Enrique Bernal-Delgado, Manuel Ridao-López and Micaela Comendeiro-Maalooe

The purpose of this paper is to estimate the technical efficiency as well as the productivity of general Spanish hospitals considering at the same time the quality level in terms of mortality and safety. With both data, we will propose a classification.

We use the methodology of Data Envelopment Analysis to evaluate the performance of a sample of 182 general hospitals in 2003 and 2013. We create a specific composite quality measure (inspired by AHRQ technical specification and Shwartz et al. 2005 in Milbank Quarterly) because of the interest they have to measure into an overall score the performance of each hospital. We aggregate then four measures (mortality rate in cardiovascular diseases; Patient safety 07, 12 and 13) that represent the medical, surgical and nurses level of quality in inpatients processes. We calculate an adjusted fatality rate, including the effect of gender, age and Elixhauser capability.

We use a set of 3 inputs, 4 outputs and observe, that in this period, hospitals have lost in terms of technical efficiency but generally, improve quality. We calculate the productivity with Malmquist applying DEA and observe that hospitals are situated in a major distance to the frontier in 2013. The composite quality measure evolution is quite different between regions and those which are reaching worst results is due to the bad results in cardiovascular disease treatment.

If we establish a TOP20 in 2013 of efficient hospitals with the highest quality level we observe that a large majority of them have between 400 and 1,000 beds and the rest are smaller. A great group is losing quality to improve efficiency between both years (following the methodology proposed by Leute, 2010). We still have to study on which returns to scale hospitals are operating.

This study keeps going on the importance of measuring hospital's performance, introducing aspects of quality in order to go towards an outcome measure using a consolidated methodology (DEA) and suggesting a new one to calculate a composite quality measure.

Impact of the 1990 Clean Air Act, RECLAIM program, and ISO membership, on production cost and efficiency in the electric utility industry
Gerald Granderson* and Finn Førsund

This paper investigates the impacts of the 1990 Clean Air Act, Regional Clean Air Incentives Market (RECLAIM), and Independent System Operator (ISO) membership, on production cost and cost efficiency in the U.S. Electric Utility industry. Several power plants (1995-1999) were required to reduce their sulfur dioxide (SO2) and nitrogen oxide (NOX) emissions. Firms can reduce (i) SO2 emissions by using less coal (more other fuel sources), more lower sulfur content coal, or installing equipment (i.e. scrubbers), and (ii) NOX emissions by retrofitting power plants with low nitrogen oxide burners or employing modifications that control fuel and air mixing to limit the emissions. Both oil and natural gas have typically been more expensive fuel sources than coal. Also, more low sulfur coal (having less heat content than higher sulfur coal) may be needed to produce electric power. We examine whether Phase 1 compliance impacted production cost, higher marginal cost, and cost efficiency.

Second, Phase 1 power plants (via the Environmental Protection Agency, EPA) could obtain (initial allocation, purchase) permits to emit SO2. There was no EPA trading permit program for NOX until 1999. Under the RECLAIM emissions trading program in California (starting in 1994), many facilities in Southern California were required to reduce their SO2 and NOX emissions to desired levels. Like the EPA SO2 program these facilities could obtain permits, but unlike the EPA program they could not bank them. One utility in the data sample (utility not subject to Phase 1) was required to reduce its NOX emissions under RECLAIM. Assuming the utility also used other methods mentioned above to comply with RECLAIM, we test whether having to comply with RECLAIM impacted cost efficiency.

Third, beginning in 1997 FERC approved the formation of Independent System Operators (ISOs). These organizations (which were typically non-profit) would coordinate the generation of electric power across large geographic areas (typically one state). Firm membership in an ISO could lead to more competition among electric utilities, and possibly lower profits for electric utilities. ISO member firms may try to operate more efficiently (to maintain profits) by undertaking actions such as improving heat rates of power plants, and relying more on newer fuel efficient power plants (compared to the older plants). If the older plants that relied more on fossil fuels were subject to Phase 1, then relying less on these plants could impact the cost of complying with Phase 1. Relying on newer fuel efficient plants could lead to (1) lower SO2 and NOX emissions, but also (2) higher production costs (newer units being more expensive). We test for the impact of ISO membership on (i) the cost of having to comply with Phase 1, and (ii) how having to comply with Phase 1 affected cost efficiency.

Recent developments in modeling technology with unintended outputs
Shawna Grosskopf*, Rolf Färe, Tommy Lundgren and Moriah Bostian

We update developments on modeling technology including unintended outputs and show how these can at least to a large extent, be incorporated in a network model framework. Recently there have been efforts to specify more detailed models which include multiple functions to separately capture intended and unintended products (e.g. Murty et al., 2012 or for an application to CSR see Chambers and Serra, 2016). Yet another recent strand of the recent literature has also explicitly tried to include a material balance condition in the model (e.g. Rødseth, 2015, 2016). For recent non-parametric developments see Dakpo et al. (2016) and in general see Førsund (2017).

We see this general evolution as beginning with what might be called a black box technology, with inputs entering the box, and good and bad outputs exiting the box. The more sophisticated models can be thought of as filling in the black box with the more detailed processes involved with production, prevention and abatement with production accompanied by undesirable byproducts subject to legal regulations and laws of nature. This can be modeled as a network within the black box.

Employment and pollution abatement: A nonparametric cost function approach
Shawna Grosskopf*, Rolf Färe*, Carl Pasurka and Ron Shadbegian

Morgenstern et al. (2002) investigated the employment effects of environmental regulations using a cost function that relied on survey data of the cost of inputs assigned to pollution abatement. In contrast, Färe et al. (2013 and 2016) investigated the link between pollution abatement and employment by specifying regulated and unregulated production technologies that model the joint production of good and bad outputs, where the regulated technology exhibits weak output disposability and null-jointness while the unregulated technology exhibits outputs that are strongly disposable. Färe et al. (2016) specified input distance functions to model the regulated and unregulated production technologies and decompose changes in employment, while our decomposition employs a nonparametric cost function (Ball et al 2005) that models the joint production of good and bad outputs.

Like Färe et al. (2016) we measure the relative importance of factors associated with changes in employment without pollution abatement cost data. Here, we will decompose changes in employment into the following components: (1) the cost effect - reflecting employment changes associated with differences in the regulated and unregulated isoquants, (2) the scale (output) effect – reflecting employment changes associated with changes in output levels due to a change in factor prices, (3) the substitution effect – reflecting employment changes associated with changes in factor prices holding output constant, (4) changes in overall (technical and allocative) efficiency – reflecting employment changes associated with increases or decreases in efficiency, and (5) technical change – reflecting employment changes associated with shifts in the regulated isoquant.

Heterogeneous spillovers among Spanish provinces: A generalized spatial stochastic frontier model
Alberto Gude*, Inmaculada Alvarez and Luis Orea

This paper introduces new spatial stochastic frontier models to examine Spanish provinces' efficiency and its evolution over the period 2000-2013. We use a heteroscedastic version of the spatial stochastic frontier models introduced by Glass et al., (2016) that, in addition, allows us to identify the determinants of the spatial dependence between provinces. This feature of the model lets us to rank all Spanish provinces are ranked in accordance with their degree of spatial dependence, information that will aid policymakers to better allocate public resources between provinces. The period examined is of special interest given that it coincides with a break in the economic growth tendency, coinciding with a deterioration in Spain´s economic situation.

How to minimize the production cost of marine cage lobster aquaculture in Vietnam
Au Ton Nu Hai*, The Bui Dung and Stijn Speelman

Marine cage lobster aquaculture in Vietnam, which started in 1992, has been expanding significantly and has become very important to the economy over the past two decades, especially since wild catch of the lobster is either at its maximum sustainable yield or overexploited and in decline. However, this industry relies on wild-caught puerulus for fingerling and trash fish for feed and the stocks of these are in decline resulting in their scarcity and price increase (Long & Hoc, 2008)(Petersen & Phuong, 2010). In this situation, it become important that these inputs are used efficiently given the price information to avoid wasting resources and reduce the producing cost. Therefore, this study aimed to measure the cost efficiency of lobster farms in Vietnam and to explore its determinants.

Cross sectional data of 361 marine cage lobster farms in Vietnam grouped into spiny lobster (Panulirus ornatus), green lobster (P. homarus) and mixed cultivation (Panulirus ornatus and P. homarus) were used in this study employing a two-stage data envelopment analysis approach. In the first stage, the bootstrapped data envelopment analysis following Simar and Wilson's (1998) was used to correct the bias and estimate the confidence interval of the technical, allocative and cost

efficiency of those farms. Lobster production in kilogram was taken as an output and three main inputs :fingerling in unit, feed in kilogram and labor in working hours were considered. Then in a second stage the reciprocal of those bias corrected efficiencies were regressed on a set of explanatory variables employing the double bootstrap truncated regression approach of Simar and Wilson's (2007).

The mean of the bias corrected cost efficiency for spiny lobster, green lobster and mixed cultivation farms were measured to be 0.571, 0.578 and 0.649, respectively. This result shows that there is substantial cost inefficiency in lobster aquaculture due to overuse of inputs. Moreover, in the second stage regression, the cage cleaning times during the cultivating period was showed as an important factor affecting the efficiency scores of all three groups of producers.

The efficiency and distributional effects of China's carbon mitigation policies: A distance function analysis

Atakelty Hailu* and Chunbo Ma

Climate negotiations are made difficult by the hard realities of carbon reduction costs. Costs are expected to be high, although, to date, there has been little empirical evidence on how rapidly costs would rise if countries adopted significant commitments. We address this shortcoming for the case of China by using an empirically estimated distance function to generate provincial level marginal abatement cost (MAC) profiles for carbon reduction targets ranging up to 50% relative to 2005 (base) levels. We find substantial heterogeneity in MAC values across China's provinces and show that the current equal proportionate reduction scheme is inefficient. By establishing a national cap and trade program, China can dramatically reduce its mitigation costs by 35%-70% for reduction targets up to 20% of base levels. We also demonstrate that China could have significantly reduced the learning costs of its pilot cap and trade program by selecting a different set of provinces.

Estimating and decomposing optimal shifts of the world technology frontier

Benjamin Hampf* and Jens Krüger

In this paper we propose a nonparametric approach to estimate optimal shifts of the frontier of production technologies. These shifts are associated with maximal productivity growth during periods of technical progress, while they are associated with minimal productivity decline during periods of technical regress (i.e. backward shifts of the frontier). Our approach follows previous models (e.g. Lansink and Ondersteijn (2006), Mahlberg and Sahoo (2011)) by using non-radial measures of inefficiency and productivity change. In contrast to the conventional Malmquist index by Caves et al. (1982) and Färe et al. (1994), which is based on radial distance functions, these measures allow to estimate individual directions of improvement for each input and output, thereby allowing to quantify input- and output-specific rates of technical change. The previous literature, however, estimates changes in the frontier between two periods by estimating and comparing the maximal distance of a decision making unit to each frontier. In contrast, our model determines the maximal distance between the frontiers by endogenously selecting directions of efficiency measurement. Building upon the extended Färe-Lovell measure by Briec (2000), we propose an algorithm based on solving a series of mixed linear binary programming problems to estimate optimal shifts between the frontiers. Moreover, we derive a decomposition which allows to identify and quantify input- and output-specific technical change.

We apply our model to evaluate optimal shifts in the world technology frontier. Analyzing a sample of 93 countries covering the period 1970 to 2014, we estimate optimal technical change with respect to the inputs human capital, raw labor and physical capital as well as the output GDP. Preliminary results show that following optimal technical change over the whole sample period would have resulted in a cumulative increase of GDP of about 35% on average. Jointly with increasing the output, the countries could have reduced their input of human capital and raw labor by about 50% and their stock of physical capital by about 40%. Moreover, our results indicate that during the 1970s and 1980s technical progress has particularly enhanced the productivity of human capital.

However, since the 1990s we find larger technical progress for raw labor leading to a convergence of the productivity gains of these inputs by the year 2000.

In order to analyze whether following technical change or reducing existing inefficiencies leads to different optimal directions of input reductions and output enhancement, we conduct a comparison of the results from our dynamic approach and those obtained using a static model. In this static model, optimal directions are estimated based on the maximal distance to the contemporaneous frontier of the production technology. The results show that while both approaches indicate the same directions for changes in the physical capital input, they differ with regard to the assigned weights for output increases and in particular to the reduction of human capital and labor. While we find that in order to follow optimal technical change the countries should focus on enhancing their output, the largest potentials for increasing efficiency could be exploited by focusing on reducing the input of human capital and labor. This difference has become even more pronounced in recent periods, highlighting that there exists a substantial trade-off between exploiting optimal technical progress and increasing efficiency in order to enhance productivity.

Welfare growth accounting revisited
Tarek Harchaoui* and Paul Willemsen

Welfare gains—defined to include trading gains and multifactor productivity gains—have taken an increased importance in determining nations' prosperity. An important line of research has contended that improvements in trading gains in one period tend to be offset by losses from subsequent deteriorations, leaving productivity gains as virtually the sole major long-term source of increased prosperity. We revisit this consensus view by using a unifying dual framework that offers a symmetric treatment of welfare and multifactor gains all the while adjusting the estimates for two measurement problems that arose with globalization—double counting of exports and offshoring bias. The results, based on a representative set of ten economies over the 1996-2009 period, emphasize the importance of trading gains which now contribute for about 8.1% of welfare gains compared to a dampening effect of -6.8% under the unlikely scenario where these measurement problems do not occur—a hefty 15 percentage point turnaround. This aggregate 8.1% upgrade in the relative importance of trading gains masks a great deal of variation ranging from 4.1% for NAFTA to 35.0% for Europe, compared to 10.4% for emerging nations. To some important extent, our results contribute to nuance the well-established narrative that limits trading gains to a quantitatively small and transitory effect.

A new metric for scale elasticity in data envelopment analysis
Maryam Hasannasab, Dimitris Margaritis, Israfil Roshdi and Paul Rouse*

Robust measurement of scale elasticity (SE) in data envelopment analysis (DEA) remains elusive, primarily reflecting the computational challenges brought about by the piecewise linear structure of the DEA technology. A long standing issue is that the value of SE is not uniquely determined for efficient units since they are frequently located either on vertices or on ridges of the efficient frontier. In this paper, we propose a linear programming model that provides a unique measure of SE based on a proposition of closeness to the most productive scale size (MPSS) frontier. The model, being non-oriented and frontier-based, not only provides a meaningful (i.e. in an MPSS sense) SE measure but also allows the type of returns to scale to be determined. We use data from 95 European banks across 11 years to test the model and compare our results with interval approaches commonly used in the literature.

Large and small farms excel in Brazil
Steven Helfand, Nicholas Rada* and Marcelo Magalhaes

Drawing on decadal agricultural census data (1985, 1995/1996, 2006) covering the whole country and all farm types, this study constructs a pseudo-panel of five farm size classes for each county and year in Brazil. Controlling for temperature and precipitation shocks to production, the pseudo-panel

is used to examine which farm size class achieved the highest agricultural total factor productivity (TFP), to evaluate the TFP growth distribution, and to identify factors contributing to TFP. The paper finds that while the differences in TFP were relatively small in 1985, the smallest (<5 ha) and largest (>500 ha) farm size classes achieved the fastest TFP growth, resulting in a pronounced U-shape by 2006. Little consistency is found in the effect of technical assistance, credit, or electricity across farm size classes on input, output, or TFP growth. Education is the exception, which raised output and TFP growth among all size classes. Contrary to expectations, greater capital intensity was associated with slower TFP growth for small and medium sized farms, as was specialization in chickens, pigs, or horticulture. For the largest farms, specialization was associated with faster TFP growth.

Parsimonious functional forms for multiple-output cost functions: Output-output relationships
Arne Henningsen*

The cost function is a microeconomic tool that researchers and analysts frequently use to empirically analyse multiple-input multiple-output technologies. Furthermore, regulators use the cost function as a benchmarking tool in order to set price caps in monopolistic markets. This study theoretically and empirically assesses various parsimonious functional forms for multiple-output cost functions, focussing particularly on the output-output relationships.

We argue that the iso-(minimal-)cost curves that indicate all maximal output-output combinations that can be produced with a given cost are similar to transformation curves but are not the same.

We further argue that the curvature of the iso-(minimal-)cost curves is related to the concept of economies of scope but that the curvature of the iso-(minimal-)cost curves and the concept of economies of scope measure two different things.

Standard microeconomic theory assumes (mostly for convenience) that iso-(minimal-)cost curves are concave, which implies diseconomies of specialisation. We argue that iso-(minimal-)cost curves of real-world technologies may also be convex and that the curvature of the iso-(minimal-)cost curves is an empirical question.

Our theoretical and empirical assessment of parsimonious functional forms of multiple output cost functions includes two regularly used functional forms, i.e. the normalized linear and the Cobb-Douglas (log-linear) functional forms, and two new parsimonious functional forms, i.e. one in which the vector of output quantities is expressed as polar coordinates (as it is done in the `Stochastic Ray Production Frontier') and one which applies the Constant-Elasticity-of-Transformation (CET) functional form in a cost function approach. All functional forms have their strengths and weaknesses and it is an empirical question, which of them is most suitable for a specific empirical application.

Do we use fertilizer efficiently? Performance of fertilizer overuse in China's arable agricultural production
Wei Huang* and Li Jiang

Fertilizer overuse is regarded as one of the main contributors of agricultural pollution and environmental problems in China. The purpose of this study is to evaluate the technical efficiency and fertilizer overuse index with respect to China's arable agricultural production, and to examine the regional variations in terms of fertilizer overuse. The maximum likelihood random effects time varying inefficiency effects model is applied to estimate the technical efficiency, fertilizer use efficiency, and fertilizer overuse index. The results indicate that fertilizer use has a significant positive impact on the production in China's arable agricultural sector. Over time, technical efficiency has steadily increased for each individual province. The mean of the annual average technical efficiency is 0.827, implying that on average Chinese provinces can increase 17.3% of the output given unchanged levels of inputs and technology. The annual average fertilizer overuse index ranges from 0.013 to 3.452, with a mean of 0.513, suggesting that there is fertilizer overuse for all provinces, and large regional variation exists. It is found that coastal provinces have the highest

technical efficiency scores, while the central region experiences the highest degree of fertilizer overuse. High technical efficiency is not necessarily associated with low fertilizer use efficiency.

Three-step returns to scale analysis using SFA: Russian manufacturing industry
Irina Ipatova*

We studied the returns to scale dynamics of Russian manufacturing industry firms in 2006-2014. Our analysis was based on estimation of stochastic production frontier using SFA method. The main conclusion relies on results of three steps: 1) estimation marginal products from production functions; 2) modelling the relation between firm size and technical efficiency; 3) scale efficiency dynamics analysis. We concluded that 1) the major part of Russian manufacturing industry firms had decreasing returns to scale in 2006-2014; 2) the relation between firm size and technical efficiency was positive only until achievement particular technical efficiency level; 3) scale efficiency dynamics analysis results conformed to results of the first step.

Sorting items with DEASort in ABC classes
Alessio Ishizaka*, Rita Cavallieri and Francesco Lolli

Multi-criteria inventory classification groups similar items in order to facilitate their management. Data envelopment Analysis (DEA) and many variants have been extensively used for this exercise. However, DEA provides only a ranking and classes are often constructed arbitrarily with percentages. This paper introduces DEASort, a variant of DEA for sorting problems. In order to avoid unrealistic classifications, expertise of the decision-makers is incorporated. They provide typical examples of items for each class. They also give the weights of the criteria with AHP. This information bounds the possible weights and is added as a constraint in the model. DEASort is illustrated with a real case study of a company managing warehouse stocking spare parts.

The effect of institutions on sectoral performance: The case of electricity distribution in Indian states
Tooraj Jamasb*, Pavan Khetrapal, Manuel Llorca and Tripta Thakur

Since the 1990s, India has adopted a number of measures to reform its electricity sector as in many countries around the world. From an economic perspective, the main objective of electricity reforms is to provide utilities with incentives to enhance their efficiency both in terms of operation and investment. The aim of the Government is to ensure that consumers benefit from the achieved efficiency gains. In the case of India, specific focus has been on achieving social objectives such as electrification and this has led to large energy losses and inefficiencies in the sector. The quality of institutions and governments affect the performance of utilities. However, there is a significant lack of understanding of this issue as its scope has not been deeply analysed.

This paper uses a stochastic frontier analysis approach to analyse the performance of 52 electricity distribution companies in India for the period 2007-2012. We estimate a set of models that allow us to identify determinants of firms' cost efficiency of the state networks. Some of the variables included as determinants of firms' performance relate to the quality of institutions of the Indian states.

Our preliminary estimates suggest that per capita GDP of the states and its rate of growth have a significant effect on firms' performance. In addition, we find that there is an ambiguous relationship between network energy losses and firms' costs. On the one hand, energy losses increase network costs as larger energy losses imply more intensive use of the network and this involves higher maintenance and operation costs. On the other hand, energy losses increase firms' efficiency, which results in lower costs. These larger efficiencies may arise from reductions in capital costs and investments that make the capital appear to be more efficiently used. The results obtained in the paper are further explored to provide policy suggestions with the aim at achieving long-term efficiency improvements.

Computational complexity of shape constrained estimation
Andrew Johnson*

Most microeconomic textbooks introduce production functions by describing a shape restricted function, typically S-Shaped, that is describe by economic theory such as the Regular Ultra Passum Law. Many concepts related to the production function such as marginal rates of substitution and marginal products are only well defined if the production function satisfies certain shape restrictions. However, simpler parametric functional forms are often used on the basis that shape restricted nonparametric estimation is too difficult or that parametric approximations are not particularly restrictive. This talk will review the current progress on estimating production functions that satisfies shape restrictions by construction. We will describe estimation procedures with a variety of computational complexities the simplest of which can be solved in seconds.

Operational and environmental performance in wine sector: A unified efficiency DEA-based assessment
Samah Jradi*, Tatiana Bouzdine-Chameeva, Bernard Delhomme and Anicia Jeagler

Environmental performance is a highly complex notion, which requires to combine the techniques of economic analysis with the specific measurements of ecological activities. In the recently published works based on data envelopment analysis (DEA), a unified efficiency has been induced with the classification of outputs into desirable (good) and undesirable (bad) outputs induces, as well as developing new specific indicators.

Our study extends the use of DEA to this type of environmental assessment. To explore the estimation of environmental costs of pollutants we suggest to decompose the problem into two separate parts: first measuring technical efficiency (as the relation of the desirable outputs to the inputs) and second ecological efficiency (as the relation of the desirable outputs to the undesirable outputs). These two efficiency indicators are then combined to make a unified performance measure. Treating further on pollutants as the inputs allow to increase desirable outputs and decrease pollutants and inputs. The third performance measure obviously incorporates desirable and undesirable outputs into a unified measure (operational and environmental).

This three stages' approach is implemented in the case of wine sector. The sustainability efforts of the sector focus for many years by now on the areas of energy efficiency, water management, integrated pesticide management and ecosystems' onset, which contribute to carbon emissions, pollutants usage and waste production.

We apply the environmental assessment to measure a unified efficiency of 44 wine producing companies in Bordeaux region in France. With the results of this study, we expect to provide winemakers and regional authorities with the relevant information regarding eco-efficiency of sustainable practices existing in the French wine sector.

Agricultural productivity and farm size in Malawi, Tanzania, and Uganda: A total factor productivity approach
Jacques Julien* and Boris E. Bravo-Ureta

This study examines the inverse relationship hypothesis (IR-H) regarding farm size and productivity using Total Factor Productivity (TFP) derived from Cobb-Douglas Random Parameters Stochastic Production Frontier models. We use nationally representative LSMS-ISA panels from Malawi (2010, 2013), Tanzania (2008, 2010, 2012) and Uganda (2010, 2011). The empirical models incorporate an expanded set of regressors to capture agro-ecological, environmental and climatic attributes, which are variables that are typically ignored in the related literature. An important issue concerns likely errors in land measurement and this is addressed by making use of two alternative measures of farm area: 1) hectares reported by farmers (Self-reported model); and 2) GPS measurements undertaken by enumerators (GPS model). Due to the short time span of the panels, the study focuses on comparing land, TFP and technical efficiency (TE) across 10 farm size classes. The findings show that

for both the Self-reported and GPS models, the smallest farm size groups have the highest average TFP consistent with the IR-H. In addition, the results reveal for the tree countries, both measures of land area and across farm size classes, suggest substantial managerial gaps reflected by low levels of TE.

In providing new evidence concerning the IR-H, we address several shortcomings found in the literature. The model specification incorporates a number of covariates beyond traditional inputs, including agro-ecological, environmental, climatic, farm, and household attributes. A common criticism concerns errors of measurement primarily for land; to address this issue, we use two alternative measures of land area: self-report by the farmer and a GPS-based measure. By addressing the problem of land, infrastructure, and development programs as factors related to low productivity, this study will provide decision makers and international agencies with information for designing evidence-based policies and strategies to improve agricultural productivity in East Africa.

Adaptive LASSO for stochastic frontier models with many efficient firms

Hyunseok Jung*

The LASSO (Tibshirani, 1996) is applied to select a subset of maximally efficient firms in the fixed-effect stochastic frontier model for panel data of Schmidt and Sickles (1981). Asymptotic properties of the estimator are derived in this context. Under regularity conditions the LASSO estimator exhibits the oracle property, and simulations suggest that it outperforms the least squares dummy variable estimator in terms of the root mean squared error of the estimated firm-level inefficiencies. An application of the LASSO to rice farm data suggests that the resulting subset of maximally efficient firms is comparable to the efficiency subsets calculated from the same data in Horrace and Schmidt (2000).

Does market information improve technical efficiency? A stochastic frontier analysis for Peruvian farmers

Joanna Kamiche-Zegarra* and Boris Bravo-Ureta

Farmers require information along the agricultural production cycle to make their decisions. Examples of these decisions include: the selection of what crops to plant and when; the choice of appropriate seeds, fertilizers and other inputs; planting and harvesting dates and methods; and marketing decisions to secure high prices (Aket et al, 2016; Mittal et al, 2010). In fact, information can be seen as an input in the farmer decision-making and it is expected to contribute to agricultural outcomes like productivity, profits and welfare. A limited number of studies focus on measuring the effect of information use on agricultural profit or welfare variables (Aker and Fafchamps, 2015). Aker, Ghosh and Burrell (2016) highlight that the scant literature on the impacts of information (via ICTs) on farmers' profits or welfare shows mixed results. The role of information on output and productivity is a topic that deserves more attention in the literature.

The goal of this study is to determine if the use of information contributes to increase farm productivity and efficiency. Our main hypothesis is that the use of information (such as input and output prices, weather patterns, among others) improves the quality of a farmer's decision-making (e.g. the farmer can buy less costly inputs or can find higher output prices; he/she can assign its land to higher profitable crops) and that will imply higher productivity and efficiency. For this purpose we use the Stochastic Production Frontier approach (SPF) along with a Cobb-Douglas specification (Aigner, et al 1977). The study focuses on Peru and we use the National Agricultural Survey (ECA) for 2015 that provides information for about 26,000 agricultural units. The data includes information on quantity and value of production; quantity and/or value of different types of inputs; type of information used (prices of outputs or inputs, weather conditions) and its source (radio, phone).

Measuring productivity change accounting for adjustment costs: Evidence from the food industry in the European Union
Magdalena Kapelko*

This paper extends the measurement of dynamic productivity change over time to provide its full decomposition into economically meaningful components in the Data Envelopment Analysis framework. The dynamic approach accounts for dynamics of production decisions via adjustment costs and is visualized as a dynamic Luenberger productivity change indicator. The paper also estimates the dynamic productivity change and its components for a large dataset of European food companies from 2004 till 2012, grouped into Eastern, Southern, and Western regions. The study reveals three main results. First, the overall trend of technical regress and positive dynamic technical inefficiency changes across almost all regions and sectors was found. Second, some differences for this general pattern were found for the bakery industry and for Eastern European firms. Thirdly, there are also some remarkable changes in indicators observed during the periods related to the financial crisis and the volatility of agricultural commodity prices.

Measuring price efficiency in infant milk market
Roxani Karagiannis* and Giannis Karagiannis

Infant and follow-on milk formulas are products designed to satisfy the specific nutritional requirements of healthy infants. These products are regulated by national and EU legislation in order to ensure a high level of protection for infants' health. In Greece, the liberalization of supply chain of infant milk products after 2012 aimed to improve competition among suppliers with a direct positive impact on consumer welfare due to lower prices. However, market research showed significant price differences between infant milk products. Are households paying more than the minimum price for a given infant milk brand-name?

Our objective is to measure the extent to which any particular brand is price efficient according to a given bundle of attributes, given the presence of all other brands on the market. We apply a non-parametric DEA methodology to identify the efficient brands and to indicate how much the price of each infant milk product should be reduced to make the brand efficient.

Olley-Pakes decomposition with revenue and physical productivity measures
Giannis Karagiannis* and Suzanna-Maria Paleologou

The objective of this paper is to measure the extent of the bias induced into aggregate (industry-level) productivity when firm-level revenue-based productivity measures are used, where the revenue-based measure is based on sales deflated by an industry-level price index. In this case it can be shown that aggregate productivity deviates from average (representative firm) productivity not only by a reallocation (covariance) term, reflecting the relation between performance and market achievements, as suggested by the Olley and Pakes (1996) decomposition, but also by a "price adjustment" term, capturing the deviation of the industry-level price index from the revenue-weighted geometric mean price across the firms in the sample. Most likely, these two terms are positively correlated and thus tend to exaggerate the induced bias on aggregate productivity.

We provide empirical evidence on the magnitude of and the relation between the reallocation and price adjustment term using FADN (Farm Accounting Data Network) data for a sample of olive oil producers in Greece. The FADN is unique for our purposes because it contains output price information at the farm level. We estimate three production function models using alternative measures of output: the first uses as output the sales deflated by an industry-level price index, the second uses the same output measure but adopts the Klette and Griliches (1996) procedure to account for this measurement error, while the third uses the physical quantity of output. From these three models we obtain estimates of output elasticities, which are then used to compute TFP at the firm and the industry level. Using these and the market value shares we can compute the

reallocation and the price adjustment terms, as well as the "corrected" aggregate productivity figures.

Yield gaps and technical efficiency: The case of wheat farmers in Afghanistan
Aziz Karimov* and Rajiv Kumar Sharma

Agriculture is the backbone of the Afghan economy. Cereal production contributes to 77% of the Agricultural GDP and wheat is the most important crop. While wheat is the main staple food in the country, due to the lower productivity, the country is always in deficit condition and need to import wheat from other countries (MAIL, 2012). In order to improve food sufficiency levels, prevailing yield gaps need to be reduced. With the funding from ACIAR, CIMMYT conducted wheat baseline survey in 2012/2013 in different agro-ecological regions of Afghanistan in the scope of 'Sustainable wheat and maize production in Afghanistan' project. The project with objective of sustainable increase in wheat production in country by the introduction and dissemination of improved, stress tolerant seed varieties and agronomic practices through diffusion of technology, ensuring smooth and accelerated dissemination and adoption of varieties and agronomic practices and spreading of information at the grass root level through the four hubs established, that represent different agro-ecological regions of the nation. This study used the survey data to assess status of technology awareness, availability, and adoption of improved seed varieties among farmers in target regions at the project take-off stage. The research used recent advances in DEA and SFA methodologies to investigate the factors influencing low wheat productivity and yield gaps in the surveyed regions. Overall, this study reveals that there are significant yield gaps and that substantial benefits for food production and environmental performance are possible through closing these gaps. Policy recommendations of the study include finding the ways to more effectively transferring technologies and improving agricultural extension services. Such efforts would help improve domestic wheat production and reduce dependency on wheat imports.

Assessing substitutability among undesirable outputs using parametric directional output distance function: A Monte Carlo analysis
Viktor Khanzhyn*

In recent years more and more studies on the effects of environmental regulation have utilized the parametric directional output distance function approach. The evidence produced by these studies is based on the calculation of the elasticities of substitution between undesirable outputs. The number of calculated parameters may be large relative to the sample size in some applications, in addition to small variability in some inputs or outputs, and/or presence of extreme observations with important information about technology. This study expands on the existing literature investigating the properties of the approach by explicitly modeling well-behaved data set for multi-output technology with undesirable outputs. I find that a goal programming approach to fitting the directional output distance function produces accurate estimates of the true parameters and is a robust approach for a variety of empirical problems such as outliers and heteroskedasticity of the inefficiency terms. A discussion of the sign of Morishima elasticity of substitution explains some surprises in the empirical findings.

Parametric decomposition of the input-oriented Malmquist productivity index: With Ethiopian agriculture
Anbes Tenaye Kidane*

I identify and quantify the main sources of productivity growth using stochastic frontier analysis via a translog input distance function on Ethiopian Rural Household Survey (ERHS) dataset. I use also the true fixed effects (TFE) panel data estimator to account, control and separate inefficiency from observed and unobserved heterogeneity. Farmers risk behavior is also controlled. The parametric Malmquist productivity index (MPI) decomposition for Ethiopian agriculture shows that the average annual productivity growth is 17.9% between 1994 and 2009. Scale effects are the most important source of this growth that accounts for about 14.5%. Technological improvement accounts for

approximately 4.8% of said productivity growth. On the other hand, the contribution of technical efficiency change is negative, leading to an annual productivity decline of 1.3%. This finding suggests that scale effect and technology are the most important sources of productivity growth in the Ethiopian agricultural sector. Improving technical efficiency is also important way to increase productivity in the future.

Scale and quality in Nordic hospitals
Sverre A.C. Kittelsen*

Objectives: Empirical analysis of hospitals in production economics often find little or no evidence of scale economies and quite small optimal sizes. Medical literature on the other hand provides evidence of better results for hospitals with a large volume of similar procedures. Based on a sample of Nordic hospitals and patients, we examines whether the inclusion of quality variables in the production models changes estimates of scale elasticity.

Data: A sample of 60 million patient records from 2008 and 2009 in 149 hospitals in Finland, Sweden, Denmark and Norway were collected by the Nordic Hospital Comparison Study Group (NHCSG) in the EuroHOPE project. Patient data DRG-points were aggregated into 3 outputs (medical inpatients, surgical inpatients and outpatients) and linked to operating costs for 292 observations. The patient data were used to calculate quality indicators on emergency readmissions and mortality within 30 days, adjusted for age, gender, comorbidities, hospital transfers and DRG using DRG-specific logistic regressions.

Methods: The hypothesis that the elasticity of scale increases when quality variables are included was tested against the null hypothesis of no change in the scale elasticity. The observations were used to estimate a cost function using Stochastic Frontier Analysis (SFA). The Cobb-Douglas functional form was chosen since the estimated scale elasticity is then a constant. Country dummies as well as dummies for University hospitals, capital city hospitals and the average travelling time for the patients were included as environmental variables. To test robustness a Data Envelopment Analysis (DEA) cost function was also estimated. Since Sweden does not have indicators of emergency readmissions, analysis was done with and without Sweden.

Results: The estimated scale elasticities did not change with the inclusion of quality indicators. With both quality indicators (mortality and emergency readmissions) included and Sweden excluded the point estimates of the scale elasticity changed from 1.041 to 1.039 with a z-value for the change of -0.11. With only the mortality indicator included the estimates changed from 1.049 to 1.048 (z=-0.04). In the latter model the scale elasticity was significantly larger than 1.0 at the 99% level (z=2.92). All models estimated that the larger part of the residual variation was due to inefficiency rather than stochastic noise (gamma=0.82 - 0.91). Travel time and University hospital significantly increased costs. University hospitals had an estimated 13% higher cost than non-university hospitals (z=3.8).

Conclusions: The analysis does not support the existence of medical volume effects on key quality indicators of a sufficient strength to increase the scale elasticity at the hospital levels. This may be because medical volume effects are confined to few patient groups or possibly even offset by other groups where quality is reduced by volume. The result of increasing returns to scale contradicts previous studies which have found decreasing returns.

Frontier visualization algorithms for FDH models
Vladimir Krivonozhko* and Andrey Lychev

Free Disposal Hull (FDH) model introduced by Deprins, Simar and Tulkens (1984) expanded the DEA models by relaxing the convexity assumption. In the DEA scientific literature, many papers were devoted to development of solution methods for computations of various scale characteristics in FDH models. These methods are divided into two groups. In the first group, methods are based on mathematical programming (MP) approach. The second group of methods involved enumeration

methods. However, as Cesaroni, Kerstens and Van de Woestyne (2016) noted, very few papers were devoted to methods for FDH frontier reconstruction.

In this paper, we propose two groups of methods for FDH frontier visualization. They are based on two approaches mentioned above. Every approach possesses its own advantages. In our work we present and describe peculiarities and advantages of every approach. Our theoretical results are confirmed by computational experiments using real-life data sets from different areas.

Endogeneity in panel data stochastic frontier model with determinants of persistent and transient inefficiency

Hung-Pin Lai* and Subal C. Kumbhakar

In this paper we consider a stochastic frontier panel data model in which the random firm-effects are introduced along with the persistent and transient technical inefficiency. Unlike the previous studies we allow firm-effects and persistent inefficiency to be correlated with the regressors. Further, we allow determinants of both persistent and transient inefficiency. We discuss a two-step MLE to estimate parameters of the model and prediction of persistent and transient technical efficiency.

How to integrate material balance issues in productive efficiency analysis: Review of models and practical use

Ludwig Lauwers* and Jef Van Meensel

The presentation gives an overview of drivers for a materials balance (MB) based adjustment of traditional frontier efficiency methods, their empirical applications and theoretical refinements and current challenges for further research. The idea for an MB adjustment of efficiency methods emerged from practical problems issuing from modelling agricultural nutrient surpluses in the nineties. Specific features of agricultural production and its externalities led to empirical evidence that efficiency improvement might be a major avenue for reducing nutrient emissions. More, such improvements can lead to economic-ecological win-wins instead of the mere trade-offs as was supposed in that period both in theory and practice. Traditional methods do not account for detecting win-win, and some of them were even not useful, because of inconsistency with the materials balance principle. A joint effort between farm management researchers (Lauwers and Van Huylenbroeck from ILVO and UGent, Belgium) and a productive efficiency analysist (Coelli from Queensland University, Australia) led to publication in 2007. Since, some tenths of applications got published: they cover both macro-economic and firm-economic applications, in agriculture and other industries. The method has been criticized, in particular because of the absence of abatement options, and has been subject to various theoretical adjustments. Now, coming back to empirics, one observes now myriad of model alternatives from which it becomes difficult to esteem the information values. Some ideas are launched for further research efforts.

Direction selection in stochastic directional distance functions

Kevin Layer*, Andrew Johnson and Robin Sickles

A distance function allows multiple product production to be modeled. A stochastic directional distance function (SDDF) allows for noise in potentially all input and output variables; however when estimated, the direction selected will affect the functional estimates because deviations from the estimated function are minimized in the specified direction. This paper addresses the question, how should the direction be selected to improve the estimates of the underlying production behavior. We are motivated by the estimation of a cost function for hospital production in the U.S. Initially, we focus on the estimation of a single iso-cost level set of the cost function. A contribution of the paper is we explore through Monte Carlo simulation the quality of the iso-cost functional estimate as we change the following characteristics of the data generation process (DGP): 1) direction of the noise, 2) the level of noise, 3) the curvature of the function, 4) the distribution of the output variables, and 5) the direction used to estimate the SDDF. We find the following guidelines to select a direction to

improve estimation, 1) when a function has significant curvature, picking a direction orthogonal to the center of the function, 2) when the distribution of data is skewed, selecting the direction consistent with the shortest distance for most of the data to the estimated function, 3) the direction and level of the noise and the curvature of the function and distribution of the data have an interactive effect on the best direction for SDDF and 4) selecting a direction consistent with the noise in the DGP improves estimates of the underlying function.

The effects of regional differentials in macroeconomic conditions on cost structures of banks
Yuzhu Li* and Richard Simper

The assumption that banks within the same country operate under the same production technology is rejected in this study. By grouping a panel dataset of Chinese banks of 10 years from 2005 to 2014 into different regions using cluster analysis based on macroeconomic factors on a provincial level, we estimate a system of a translog cost function with share equations allowing full correlations between the error terms of the cost functions and the error terms of share equations. The coefficients and cost efficiencies are estimated using the cost system equations for each economic cluster as well as the whole country sample. Our results indicate that banks operating in different economic regions present different degrees of substitutability between factors of production and these degrees of input substitutability in groups differ significantly with the input substitutability estimated using the sample of the whole country. Moreover, the estimated average efficiency scores vary in different clusters. We conclude that for countries with regional disparity in economic conditions, a regional partitioning may deem to be necessary when estimating banks' production technologies and x-efficiencies.

Short-run and long-run efficiency and their determinants: A study of crop production in Norway
Gudbrand Lien*, Subal C Kumbhakar and Habtamu Alem

The most recent stochastic frontier models for panel data model decompose the error term into four components. Of these, the first component captures firms' latent heterogeneity, the second one captures short-run inefficiency, the third one captures long-run inefficiency and the last one captures random shocks. The first two components are time-invariant while the last two vary across firms as well as over time. In this study we extend the above-mentioned model by including determinants for both the short-run and long-run inefficiency components. We apply this model to an unbalanced panel dataset from Norwegian crop-producing farms observed from 1993 to 2014.

Fuel poverty, health and subjective assessment: A latent class approach and application to the case of Spain
Manuel Llorca*, Tooraj Jamasb and Ana Rodríguez-Álvarez

The rising energy prices along with the decline in per capita income in recent years have resulted in increasing risk of being in fuel poverty for households in many countries. Fuel poverty can pose a social policy problem even in milder climates. According to the Association of Environmental Sciences in Spain, in 2014, 5.1 million people could not afford to keep their homes at an adequate temperature during the winter, a 22% growth from 2012. It is generally recognised that fuel poverty has a detrimental effect on health, although there are difficulties in defining this effect. Despite its relevance, the compelling need for addressing fuel poverty, the issue is not a high priority policy matter.

This paper uses a latent class ordered probit model to analyse the effect of fuel poverty on individual self-assessed health. This model is applied to a sample of Spanish households for the period 2011-2014. Our health production function is approximated through an ordered probit model in which a set of variables that have a direct influence on health such as age, income, employment situation or education are included. The use of a latent class framework allows controlling for unobserved heterogeneity. In addition, by including a subjective measure of fuel poverty in the probabilities of class membership, the approach permits to purge the influence of 'objective' fuel poverty on self-

assessed health from personal perceptions. Moreover, it can be argued that this model avoids the endogeneity issue that may arise when trying to include subjective measures of fuel poverty within health production functions.

Preliminary findings show that poor housing conditions, fuel poverty and material deprivation have a negative impact on health. They also show that individuals who rate themselves to be in a situation of fuel poverty tend to report poor health status regardless of their living conditions. We also observe that the effect of fuel poverty on health appears weaker when individual perceptions are not controlled for. This extension of the link between health and fuel poverty has not been explored previously and can help to target the affected individuals and groups more accurately. In the conclusions of the paper policy recommendations are offered.

The relationship between democracy index and corruption perception index and a nation's innovation efficacy and productivity

Yung-Hsiang Lu and Yi-Chen Lee*

Under the trend of globalization, today's countries are all faced with the challenge of innovation while "innovation efficacy" has become a major criterion by which a nation's ability is measured. Co-published by Cornell University, European Institute of Business Administration, and World Intellectual Property Organization, Global innovation index (GII) is regarded as an evaluative criterion comprising comprehensive indicators that appraise political maturity. Since 2007, GII has targeted at more than 30 companies and compiled a datasheet that contains traditional indicators such as R&D expenditure and the number of patents, as well as new indicators like market sophistication and business sophistication. Currently a good number of leaders of governments view GII as a trustworthy criterion by which the achievement of governance is measured. Past literature used to view GII as a referential indicator in a study (Usman amd Liu, 2015; Alfantookh and Bakry, 2015; Cvetanović, Ilić, Despotovic and Nedić, 2015), which means only a few researchers ever took its structural rationality into consideration (Sohn, Kim and Jeon, 2016; Crespo and Crespo, 2016).

The GII measurement does not consider the weight of every specific indicator when measuring a firm or country's innovation efficacy. Therefore it fails to evaluate the situation as a whole because uses the "mean" instead of classifying all indicators by the order of importance. The present paper employs a different method to re-examine the result and see if GII is a sufficient assessment of a country's innovation efficacy. Currently data envelopment analysis (DEA), which is non-parameter method, and stochastic frontier analysis (SFA), which is of parameter method, are most widely used to evaluate efficacy. DEA is susceptible to extreme values, which makes a statistical test impossible. SFA takes random error into consideration, corresponds to the theory of economics, and can be used for statistical tests. SFA can be used to more objectively measure a country's innovative efficacy and productivity. Considering a country's innovation efficacy should be assessed by multi-input multi-output measurement, while its technological efficacy cannot be estimated by a single production function, this study uses multi-product cost function to conduct analysis. Using Shephard's (1970) input-oriented distance function or output-oriented distance function to estimate technological efficacy and productivity has been a standard multi-input multi-output measurements.

Due to remarkable discrepancy in the respects of economic condition, production technologies, and natural resources endowment of a country, a single production function will not be sufficient to analyze and compare the innovation efficacy of various countries. This study opts for co-production function to analyze the relationship between input and output occurring in these countries. Therefore this study employs the stochastic meta- production frontier model developed by Huang, Huang and Liu (2014) to measure innovative inputs and outputs of these countries. With regard to grouped boundary and shared boundary, endogenous environmental variables as a factor may account for the differences of production technologies owned by differing countries, but can be used to compare a country's production technology level and efficiency.

This study first collected the data of GII of 128 countries ranging from the period 2013~2016. These countries were categorized into four groups according to GDP released by World Bank: high income, upper-middle income, lower-middle-income economies, and low income economies. This study uses stochastic meta-production frontier model to analyze each country's innovation efficacy and productivity. Lastly the author identifies those countries with higher innovation efficacy and conducts analysis over why they hit success, so that future policy-makers may learn from these successful models. This paper then continues to explore how democracy index and corruption perception index may exert influence over a country's innovation efficacy and productivity.

To sum up, main purposes of this study includes the following: 1) to examine the difference of rankings in national innovation efficacy arisen from using parameters or GII; 2) to identify the reasons that are responsible for the improvement or decline of national innovation or productivity; 3) and to analyze the correlation between a nation's democracy index & corruption perception index and its innovation efficacy and productivity. This study aims to find the relationship that higher-income economies guarantee better innovation efficacy, whereas democracy index and corruption perception index are of a high, positive correlation to a nation's innovation efficacy and productivity.

The rebound effect in Swedish heavy industry
Tommy Lundgren*, Golnaz Amjadi and Lars Persson

Energy efficiency improvement (EEI) benefits the climate and matters for energy security. The potential emission and energy savings due to EEI may however not fully materialize due to the rebound effect. In this study, we measure the size of rebound effect for the two energy types fuel and electricity within the four most energy intensive sectors in Sweden – pulp and paper, basic iron and steel, chemical, and mining. We use a detailed firm-level panel data set for the period 2000-2008 and apply Stochastic Frontier Analysis (SFA) for measuring the rebound effect. We find that both fuel and electricity rebound effects do not fully offset the potential for energy and emission savings. Furthermore, we find CO2 intensity and fuel and electricity share as the two main determinants of rebound effect in Swedish heavy industry. Our results seems to imply that it matters both to what extent and where to promote EEI, as the rebound effect varies between sectors as well as between firms within sectors.

Measuring income inequalities beyond Gini coefficient
Mikulas Luptacik* and Eduard Nezinsky*

Nowadays there has been an increasing interest in the analysis of interrelationships between income distribution and economic growth. This growing interest has recently stimulated new theoretical as well as empirical research. Since existing theoretical models propose inequality is detrimental to growth, while others point at income inequality as an essential determinant supporting economic growth, for the survey see e.g. Benabou (1996) or Aghion et al. (1999). The mechanisms linking inequality and growth have also been addressed in empirical literature, e.g. Campano – Salvatore (2006). Measures describing income inequality range from the simplest head-count ratio for poverty index to the most popular and widely used Gini coefficient. Both indices are aggregated indicators without deeper insight into income distribution among the poor (for the poverty index) or the households (for Gini coefficient). To derive an indicator accounting for income distribution among the income groups, we propose output oriented DEA model with inputs equal unit and weights restrictions imposed so as to favour higher income share in lower quantiles. We demonstrate the merit of this approach on the quintile income breakdown data of the European countries. Countries with the same Gini index – e.g. Sweden and Finland – can thus be distinguished by the new proposed indicator with respect to the Rawlsian prioritizing lower income groups´ welfare.

Productivity change analysis of Polish dairy farms after Poland's accession to the EU – An output growth decomposition approach

Kamil Makieła*, Jerzy Marzec and Andrzej Pisulewski

The aim of the study is to assess changes in productivity of Polish dairy farms after Poland's accession to the EU. For this purpose, Bayesian stochastic frontier analysis is applied to a new decomposition of output growth. Bayesian output growth decomposition in a single-output and multi-input setting was first proposed by Koop et al (1999) who show a full decomposition of output change into three components: input change, technical change and technical efficiency change. Productivity change, however, is made up of only technical efficiency change and technical change. Since there is no component measuring the impact of economies of scale to productivity, the method lacks a standard three-way decomposition of productivity growth (see, e.g., Färe et al, 1994, Bertazzoli et al, 2014, Theodoridis et al, 2014). In this study we show how changes in economies of scale can be isolated, which leads to redefined components of output growth. We derive the following additional elements: scale effect change, scale structural change (which add-up to the total scale change), pure input change and real technical change. The new decomposition provides a better measure of productivity growth, which can now disaggregated into its three generic sources: total scale change, real technical change and efficiency change. Moreover, we show how to further decompose real technical change into elasticity structural technical change and neutral technical change components. The empirical analysis is based on a panel of 1,191 Polish dairy farms between 2004-2011. It has revealed that production growth (3.91%) is due to inputs accumulation (3.4%) rather than productivity growth (0.51%), and that previous decomposition methodology undervalues the role of input growth, capital accumulation in particular. Further analysis indicates that productivity change component is driven by real technical growth (1%) and changes in scale elasticity, which have had a negative effect on productivity (-0.81%). Technical efficiency growth (0.36%) plays a rather minor role in the growth of milk production in Poland when compared with other factors.

Cost efficiency analysis of electric energy distribution sector under model uncertainty

Kamil Makieła and Jacek Osiewalski*

Efficient distribution and provision of energy is a requirement set by many national regulatory agencies nowadays. Cost efficiency analysis is one of the preferred frameworks used to monitor economic conduct of Distribution System Operators.

The study discusses Bayesian approach to analysing cost efficiency of Distribution System Operators. Bayesian model selection and inference pooling techniques are adopted in stochastic frontier analysis to mitigate the problem of model uncertainty. All possible model specifications can now be jointly used in order to analyse cost efficiency of Distribution System Operators. Adequacy of a given specification is judged by its posterior probability, which makes the benchmarking process not only more transparent but also much more objective. The proposed methodology uses a recently developed Corrected Arithmetic Mean Estimator in order to precisely calculate marginal data densities in all models considered.

Empirical example is based on field branches of one of Polish Distribution System Operators. We find that only a handful of models contribute significantly to the results in the joint model and that models, which are the best at describing the data, are rather parsimonious. They rely on just a few variables determining the observed cost. However, these models also show very high average relative efficiency scores among the analysed objects. Using posterior probabilities we also analyse significance of SF specification in the cost model and the impact of including average wages as a "justified" determinant of cost differences between objects. We find that although information on average wages does not significantly impact the order of the efficiency ranking, it does decrease differences between cost efficiency scores of the analysed objects and makes the SF specification less likely.

Markups, exports and R&D: Evidence for Spanish manufacturing
J.A. Máñez, M.E. Rochina-Barrachina and J.A. Sanchis-Llopis*

This work analyses the relationship between firms' exports and R&D, and *markups* (defined as price over marginal costs ratio). To estimate firms' markups we follow De Loecker and Warzynski (2012) methodology. While there are many works studying the relationship between exporting and engaging in R&D and firm's productivity, the study of their relationship with firm markups is scarce, and yet is it more if we consider the joint study of the two activities. The database used for this work has been drawn from the business survey on firms' strategies (ESEE) for the period 1993-2009. The results we obtain reveal a positive relationship between mark-ups and either only exporting or jointly undertaking this activity with R&D. In addition, the years of crisis seem to point toward a growing importance of innovation activities on higher mark-ups.

Efficiency analysis for project portfolio adjustment
Guilherme Marcondes and Rafael Leme*

Projects have gained in importance in companies and, usually, the scarcity of resources forces organizations to select those to be executed, opting for the ones that lead to a greater chance of success and return on investment. In search for a better set of projects (portfolio), efficiency analysis can offer an important support for the decision. However, after the analysis, some important or strategic portfolio/project can be considered not efficient and therefore ineligible to choose. In this case, by the means of data envelopment analysis tools, the impact of projects contextual variables on efficiency can be measured. This approach can be used for the adjustment of projects, to increase the number of portfolios suitable for the selection (efficient). The adjustment proposes evaluating the impact of contextual variables, applying Two-Stage Data Envelopment Analysis technique, and any possible changes, seeking to increase the number of efficient portfolios and, consequently, the options for the decision maker. It is exemplified by applying the proposed approach in a set of ten real projects.

Predicting recessions in Italy: A nonparametric discrete choice models for time series
Camilla Mastromarco*, Leopold Simar and Valentin Zelenyuk

We estimate efficiency frontier for Italian economy using quarterly data from 1995 to 2016. A flexible nonparametric two-step approach on conditional efficiencies allows us to eliminate the dependence of production inputs/outputs on time. The efficiency measure can be interpreted as output gap and employed as a predictor of economic slowdown. Applying a generalised non-parametric quasi-likelihood method, suggested by Park, Simar and Zelenyuk (2016), in the context of discrete choice models for time series data, we investigate how the spread variable, constructed as the difference between the 10-year German Treasury bond and 10-year Italian Treasury bond and our estimated efficiency scores predict the recession in Italy. By using a dataset from 1995 -2014 with quarterly frequency we emphasize the usefulness of this model for the prediction of Italian recessions in case of two explanatory variable (the lagged spread and efficiency scores). Our model involves two continuous predictors, the spread and the efficiency scores and one discrete variable, the lagged dependent variable. We find that this flexible nonparametric approach offers additional insights than the usual linear probit frequently used in the literature in this context.

The impact of labour subsidy on total factor productivity
Pontus Mattsson*

Lower expected productivity is the motivation for subsidizing labor, but all research, with one exception, focuses on other effects while some investigates the TFP effects of capital subsidies. This study is the first to determine the impacts of labor subsidies using total factor productivity (TFP) as a dependent variable. Coarsened exact matching (CEM) is performed on the key variables; difference-in-difference is then applied to the matched data. It is found that firms employing workers with wage subsidies experience negative and significant effects on both TFP and profitability.

Heterogeneity is, however, observed; firms within one sector do not show any TFP deficit and those in other sectors do not show any profitability difference, while the TFP deficit disappears during the second year with subsidies in most sectors. The policy conclusion from the analysis is that subsidizing individuals from particular groups is necessary to induce firms to hire workers from these groups. However, the time period for which a single firm is subsidized should be considered.

Predicting financial sustainability in a competitive higher education marketplace
Andrew McConnell* and Jill Johnes

Introduction: The higher education sector in the UK, like higher education sectors worldwide, operates in a challenging context following the squeeze on public funding in the wake of the global financial crisis, the increase in student fees to £9000 and the abolition of the cap in student numbers; universities are operating in an increasingly competitive market. It is therefore vital that we are able to assess the financial viability of individual institutions. Amongst the array of performance indicators produced by the Higher Education Statistical Agency (HESA) the financial security index (SI) provides an indication of financial sustainability.

The SI is published annually by HESA and is based on four metrics: historical cost surpluses, general reserves, liquidity, and borrowings. Universities are ranked on the basis of each metric and the SI is calculated as the average rank of these four. Thus equal weighting is assigned to each of the components.

The purpose of this study is to explore how well this index reflects an institution's financial strength. First we consider how sensitive the SI is to the components used in its calculation and to the weightings attached to those components. Second we explore whether there are other variables that should also be incorporated into a measure of a university's financial strength.

Methodological Approach: We use principal components analysis (PCA) to examine whether the SI as it is currently calculated represents a balanced reflection of its components. In a second stage of the study we use PCA to explore the relevance of additional variables which could possibly be used to represent financial sustainability.

Results: The PCA reveals that the single composite index based on the 4 variables in the current SI does not adequately reflect the information in those variables. Furthermore, when additional variables are considered, an extra dimension is needed to reflect financial sustainability.

Conclusion: The current SI gives too much relative weight to the closely correlated metrics for surpluses, reserves and liquidity than to the metric for borrowings. A new composite indicator constructed using a combined ranking of the equal average of the first 3 variables of the original SI plus a ranking for the 4th variable, gives us more balanced information about the dataset than the original SI which was constructed using equally weighted rankings for all 4 variables.

However the PCA reveals that there are two important dimensions in the data used by HESA to construct the SI. Thus a CI based upon a 1-dimensional ranking hides valuable information that is revealed by a 2-dimensional plot of its principal components. So some HEIs would appear to be financially stronger in the SI ranking than would be shown in the plot and vice versa. These findings have important implications both for policy makers and for university managers.

Discrete approximation of the stochastic frontier model
Aljar Meesters and Christopher Parmeter*

This paper develops a stochastic frontier model where the inefficiency component is discrete instead of continuous. The main advantage of this approach is that no strong assumptions on the inefficiency distribution are needed. The paper shows the properties of this model and how it is related to latent class stochastic frontier models. Moreover, the paper explores how the model behaves under misspecification. Extensions to determinants of inefficiency are considered.

A family of superlative indexes under Hicks neutral technical change
Hideyuki Mizobuchi* and Valentin Zelenyuk*

When an index number formula coincides with a theoretical index under some functional form for the underlying aggregator function, then it is called an exact index. When the aggregator function is also a flexible functional form, then the exact index number is called a superlative index. The present paper proposes a family of productivity indexes based on the quadratic-mean-of-order-r and shows that all index number formulae belonging to this family are superlative indexes, under the Hicks neutral technical change. In particular, in the special case when r=2, the resulting index is the famous Fisher productivity index and so our results generalize the equivalence result between the Fisher and the Malmquist productivity indexes, which is originally derived by Diewert (1992). Our results also give new justifications for productivity measurement via other interesting indexes where, e.g., the Walsh index.

Sustainability and efficiency of dairy sheep production systems in Castilla-La Mancha, Spain
Martiña Morantes, Rafaela Dios-Palomares, David Alcaide-Lopez-De-Pablo*, José Rivas and Antón García

This paper presents the results from the research performed on the levels of sustainability and efficiency in the dairy sheep production systems in Castilla-La Mancha, Spain. On Spanish rural areas, the economic sector based on flocks of sheep and herds of goats has a crucial role to establish stable economic structures for people to live steadily and permanently in unfavourable agrarian areas. The general tendency of the farms of the European Union to disappear is also observed in Castilla-La Mancha. Therefore, the ovine economic sector, and all the economic production related to the sheep, performs an essential role to preserve the natural ecosystem and rural life. On the other hand, previous studies conclude that these economic systems do not have an efficient management of the resources. Therefore, to analyse the sustainability and technical efficiency of these firms is interesting. Moreover, a study to characterise the relations between sustainability and efficiency could be useful for better understanding the firm weaknesses and relieve them.

The empiric evaluation of sustainability must be founded in the 3-dimensional aspects of this issue: environmental, economic, and social. Thus, this paper assesses sustainability and a Sustainability Synthetic Index was defined. The study was conducted in a population of 6,781 firms, using Stratified Random Sampling, where the strata are defined by geographical situation and herd size. The estimation error was 7.7 % with a level of significance of 5 %. A survey was designed to get data from the sample individuals regarding 11 relevant aspects. The technical efficiency, pure technical efficiency and scale efficiency indices, were estimated by Data Envelopment Analysis (DEA) methodology. Output orientation was chosen with one output: milk production (litres), and five inputs: sheep (number), area (hectare, ha.), labour work (hours), fixed capital (€) (amortisation of buildings, equipment, and animals), floating capital (€) (feeding cost, social security, public health system, health care, capital interests). The study concludes that the estimated levels respect to the sustainability and also respect to efficiency are of medium range. Thus, there is room for improvement of the current systems, paying attention on their weaknesses. The relations found allow us to establish suitable strategies in order to guarantee the stability and permanency of the firms in the economic sector.

Regional comparisons of energy use efficiency in Indian manufacturing: An index number approach
Kankana Mukherjee*

India is currently the fourth largest energy consumer in the world. Given the constraints in energy supply and heavy dependence on imports for energy, achieving efficiency in energy use is of fundamental importance to the future growth of India's manufacturing sector. This study uses state level manufacturing data from the Annual Survey of Industries, India for the years 2004-05 through 2011-12 to gain insights into the energy use efficiency across the states in India. The index number

approach proposed by Färe et al. (2004) for measuring environmental performance is adapted to measure energy use efficiency. The distance functions utilized to compute the index numbers are estimated using Data Envelopment Analysis for a two-outputs, four-inputs case. Results indicate that at the national level, the Indian manufacturing sector experienced improvement in energy efficiency each year over the period 2004-05 to 2011-12. However, some of the major manufacturing states exhibit lower energy use efficiency and could learn from the best practices of their efficient peers.

The role of services in enhancing the technical efficiency of Indian manufacturing firms: An analysis using the stochastic production frontier method

Sonia Mukherjee*

The classical micro-economic theory assumes that firms are homogenous units present in any nation. Accordingly, all the operating firms are assumed to operate at the equivalent levels of productivity or so called technical efficiency. However, in reality there is a considerable amount of difference in terms of technical efficiency among all the operating firms.

The important or notable factors which are responsible for the differences in the technical efficiency are quite exhaustive. Some of the prominent factors are like size of the firm, age or experience of the firm, ownership (business group and non-business group), difference in terms of exporter and non-exporter, import intensity of the firm, labor productivity, use of services such as advertising, marketing, research and development, business services and other professional services etc.

With the notable factor (services) showing a tremendous expansion over the years as compared to the other sectors, manufacturing and agriculture, the Indian manufacturing firms are readily procuring cheap services from external sources. The services procured mainly comprises of two types. They are namely, traditional services (financial services, insurance, and transport) and modern services (advertising, selling and distribution, business services and other professional services). Presently, this two kinds of services are assisting the manufacturing firm to focus on their core competencies and improve their performance further.

According to World Bank (2006), firms that use more information, communication and technology (ICT) enabled services grow faster and productive as compared to firms who do not use ICT intensively. Also, in the decade of rapid global competition, firms frequently need to restructure their production process in order to improve their performance in terms of both efficiency and productivity.

The earlier Indian studies done by eminent persons at the industry level have clearly shown that services have played a positive role in improving the total factor productivity. However, none of the studies till date have examined the fact, as to how the expansion in services and its intensive usage have made a positive contribution on the technical efficiency of the Indian manufacturing firms in the 21st Century.

Hence this study mainly intends to analyze the role of services in enhancing the technical efficiency of the manufacturing firms since 2000.

The literature on technical efficiency show that a number of methods have been used to measure the technical efficiency. However, after studying the methods in details, the study chose a parametric analysis, i.e. Stochastic Production Frontier Analysis (Battese and Coelli, 1995) to estimate the technical efficiency and its factors explaining improvement in the technical efficiency of the Indian manufacturing firm. This study was carried out for both the aggregated as well as the disaggregated group .

The results obtained indicated that services had improved the technical efficiency of the Indian Manufacturing firms for both aggregated as well as disaggregated level. The manufacturing firms using services intensively were found to demonstrate a higher level of efficiency as compared to the

other manufacturing firms. Lastly, the other explanatory factors such as age, size, exports, and ownership etc. also played a prominent role in explaining the technical efficiency of the firms.

Bad outputs
Sushama Murty and R. Robert Russell*

Building on the ideas of Førsund [2009], Murty, Russell, and Levkoff [2012], and Murty and Russell [2016], we construct a generic model of technologies that generate bad outputs as unintended by-products in the production of good outputs. The key feature of these earlier studies is the necessity of employing multiple functional (or set theoretic) restrictions, with restriction-specific disposability (monotonicity) conditions, in order to adequately represent the properties of a pollution-generating technology (with or without abatement). Paying close attention to the fundamental distinction between rivalry and jointness of inputs and (intended and unintended) outputs in the production process, we correct some shortcomings of some of these earlier modeling efforts. Finally, we propose a new measure of production efficiency for pollution-generating technologies, an extension of the efficiency index in Murty, Russell, and Levkoff to account for slack in all dimensions of the ambient space of the technology, rather than in (intended and unintended) output space only.

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Lost economies of scope and merger gains in the Norwegian electricity industry
Ørjan Mydland*

In 2016, the Norwegian Parliament amended the Energy Act, with changes taking effect from 2019. The amended legislation will introduce strict separation of all generation- and distribution companies within the electricity industry in Norway. This represents a more rigid practice of unbundling ownership compared to the situation within the European Union. One resent economies of scope study from Norway shows evidence of large economies of scope. Further, there exists several economies of scale studies on the electricity distribution industry that suggests that the companies in Norway are too small. Hence, the industry do not utilize the economies of scale potentials, which it could if the distribution companies would merge. In this paper, I use panel data for the period 2004-2014 from the Norwegian Water Resources and Energy Directorate to investigate economies- of scope and scale in the Norwegian electricity sector, focusing on the distribution and generation of electricity. Further, I perform merger analysis to investigate best- and worst scenario outcomes regarding the cost effects on the industry from the amendments in the Norwegian Energy act. The results suggests that the losses from not utilizing economies of scope effects by separating all generation- and distribution companies, to some extent can be compensated by utilizing economies of scale in the distribution companies through mergers.

Biased technological change in the Japanese non-life insurance industry
Takayoshi Nakaoka*, Takuya Urakami and Hiroyuki Inaba

Since 1996, insurance industry deregulations in Japan has allowed Life and Non-Life insurers to enter into each other’s business sectors through subsidiaries. Many of previous studies in the world have conducted empirical analyses to investigate impacts of mutual entry, suggesting there have been (dis) economies of scope, conglomerate discount (premium), etc. However, in the case of Japanese insurance industry, the impact of mutual entry is still controversial; technical change in their production process might be affected by newly developed services, mutual use of customer

information, and among others. Therefore, the purpose of this paper is to investigate the impacts of Japanese insurers' mutual entry on the production technology with estimating the translog cost function. Japanese Non-Life insurance industry data over the 1985-2014 periods is used, and obtained results are as follows: (1) technological change has been biased due to labor-saving and insurance agency-using, (2) the intensity of bias tends is much stronger among the mutually entered companies, (3) mutually entered companies relish economies of scale with the increasing trend of their core business.

A multi-level cost model with sub-DMU specific economies of scale: An application to Dutch school boards and schools

Thomas Niaounakis* and Jos Blank

DMU's may govern multiple sub-DMU's or locations that vary in size. While conventional cost or production models at the DMU-level often use aggregated in- and output indicators, the configuration and size of sub-DMU's may be an important determinant of economies of scale and the technology in general.

One example that comes to mind are Dutch school boards (the equivalent to US school districts) that govern up to as many as thirty public schools. An important question is to what extent scale economies are determined at the school versus school board level. Motivated by the notion that Dutch school boards receive additional funding for small schools, we argue that an appropriate model of school boards' cost takes into account the size of underlying schools governed.

We test (and reject) if school boards with an equal naïve scale (i.e. number of pupils) but with varying average school size adopt similar technologies. To deal with these issues, we develop a cost model that preserves analysis at the level of school boards (the DMU) but incorporates its school configuration. The proposed model is an aggregated cost model in which scale economies are partially determined at the school level, and partially at the school board level. An important aspect of the model is that cost data at the board level and production data at the school level are sufficient to estimate the model.

The model is applied to a large panel data set of roughly 600 school boards and 4,000 schools for multiple years. The results indicate that both the scale of schools and school boards are relevant for economies of scale. Specifically, the results are relevant for policy regarding the (maximum/minimum) scale of both school boards and schools, for which legislation is currently being drafted in the Netherlands. More generally, the model provides methods to incorporate the configuration of sub-DMU's in an aggregated cost or production model.

Procurement auctions for road resurfacing projects – The efficiency of regional procurement engineers

Jan-Eric Nilsson, Ivan Ridderstedt and Daniel Wikström*

The Swedish Transport Administration is inter alia responsible for the construction and maintenance of the country's national road network. The organization comprises six regions, each tendering all activities to be implemented within its boundaries. Regional procurement engineers design the quote for bids and the subsequent Unit Price Contract (UPC) for each tendered project. A UPC contract provides a list of all activities to be implemented by the entrepreneur and in which quantities. A unit price is submitted for each activity and the entrepreneurs' aggregate is the vector of prices times quantities.

This study focuses the cost-efficiency of the engineers that design the contacts in each region; there are several engineers in each region. Road maintenance projects range from simple to very complex and the maintained hypothesis is that differences in experience and skills of the engineers will lead to different costs of the projects.

Projects in our dataset are heterogeneous and it is important to capture differences that are related to the unique preconditions of each project. After an initial idea to use all information about prices and quantities, it was obvious that this would eliminate all inefficiency between contracts. To address the (in-)efficiency of engineers it is necessary to use information about the roads and the projects that are exogenous in relation to the engineers. Since the Swedish Transport Administration has detailed information about the characteristics of the road network as well as making frequent quality measures this data has now been compiled.

The paper analyses some 300 pavement renewal projects with information about each project retrieved from the national road database (NVDB) and a separate database annually updating road quality measures. Each contract is linked to the specific section of the road network and to its quality characteristics using GPS coordinates. The data set is unique in the creation of links between the three types of information on a micro level. The efficiency analysis focuses differences between individual engineers using stochastic frontier models, controlling for unique characteristics of the roads, including the quality before and after the maintenance activity has been performed.

Facilitating supplier development in construction supply chain: Data envelopment analysis approach

Abdollah Noorizadeh* and Antti Peltokorpi

In the fragmented construction industry, a large number of suppliers are collected together by a general contractor to execute the projects. While design and requirements of projects mostly differ from each other, hence the recency, frequency and monetary value (RFM) of purchases from suppliers can be different. The RFM is an established marketing technique which frequently is applied for customer value analysis. In this study, we find it useful to apply RFM in the context of construction projects. Therefore, we add the number of suppliers shared projects (P) with the general contractor and build the RFMP variables to measure the value of suppliers. For doing so, data envelopment analysis (DEA) is applied to recognize the performance of suppliers in terms of RFMP score. In the next phase, the obtained RFMP score is used to facilitate implementing the different levels of supplier development (SD) initiatives. The aim of SD is to improve suppliers performance by a general contractor's time, expertise, and financial resources. As a result, utilizing DEA to evaluate suppliers' RFMP scores help the general contractor to realize effective allocation of resources in SD program through which this can turn to its performance improvement.

Productivity analysis in the presence of uncertainty

Christopher O'Donnell*

Productivity analysis involves measuring and explaining productivity change. To measure productivity change, we must measure output change and input change. This paper discusses measures of output and input change that satisfy common notions from measure theory. To explain productivity change, we must explain how outputs and inputs are determined. This paper looks at how outputs and inputs are determined in the presence of demand and environmental uncertainty. It explores the implications for estimating technical change, environmental change and various types of efficiency change. Empirical examples are provided.

Efficiency analysis with ratio measures

Ole Ben Olesen*, Niels Christian Petersen and Victor V. Podinovski

In applications of data envelopment analysis (DEA) data on some inputs and outputs is often available only in the form of ratios such as averages and percentages. Ratio measures do in general not satisfy the standard axioms in DEA, e.g., that the technology is a convex set. This paper demonstrates how ratio data can be used in DEA. We suggest an axiomatic approach for the specification of the production possibility set based upon the formulation of new production assumptions that explicitly account for ratio measures. This leads to the estimation of an empirical possibility set under variable and constant returns-to-scale assumptions in which both volume and

ratio measures are integral types of data. The resulting DEA models allow the use of ratio measures without any transformation or use of underlying volume measures. The paper provides theoretical foundation based upon an axiomatic approach for the use of DEA in applications, where important data is available in the form of ratios only.

DEA models with ratio measures & potential ratio inefficiency
Ole Bent Olesen, Niels Christian Petersen* and Victor V. Podinovski

Focus in this paper is on the practical evaluation of strong and weak efficiency of decision making units (DMUs) in cases, where important data is available in the form of ratio measures only. The underlying axiomatic approach for data envelopment analysis (DEA) does not include the axiom of a convex production possibility set, since ratio measures in general are in conflict with the assumption of convexity. The computational solution of ratio models in DEA goes for this reason among others beyond the application of standard linear programming techniques, and binary variables embedded in Big-M constructs are needed. A new type of so-called potential ratio (PR) inefficiency is shown to be an integral part of DEA with ratio measures. PR-inefficiency characterizes DMUs that are strongly efficient in the model of technology with ratio measures but become inefficient if the volume data used to calculate ratio measures become available. Potential ratio inefficiency can be tested by the programming approaches to be presented.

The assessment of corporate social responsibility of mining firms
Renata Oliveira*, Andreia Zanella and Ana Camanho

This study proposes an innovative composite indicator to evaluate Corporate Social Responsibility (CSR) of mining firms. The performance variables are defined according to the Triple Bottom Line, to ensure that economic, environmental and social dimensions are represented. A DEA-based model is used to obtain a relative measure of CSR achievements and guide performance improvement efforts at the firm level. This is followed by the specification of a goal programming model to identify a common set of weights for the indicators of CSR, enabling the construction of a robust industry ranking. These weights are obtained with the objective of identifying a consensual weighting system that shows the industry in the best possible light. The advantage of this method is that the weights are determined with optimization techniques, respecting the trade-offs observed at the frontier of technology. An illustrative application of the method proposed, using data published in sustainability reports and corporate financial reports of mining firms, is also presented. The results and their managerial implications are discussed, with the objective of promoting the awareness of this topic among decision makers and the society in general.

A new stochastic frontier model with spatial effects in both noise and inefficiency terms
Luis Orea* and Inmaculada Alvarez*

This paper develops a new stochastic frontier model with spatial effects. Our model can be viewed as a spatial version of the Wang and Ho (2010) model, originally developed to remove time-invariant firm effects. Our framework also allows extending the spatial stochastic frontier model introduced by Glass et al (2016) by including spatial spillover effects in both noise and inefficiency terms. Our empirical strategy takes advantage of the so-called scaling property to carry out generalized spatial transformations that yield a closed form for the maximisation of the likelihood function. The model is illustrated with two applications. The first uses microdata from electricity distribution utilities and aims to control for unobservable environmental conditions. The second uses macrodata from the Spanish provinces in turn aiming to measure causal effects across regions.

Improving pension funds' performance by considering an expert's opinions and mutual funds' information using DEA
Joseph Paradi* and Maryam Badrizadeh*

In this research, Data Envelopment Analysis is used to evaluate the private pension funds' performance by considering the main characteristics of pension funds such as regulations and non-

discretionary situations for some of the variables. Moreover, because of complexity of the pension funds industry, managerial judgements are included. Furthermore, valuable information is extracted from mutual funds' dataset and incorporated into the envelopment form of the DEA model. The results show that the discriminatory power of the DEA increases after adding expert's opinions as well as mutual funds' information and three different target levels are defined for inefficient plans. This research is applied to Canadian private pension funds which are regulated federally and Canadian open-ended mutual funds. Since private pension funds have unique characteristics compared to other investment funds as well as the significant importance of retirement income to people, the results of this research will be of interest to the government, financial and industrial managers.

Emphasizing price effects in the US economy sectors 1987-2014

Raluca Parvulescu, Jean-Philippe Boussemart, Hervé Leleu and Karina Shitikova*

In the traditional DEA literature, efficiency analysis is based on benchmarking the best observed practices in terms of technical, scale or productive efficiency, all of them being based on physical quantities. Prices are introduced into profit efficiency. However, even from this perspective the main objective is to find the best allocation of output and input in terms of physical quantities. Allocative efficiency is nothing but a reallocation of physical resources. Prices are indeed used but by no means is a price efficiency measured. Profit maximization uses the own price system of a firm to determine the optimal production plan but the decision variables in the optimization program remain output/input quantities only. A more general framework should include prices in the decision variables. Firms take their decisions by considering price and quantity matching in terms of values and not only quantities with given prices. In this context DEA analysis can also be conducted with value variables in order to take into account this price/quantity matching. Then, by comparing the latter with traditional measures in quantity, a price efficiency index can be derived and interpreted as a favorable or unfavorable price environment for firms compared to their peers.

Our methodology is based on the calculation of DEA output efficiency scores using both quantity and value data. While it is well known that when the DMUs face the same prices these two set of scores are identical, however when the prices faced by the DMUs are different, these scores also differ. Therefore the ratio, between i) technical efficiency scores calculated with quantity data and ii) value efficiency scores calculated with value data, has a meaningful economic interpretation in terms of price environment effect for evaluated DMUs. Thus, if this ratio is higher than the unit, the evaluated DMU takes benefits from a positive price environment as its distance to the benchmark is lower under the "value technology" than the distance estimated with the initial "quantity technology". Conversely, when the ratio of the two scores is lower than the unit, we infer that the evaluated DMU has been subject to a disadvantageous price environment. By considering all output and input both in value and quantity we obtain a total price effect. By focusing on some specific output or input, this methodology can also be extended to compute output-specific and input –specific price effects.

This methodology is then applied to a data set containing 63 sectors that make up for the US economy between 1987-2014. The technology is given by one output (gross output) and three inputs: intermediate inputs, labor and capital (equipment, structures and intellectual property products). Each of these components are expressed either in current value terms or in volume terms (price reference year 2009=100). On this basis, we can compute the price effect for each sector following the methodology presented above.

For the US economy over the period 1987-2014, technical efficiency has improved significantly (with the exception of the Subprime crisis 2007-2008). On the other hand value efficiency pattern is flatter which signals that price efficiency has declined over this period. These two findings need probably to be related to the degree of openness (sum of total exports and imports over the gross output) which has increased over the same period. We deduce from here that the increase in the level of competitiveness to which the US economy was exposed has led to an increase in this technical

performance and in a deterioration of its price environment. The rest of the analysis is then oriented towards understanding better the reactions of the different sectors making up for the US economy (a cluster analysis based on the price efficiency indexes). The last part of our analysis uses the output-specific and the input-specific price effects in a panel model to explain the total price effect. It is shown that each of these specific price effects has had a positive contribution to the total price effect and that the main effect comes from the capital component. We also show that the early 2000s Recession and the Subprime crisis represented two major structural breaks in what the individual price effects are concerned.

IT complementarities and software programmers' productivity: Results and insights from an online experiment

Natallia Pashkevich and Darek Haftor*

The aim of this study is to investigate which set of factors determine productivity increase of an individual software programmer that use IT tools. The assumed research model provides two main hypotheses that test specific configurations of complementary factors. Both hypotheses assume that the use of IT tools that are more aligned with the utilized work process will contribute to higher productivity gain only when complemented with other conditioning factors. The first system of complementary factors is labeled 'stable' where the worker has an adaptive cognitive style, utilizes a well-structured work-process, receives upfront work technology training that is comprehensive and mandatory, is incentivized exogenously, and operates within a highly centralized decision-making structure. The second system of complementary factors is labeled 'dynamic' where the worker has an innovative cognitive style, utilizes a flexible work-process, receives mainly optional work technology training on-demand, is incentivized endogenously, and operates within a highly decentralized decision-making structure. These two systems of complementary factors aimed to condition the productivity of an individual software programmer were tested in a well-controlled online experiment. Subjects (n = 113) are recruited globally through online staffing firms. The subjects' task is to construct a software system from a received software specification. The dependent variables include both consumed work time and output quality measures. The experiment consists of three work sessions: firstly, is a baseline session where the subjects use a standard and simple IT tool to support the programming work. Then is the second session where the subjects conduct a new programming task yet with another more advanced IT tool that offers additional functionality aligned with the work-process. Finally, the same IT tool with a similar programming task are used in the third session. The quest here is to identify if the programmers can increase their productivity of software programming, compared between sessions one and two, due to a new IT tool and session two to three due to a learning effect. The results are mixed, as no clear productivity gains are detected, yet several other insights are observed regarding productivity gains and about the design of similar experiments.

A bounded weighted additive model to assess technical inefficiency: The case of milk production in Canada

Jesus T. Pastor*, Juan Aparicio, Magdalena Kapelko, Lidia Ortiz and Juan F. Monge

Since it was introduced, Data Envelopment Analysis (DEA) has been applied to many different areas and has also been extended to numerous production contexts. In this paper, we focus our attention on the production framework under output quotas. Many types of markets throughout the world are subject to intervention by government policies, with the purpose of raising the prices that producers receive for their products through the imposition of production quotas. In this paper, we introduce a comprehensive approach based upon the extension of the weighted additive model in DEA with the aim of measuring technical inefficiency of firms producing under a quota system. Accordingly, we prove several interesting properties of the new approach and compare it with the conventional weighted additive model. The paper concludes by considering a case study that analyzes milk production inefficiency in Canadian provinces, incorporating information on the quota assigned to each of the provinces.

Measuring performance and productivity growth in education with PISA: The case of Latin-American countries

Sergio Perelman* and Daniel Santin

The main advantage of the OECD Program for International Student Assessment (PISA) is that it brings every three years information on 15-year-old students performances in reading, mathematics and science for a representative sample of schools in more than fifty countries, including several Latin-American countries. Given the cross-sectional nature of the data, at each wave schools are randomly selected, PISA does not allow schools' specific panel analysis. In this study we show how productivity growth, DEA Malmquist indices, can be computed and decomposed in its main components, efficiency change and technological change, using PISA waves. For this purpose, we apply the Simar and Wilson (1999) bootstrap procedure to deal with this pseudo-panel database.

Furthermore, two kind of PISA comparative studies coexist in the literature but without connection between them. On the one side, those studies which measure educational performances without considering resources restrictions and, on the other hand, studies which measure productivity. Following the approach introduced by Cherchye et al. (2015), we illustrate the interest of computing both measures and their ratio, R=performance/productivity, on the same data using DEA. The R ratio has a straightforward interpretation for policy design purposes; $R > 1$ indicates that there is room for performance improvements with a more efficient use of given resources, and $R < 1$ that higher performance is, at least partially, due to resource restrictions.

The aim of this paper is to compute Malmquist indices of performance and productivity growth for Latin-American countries participating in PISA 2006 and 2012 waves using the bootstrap and pseudo-panel approaches indicated above. We will pay particular attention to the Malmquist decomposition and to the evolution of the R ratio over time. Our expectation is that for each country it would be possible to identify the sources of productivity growth in education, in other words the contribution of technological change and efficiency change, and to draw at the same time a diagnosis of sources of miss-performances, inefficiency and/or scarce resources. We think that these measures might be helpful for policy design in education and other sectors highly dependent of public founding as well, particularly among low and middle-income countries in Latin-America.

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The effect of cow comfort on productive efficiency: An application to Spanish dairy farms

José Antonio Pérez, David Roibás and Alan Wall*

The relationships between animal welfare indicators and productivity has been widely studied in the veterinary science and animal science literatures. Animal welfare has several facets, both physical and psychological, and several indicators can be used depending on the aspect being studied. Whereas veterinary scientists have traditionally tended to take an 'animal-based' approach to welfare, focusing on animal physiology, behaviour and pathologies, economists will tend to take a 'human-based' approach which also takes into account education, beliefs, culture, income and experience when attempting to determine the optimal level of animal welfare.

A commonly-used conceptual framework for analysing the relationship between dairy cow welfare and productivity is the use of a production possibilities frontier that implies a trade-off in the sense that increases in animal welfare could only be achieved at the expense of reduction in their productivity. However, this trade-off implies that dairy farms are producing in a technically efficient manner. If they are not, then the possibility arises of increasing both animal welfare and productivity through increases in technical efficiency.

Our work aims to contribute to the literature on animal welfare and productivity by analysing the relationship between productive performance, measured with estimates of technical efficiency, and indicators of animal comfort for a sample of Spanish dairy farms. In particular, we use data on dairy farms in the northern Spanish region of Asturias from two sources to construct a dataset of 108 farms which combines production variables (inputs and outputs) with animal comfort indicators. First, production data, as well as some determinants of inefficiency involving farm characteristics, come from a voluntary record-keeping programme in which these farms were enrolled. This record-keeping program is conducted by the regional government and gathers information on nine Dairy Farmer Management Associations (AGELES) located in the region. Second, the data for the animal welfare indicators which we use come from a specifically-designed survey carried out in cooperation with a regional by a breeders' cooperative, ASCOL, which provides information on a series of variables covering several aspects related to cow comfort. We use stochastic frontier analysis to test for a relationship between cow comfort and efficiency and to assess the scope for improving both animal welfare and productive efficiency. Of particular interest is the identification of easily-implementable practices which improve both animal welfare and economic performance.

Municipal efficiency, management forms for the waste collection service and the impact of environmental variables

Gemma Perez-Lopez*, Diego Prior and José Luis Zafra-Gómez

In their review of prior studies of local government performance, Da Cruz and Marques (2014) identified five types of external factors that determine municipal efficiency: environmental factors, sociodemographic variables, the institutional framework, previous decisions and market conditions. With respect to municipal waste collection services, research has shown population, population density and the nature of the municipality to be fundamental to efficiency (Rogge and De Jaeger, 2013).

Another issue related to the cost efficiency of waste collection is the form of service delivery – public, private or cooperative (Hirsch, 1965; Dijkgraaf and Gradus, 2003, 2013; Bel and Costas, 2006; Bel et al., 2010; Simões et al., 2012; Zafra-Gómez et al., 2013; Bel et al., 2014). However, conflicting results have been reported as to which management form for this service produces optimum levels of efficiency (Pérez-López et al., 2016).

The disparity in the results reported may be due to the fact that not all forms of management might be equally valid, depending on the sociodemographic characteristics of the municipality in which the service is provided. For example, the effects of environmental variables, which are not directly controllable by the municipal government, might be influenced by the form of service management adopted. Accordingly, the main aim of this study is to determine whether exogenous factors have differing impacts on the efficiency of the waste collection service according to the management form employed. If this were so, it would be possible to determine which form of management is most appropriate to minimise the effects of environmental variables on the waste collection service.

Previous studies of the effects of environmental variables on efficiency have been undertaken from two different approaches (Arcelus et al., 2013; Cordero and Salinas, 2017). The effects of environmental variables on the efficiency obtained can be analysed in a two-stage analysis, in which the efficiency that is previously estimated in the first stage, is regressed in the second phase on the exogenous variables. However, this procedure is only possible when there exists separability between the inputs, outputs and environmental variables (Simar and Wilson, 2007). Alternatively, the exogenous variables can be considered jointly in the efficiency estimation, using the conditional frontier proposed by Daraio and Simar (2005, 2007a, 2007b).

Following the latter approach, this study uses conditional frontier panel data with robust order-m frontiers to analyse the moderating effects of different forms of management on the environmental variables that may affect the efficiency of the waste collection service over time. To do so, we

obtained balanced panel data for the waste collection service, comprising a sample of Spanish municipalities for the years 2002-2014.

The main contributions of this proposal are, on the one hand, to estimate the conditional frontier using panel data and, on the other, to show that it is possible to detect whether different management forms of the waste collection service moderate the effects of environmental variables, which are not directly controllable by the municipality.

The contribution of resident physicians to hospital productivity
Maria J. Perez-Villadoniga*, Ana M. Rodriguez-Alvarez and David Roibas

The aim of this paper is to analyze the productivity of medical residents. The medical residents have a working contract with special rights and responsibilities. From this point of view, learners could be considered as an input in the hospital production function and their wages the price of this input. On the other hand, teaching hospitals have, as an additional activity, the professional training of medical students. This could introduce more complexity to the activity carried out by senior physicians given that they face the added challenge of training student doctors.

The existing literature analysing the productivity of physicians with the added challenge of student-training is scarce and is usually applied to the US framework. For the latter, most of the papers written are dedicated to measures of medical efficiency at local hospital level and seem to be directed to the evaluation of either national US policies (i.e. the Medicare programme which is used to channel funds to teaching hospitals in the US) or alternatively to cost efficiency/ internal evaluation of teaching hospitals. For example, Henning et al. (2013); Bhat et al. (2014); Dowd (2005); Thibodeau (2010); Cobb (2013); Brennan (2007); Jeanmonod et al (2009); Grosskopf et al. (2001) or Ferrier et al. (2014) investigate whether the variation in performance across hospitals can be related to or explained by training activities and their results reveals significant effects of teaching dedication on the activity and productivity of the hospitals. Using data from the "Establecimientos Sanitarios con Régimen de Internado" (In-Patient Health Care Establishments) carried out by the Spanish Ministry of Health and Consumption, our results suggest that: (i) the net effect of resident physicians in the National Health System is that of an input; (2) the contribution of resident physicians to the health services production is significantly lower than that of attending physicians.

Which estimator to measure local governments' cost efficiency? Evidence from Spanish municipalities
Isabel Narbón Perpiñá*, María Teresa Balaguer Coll, Emili Tortosa Ausina and Marko Petrovic

We analyse overall cost efficiency in Spanish local governments during the crisis period (2008–2013). To this end, we first consider the most popular methods to evaluate local government efficiency, DEA (Data Envelopment Analysis) and FDH (Free Disposal Hull), as well as recent proposals, namely the order-m partial frontier and the non-parametric estimator proposed by Kneip, Simar and Wilson (2008), which are also non-parametric approaches. Second, we compare the methodologies used to measure efficiency. In contrast to previous literature, which has regularly compared techniques and made proposals for alternative techniques, we follow the method used in Badunenko et al. (2012), with the aim of comparing the four methods and choosing the one which performs best with our particular dataset, that is, the most appropriate method for measuring local government cost efficiency in Spain. We carry out the experiment via Monte Carlo simulations and discuss the relative performance of the efficiency scores under various scenarios. The results of the experiment depend on the value of the Lambda parameter, namely, the relative sizes of the inefficiency and the error terms. Our results suggest that our sample of 1,574 Spanish local governments lies in scenario 6, where DEA and FDH methodologies perform best at estimating the efficiency scores according to the findings from our simulations. Results show that the average cost efficiency would have been between 0.54 and 0.77 during the period 2008–2013.

Analysis of French logistics services providers performance using data envelopment analysis
Romain Petiot* and Laurent Cavaignac*

Today, the research debate on the key factors of logistics performance is in full swing. The Logistics Services Providers (LSP) sector forms a major pillar of the supply chain performance. This sector is undergoing profound changes. There have been many mergers and acquisitions which tend to decrease competition and the pressure on cost efficiency. This raises the questions of the performance of the firms in this sector and their optimal size. Research in this field is scarce and no analysis has been conducted on the French market (Mothilal, 2011). Data Envelopment Analysis (DEA) is typically adapted to answer such questions (Min and Joo, 2006, 2009; Zhou et al., 2008). In this paper, we provide a Data Envelopment Analysis of the Logistics Services Providers on the French market. We use a database from 2014 to determine efficiency benchmarks, inefficiency measures and return to scales for 79 French LSPs. To improve the robustness of our results we use bootstrap techniques. A Tobit model is then implemented to identify the influence of environmental variables such as the LSP status (international or national), the area of specialization, etc.

A decentralized resource allocation industry model
Antonio Peyrache* and Prasada Rao

Abstract In this paper we provide a decentralized solution interpretation to the problem of allocating resources optimally within an industry. Industry inefficiency is defined as the shortage of output due to misallocation and misuse of resources within an industry. Given estimates of the production set (either using DEA or SFA) the optimal configuration of the industry may require a transfer of resources between existing firms or towards new entrants. The standard interpretation in the efficiency literature considers this problem as a central planner problem, where the objective function of the central planner is to maximize aggregate output (or minimize aggregate loss). We consider the problem from a trade (and general equilibrium) point of view: since there is an output loss in aggregate terms, it must be possible to find a set of trading prices for the inputs (possibly different from market prices) such that all firms in the industry are better off after the trade and the transfer of resources is implemented using these prices to compensate the losers (though the compensation should not necessarily happen; i.e. there is no bias towards the status quo). The after trade configuration will have zero output loss as required by the central planner, but the outcome is achieved by trading on a secondary input market. The model also shed light on the fact that the industry inefficiency notion considered in the standard model is equivalent to the Kaldor-Hicks definition. We introduce a weaker notion of inefficiency that requires only Pareto improvements (without compensation). This second type of inefficiency is new in the efficiency literature.

Network DEA, industry structure, and backlog congestion in the Italian justice sector
Antonio Peyrache and Angelo Zago*

The average length of trials in the 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. In this paper, using a quite unique set of data, we analyze the efficiency of the Italian courts of justice for the period 2001 to 2012. Using a network DEA model, we take into account the structure of the Italian courts of justice: first, that bigger courts may have a subsidiary branch; second, that each jurisdiction includes smaller special courts in charge with minor cases. In addition, we test the hypothesis that a greater backlog of cases may be a source of further delays.

Indeed, in the labor literature it is argued that when judges' workload is too heavy, it would be a cause of lower judge's productivity (see, e.g., D. Coviello, A. Ichino & N. Persico, 'Time Allocation and Task Juggling', Am. Ec. Rev., 104 (2), 2014: 609-623. We thus extend Peyrache & Zago's model of industry optimal structure (Omega, 2016), to accommodate for intermediate inputs/outputs using network DEA and we test whether indeed the stock of pending cases – our intermediate input/output and measure of backlog – can cause congestion.

Preliminary results show that the (congestion) inefficiency caused by the stock of pending cases is smaller than other sources of inefficiency. However, in those courts with higher stock of pending cases, the inefficiency due to congestion may be greater than other sources of inefficiencies. Pending cases represent a peculiar example of intermediate inputs/outputs: (together with incoming cases) they are needed – else judges cannot define cases and thus provide justice - but if they are too high they can cause congestion. We thus estimate the optimal size of the stock of pending cases.

The inefficiency of the missing middle
Hien Pham* and Antonio Peyrache

This paper empirically investigates the linkage between the industry measure of efficiency and the missing middle phenomenon in developing countries. The missing middle refers to the empirical fact that most employment is concentrated in either small-sized or large-sized firms

(i.e. medium size firms have a low share of employment). The inefficiency of an industry (or a group of firms or production plants) is defined as the difference between the observed production of the industry and the potential production that would be possible if all the resources were to be allocated and used efficiently. We show that the small size group tends to operate closer to the potential production; while the middle size group exhibits the highest contribution to overall inefficiencies associated with scale.

The missing middle phenomena could be created by a local non-convexity of the technology set. In order to accommodate for this, we provide a definition of industry inefficiency based on non-convex production sets (i.e. free disposal and free replicable hulls). A proposition is provided to show that the industry inefficiency indicator is approximately the same, regardless of the assumptions on returns to scale and convexity of the underlying firm technology.

Weak disposability in nonparametric production analysis: Which reference technology is appropriate?
Manh D. Pham* and Valentin Zelenyuk

Adequate modelling of undesirable outputs in a production process is a very important aspect for many applications. Fare and Grosskopf (2003) proposed a solution that has been widely pushed in practice. Recently, Kuosmanen (2005) and Kuosmanen and Podinovski (2009) challenged their approach, starting the debate that seem to be not over. In this paper we try to reconcile this debate and shed some new light on the problem, proposed solutions and possible new solutions.

It takes two to tango: The impact of ICT and R&D on efficiency
Fabio Pieri, Ana Rincon Aznar, Francesco Venturini and Michela Vecchi*

The aim of this work is to provide comprehensive evidence on the role of technological innovations in industrial production of most developed countries looking at three important channels, namely technological change, input accumulation and technical efficiency.

Using industry data for a large sample of European countries, Japan and the US between 1970 and 2007, we estimate the impact of ICT and R&D on productivity and efficiency by means of Stochastic Frontier Analysis (SFA).

Our results show that both forms of technologically advanced capital increase either productivity or efficiency levels. There is however heterogeneity in the impact of these factors across sectors implying that policies aimed at raising these investments need to take account of the industrial structure of the country.

An evaluation of the Norwegian fisheries management system for the conventional coastal vessels
Ruth Pincinato*, Frank Asche, Andreea Cojocaru and Kristin Roll

The lack of propriety rights in the marine environment has been known to lead to resource rent dissipation in fisheries through stock overexploitation. The introduction of transferrable fishing

quotas provides incentives for efficient fishers to buy quotas from less efficient fishers and consequently reduce harvesting capacity. This may increase overall productivity, reduce costs and, therefore increase fishing profits. This paper presents evidence on the effect of the quota system policies on the fishing industry. The analysis looks at the Norwegian coastal vessels using conventional gear and their response to the introduction of a structural quota in 2008. The structural quota allows fisher to transfer their vessel's quota to another vessel in the same group and region of the country as long as the sold vessel is removed from the fishery. In order to assess the consequences of the policy, a cost minimization behaviour was assumed for the Norwegian coastal fisheries, since they operate under constrained/regulated output. A translog cost function model on an unbalanced panel data of vessels costs from 2004 to 2014 was used to compare the fishing costs of two vessel groups. On the one hand, the group comprises vessels base-size within 11-15m and for which the policy was applied as of 2008 and on the other hand, the control group comprises vessels base-size below 11m with no structural quota in place. Results indicate a decrease in costs after the policy introduction for the group with structural quota, in comparison to the control group. Hence, regulations allowing a higher degree of transferability in quotas may lead to enhanced efficiency and resource rent generation in the fishery.

DEA models with weight restrictions: What is the meaning of optimal weights?
Victor Podinovski*

In standard multiplier CRS and VRS DEA models, the optimal weights show the DMU under the assessment in the best light in comparison to all observed DMUs. In this sense, the optimal weights are the most favourable for the DMU under the assessment when it is benchmarked against the observed DMUs only. It is known that this interpretation is generally incorrect for models with weight restrictions. We show that, in such models, the optimal weights are the most favourable for the DMU under the assessment when it is benchmarked against the whole technology expanded by the weight restrictions, stated as production trade-offs in the dual envelopment form, and not only against the observed DMUs. This result overcomes some previous concerns about the meaning of DEA models with weight restrictions.

Misallocation and intersectoral linkages
Latchezar Popov* and Sophie Osotimehin

We study the implications of distortions in the use of intermediate goods for misallocation and aggregate productivity. We model the input-output structure of the economy allowing for nonunitary elasticity of substitution between inputs and derive the aggregate TFP loss from the presence of industry-level distortions in the use of intermediate inputs. We show theoretically that the TFP loss increases with the elasticity of substitution between inputs. For plausible values of the elasticity of substitution, our (preliminary) results suggest that industry-level distortions could reduce aggregate TFP by about 5-10%.

The good, the bad and the socially responsible: A production analysis approach to firm's performance ranking
Daniela Puggioni* and Spiro E. Stefanou

Ranking firms based on their CSR performance is a relatively new trend motivated by the growing number of investors who seem to have a preference for investing in 'greener' and more 'socially responsible' companies. As a result, several investment consulting firms have started to specialize in ESG (Environment, Society, Governance) research and analysis to support investors' decisions by creating ESG rankings and indexes. The issue with those is that they uniquely focus on the CSR performance of firms ignoring that CSR activities are in fact inseparably linked to the other complex production decisions and trade-offs that firms face. The goal of our contribution is to frame the question analytically using a formal production model and empirically derive a ranking that meaningfully accounts for these complexities in evaluating firm's performance. To this end we adopt a joint production model for characterizing the technology and representing the transformation

process of multiple inputs (conventional, undesirable and socially responsible) into multiple outputs (desirable/marketed, undesirable and socially responsible).

Empirically, our analysis relays on a parsimonious non-parametric approach known as Data Envelopment Analysis (DEA) applied to a customized dataset of 175 global firms in the food manufacturing sector that includes information on CSR performance provided by Sustainalytics. We obtain an overall output-specific measure of efficiency for each firm. Our efficiency measure is a Russell-type measure that is the sum of three different efficiency components, one for each of the outputs (desirable, undesirable, socially responsible) included in the model. We then consider the distribution of firms in our sample generated by our efficiency scores with the distribution of the same firms implied by the Sustainalytics ESG index. In particular, we focus on the distributions implied by our overall efficiency score, our CRS-specific efficiency score and Sustainalytics ESG index and we find that these three distributions are quite different. We compare the firms that are above the median (i.e. in the last two quartiles) of the ESG index distribution with the firms that are below the median in the overall efficiency and CSR-specific efficiency score distributions. We find that 89 percent of the firms above the 50th percentile of the ESG index distribution are also at the top 50 percent of the CSR-specific efficiency score distribution, but only 66 percent of them are at the top 50 percent of the overall efficiency score distribution. This demonstrates that considering only a part of the activities that firms engage into may be misleading for ranking firms' performance.

Airports efficiency over time

Ane Elixabete Ripoll-Zarraga***,*** Cecilio Mar-Molinero**,** Fabiola Portillo Pérez de Viñaspre

In recent years, the calculation of efficiency has been based on Data Envelopment Analysis (DEA) models. DEA attempts to establish if the resources that a particular unit being assessed uses could have been better employed in other units of the same system. The idea is simple but the mathematical model is relatively complex and has important shortcomings. The result of a DEA analysis is a number that summarises efficiency. But, what does this number mean? What are the implications for a unit of assessment to be found to be fully efficient? If two units are found to be equally efficient, what are the different policies by which this level of efficiency is achieved by these units? All these issues are addressed in the present study by using a new approach that combines standard DEA analysis with multivariate statistical methods. We use Spanish airport data, and explore the special features of hub airports (Madrid and Barcelona).

The work is taken one step further by explaining variation over time. This is done by means of graphical methods based on psychometric analysis. We find that there are four aspects of efficiency that are needed in order to describe each airport: efficiency in generating income, efficiency in punctuality, efficiency in passenger management, and efficiency in dealing with cargo. The analysis over time reveals how the importance of each of these aspects has changed over the period studied.

Fuel poverty and well-being: A consumer theory and stochastic frontier approach

Ana Rodríguez-Álvarez*, Luis Orea and Tooraj Jamasb

The aim of this paper is to analyse the impact of fuel poverty on individual subjective well-being (SWB). The literature on well-being and happiness has seen important developments in recent decades. These studies use a similar empirical strategy: the definition of a model where the measure of well-being or happiness is a function of a number of factors such as income, health etc. Binder and Brockel (2012) and Cordero et al. (2016) use a different approach and estimate a measure of efficiency which shows individuals search for the highest level of happiness achievable, given a set of resources. They use a production frontier model using nonparametric techniques. In these studies, happiness is considered as output and resources for obtaining it (income, health, etc.), are inputs.

The idea behind using frontier models in this context is to compare individuals in order to build a happiness frontier with individuals who, ceteris paribus, can achieve the highest levels of happiness with a given level of resources. Once this frontier is built, other individuals can be compared with

those already situated on the frontier in order to determine their level of inefficiency when trying to maximise their happiness. Hence, the estimated frontier is a relative construct and not an absolute one. Granted the relative nature of these frontiers models, this methodology is particularly suitable for analysing a relative concept such as SWB.

However, given that well-being or happiness are both concerned with individuals, in this paper we propose a new frontier model set within a theoretical framework based on consumer theory rather than the commonly used production theory based approaches. The theoretical proposed model, based on a distance function, permits estimation of individual indifference curves which take into account their consumption of goods, personal characteristics and the surroundings. We apply the theoretical model empirically using data from the 2013 Spanish Living Conditions Survey. To do this, in the empirical model, we have specified a SFA model where we permit the presence of heteroscedasticity in the variance of the inefficiency term (Caudill et al., 1995 model). Moreover, the distance function approach allows us to estimate the model consistently, even when goods can be endogenously determined by the individual, given that these are a function of personal characteristics such as personality and motivations.

The results indicate firstly, that individuals' preferences differ depending whether the individuals are in a situation of poverty. This is true for the two poverty concepts analysed: general poverty and fuel poverty. In terms of our theoretical model this is reflected by the different indifference curves. That is, individuals adapt their needs to their possibilities, so that the expenditure required to obtain a given level of utility is lower in the case of consumers who are in a poverty situation. Furthermore, the effect of fuel poverty (as shares of basic and energy expenditures of disposable income) on SWB persists even when controlling for general poverty, which indicates that they reflect different effects and, therefore, it is preferable to analyse them separately. Results also indicate that the loss of welfare is not linear and that a possible "compensation" would be more efficient (in terms of increasing the welfare of an individual), if it is focused more on households more vulnerable in terms of fuel poverty.

Evaluating the cost of waiting lists: A primal approach
Ana Rodríguez-Álvarez, David Roibas* and Ana Gonzalez-Vidales

Waiting lists for medical services result in delays in attention to patients which invariably prolong existing health problems. In this context, waiting lists can be considered as an inconvenience for patients given that the value of inpatient care deteriorates the longer the care is postponed after initial diagnosis. Nevertheless, the delay in patient attention could also give rise to some positive aspects related with the cost of providing health services. Waiting lists reflect the referral of patient attention from periods of "peak" demand to periods of "valley" demand. This referral allows overall patient attention to be provided with lower capacity on the part of hospitals, alleviating to some extent the potential excess capacity (technical inefficiency) generated during "valley" periods. This way, in the literature it is found that hospitals with longer waiting times have lower costs. Thus, those hospitals trying to reduce waiting times by providing sufficient extra standby capacity to cope with varying demand options will incur higher costs as compared to hospitals that provide this service to a lesser extent.

In this study, we develop a procedure based on the dual relationship between the input distance function and the cost function that permits an evaluation of the cost associated with a reduction in waiting lists as well as the impact on hospital technical efficiency. These results aim to shed some light on the resources needed to improve the status of waiting lists in the Spanish healthcare system and would in turn prove helpful with the decision-making process of hospitals. To the authors' knowledge, to date, no study exists that considers the impact of a reduction in waiting lists on the technical efficiency of hospitals when evaluating the cost of supplying health services.

Size efficiency reconsidered
Kenneth Løvold Rødseth*, Paal Brevik Wangsness, Finn R. Førsund and Halvor Schøyen

The potential to improve the productivity of a production unit is indicated by the most productive scale size. The concept of returns to scale – i.e., the proportional change in outputs by a proportional (incremental) change in inputs – receives much attention. An alternative measure of economies of the activity level is returns to size. It differs from the scale measure by allowing the output mix to vary when inputs are changed proportionally. This difference can be important because it may be economically rational for a unit to change its output mix when the magnitude of its operations is altered. As noted by Chambers (1988) and Dollery and Fleming (2006), while the notions of scale and size often are confused and used interchangeably they are not equivalent.

This paper revisits the concept of economies of size in the context of efficiency measurement. Size efficiency has received limited attention in the literature: To our knowledge, only Maindiratta (1990), later followed by Chattopadhyay and Ray (1996), have used this term. Their definition of size efficiency differs from our, which coincides with the notion of size economies in traditional production theory. We show that aggregate output efficiency decomposes into technical, allocative, and size efficiencies. Moreover, we find that size efficiency is the product of scale efficiency and an allocative efficiency component, defined by the ratio of allocative efficiencies at the most productive and current sizes of operation. The sign of the allocative efficiency component is unambiguous, which means that size efficiency may be greater than, equal to, or smaller than scale efficiency. Size and scale efficiencies coincide when the technology exhibits output homotheticity or when there is only one output.

Using a sample of 25 Norwegian seaports we demonstrate how size efficiency can be calculated using Data Envelopment Analysis. While many ports' size and scale efficiency scores coincide, we find that they can also be widely different. We conclude that how productivity is defined may largely influence the estimated gains from adopting economies of the activity level.

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Composite Indicators as generalized benefit-of-the-doubt weighted averages
Nicky Rogge*

Composite indicators (CIs) are usually computed as arithmetic (weighted) averages of (often normalized) sub-indicators. Several studies criticized this procedure for implying requirements and properties that are often hard to maintain in practical applications. Recent studies explored the multiplicative aggregation and more specifically the geometric (weighted) average as aggregator in CI-building. This paper takes this exploration one step further by considering other members of the family of generalized (weighted) average as aggregator in the construction of CIs. It is argued that the choice for a particular version of the generalized weighted average enables to reflect decision makers' attitudes in the evaluation. For the Human Development Index, results show that the choice for a specific version of the generalized (weighted) average as aggregator in CI-construction impacts country rankings.

Examining the economic performance of Chinese farms: A dynamic efficiency and adjustment cost approach

Supawat Rungsuriyawiboon* and Yanjie Zhang

This study contributes to the ongoing debate on the structural transformation of farm production in China. We analyzed this phenomenon by examining the economic performance of Chinese farms. To understand the state of adjustment processes and dynamic structure in Chinese agriculture, this paper proposes a dynamic frontier-based model using the shadow cost approach in the framework of the dynamic duality model of inter-temporal decision making. The dynamic cost efficiency model allows us to consider the impact of allocative and technical efficiency in Chinese agriculture, as well as the adjustment costs resulting from the change of quasi-fixed input use.

The dynamic efficiency model is implemented empirically using a panel data set of 4,201 Chinese farms in three provinces (i.e. Zhejiang, Hubei and Yunnan) from 2003 to 2006. This is the first study to investigate the allocative and technical efficiencies of Chinese agriculture using a dynamic shadow cost approach. With the parameter estimates from the model, we further calculate the partial adjustment coefficients of quasi-fixed factors, the optimal stocks of quasi-fixed factors, and the short- and long-run dynamic scale and cost elasticities.

The findings show that the adjustment of quasi-fixed inputs is rather sluggish, implying that adjustment costs are considerably high on Chinese farms. The relatively low levels of allocative and technical efficiencies indicate that most of farms are unable to catch up with the production frontier under the existing production technology and that they are unable to use various inputs in the appropriate proportion given their respective prices. Based on the findings of this study, important policy implications can be derived for the future development of agricultural production in China. Since the inefficiencies are normally associated with motivation, information, and institutional environment problems, policy makers should pay more attention to various factor market reforms as a whole. This statement is reinforced by the relatively low estimated adjustment rates of the quasi-fixed factors, implying high adjustment costs. We introduced adjustment costs in the model to capture those forces or economic situations that impose some penalty on the farm beyond the acquisition cost, and hence slow down the adjustment process of production factors.

An integrated analysis of cash flow, economic costs and economic profitability

David Saal* and Pablo Arocena

This paper provides careful consideration of the theoretical links between a company's cash flow, its actual economic costs, and its economic profitability, thereby providing a more comprehensive analysis of a firm's performance and the source of its realized economic profits. This is illustrated by application to a data base comprised of privately owned English and Welsh water companies, and the publicly owned Scottish Water, in which striking differences in the determinants of firm profitability are identified.

Spatial regimes in farms technologies

Cristina Salvioni*, Anna Gloria Billé and Roberto Benedetti

Controlling for unobserved heterogeneity is a fundamental challenge in empirical research, as failing to do so can produce model misspecification and preclude causal inference. In this article, we adopt a two-step procedure to deal with unobserved spatial heterogeneity, while accounting for spatial dependence in a cross-sectional setting. The first step of the procedure takes explicitly unobserved spatial heterogeneity into account to endogenously identify subsets of farms that follow a similar local production econometric model, i.e. spatial production regimes. The second step consists in the specification of a spatial autoregressive model with autoregressive disturbances and spatial regimes. The entire method is applied to two regional samples of olive growing farms in Italy. The main finding is that spatial autoregressive models with regimes fit the data best, proving that explicitly

accounting for unobserved spatial heterogeneity is of crucial importance when modelling the production function of farms.

Impact evaluation through frontier methods
Daniel Santín and Gabriela Sicilia*

In this research we propose a new approach based on production frontiers to analyse the impact of public programmes implemented on schools through a randomised trial. Most educational programmes and research in education nowadays are not devoted to increase the budget but to promote the organisations' productivity, via technological change and/or improvements in technical efficiency (e.g. throughout improving the school's management and the educational practices inside the classrooms). In this context, it becomes equally relevant to evaluate the interventions potential impacts on the output to unravel the channels through which the intervention operates (inputs, technological change and/or efficiency). Surprisingly to date in the economics of education, both fields of research, impact evaluation and production frontiers, run as parallel lines of research with no relationship, or very little, between them. In this work, we propose not only to compare the final average results between treated and control schools to evaluate the causal impact of an intervention, but also to analyse how a treatment implemented in the schools can influence their production activity. This strategy proposes to measure Total Factor Productivity Change (due to efficiency and/or technology changes), through the estimation of a by-group Malmquist Index. The potential and accuracy of this methodology is illustrated in a Monte Carlo experiment. Results evidence that for interventions devoted to enhance schools' productivity, the treatment effects are better measured regarding TFPC because it allows us to measure efficiency and technology changes determined by best practices detected through the production frontier. If we only evaluate the treatments in terms of the average outputs improvement, we might not find significant impacts concluding that the intervention had no effect and leading to imprecisely evidence-based policy recommendations. Even when we find significant impacts on the average output, it is crucial for policymakers to reveal the channels through which the treatment operates (additional inputs, schools' efficiency improvements and/or a technological progress in the educational sector).

Determination of efficiency scores in a partially negative DEA problem using directional distance model
Subhadip Sarkar*

A new variation of Directional Distance model is investigated here to assess the efficiency of the competing decision-making units (DMUs) under the scenario of a partially negative data presented in "the notional effluent processing system" (from Sharp et al (2006)). In contrast to Range Directional Models, the extant research uses a novel linear directional distance function, which solely depends on the axis of obliquity. The efficiency scores are found to be sensitive to the obliquity indexes derived from the angle between the axis of obliquity and other negative or mixed type of input (output) variables. An angle, equal to a threshold value, is found to be offering lowest efficiency scores but is also capable indeed to generate peers close to the inefficient rival.

Stock vs. mutual insurers: Long-term convergence or dominance?
Philipp Schaper*

We find evidence for long-term convergence of stock and mutual insurers in an analysis of metatechnology DEA efficiency for 2002–2015. This result may emphasize that even though one organizational form may dominate in terms of performance over a certain period as documented by extant literature, insurers operating under the inferior organizational form are under increasing pressure to catch up leading to more homogeneity over the long-term. Thus, dominance of either stock or mutual insurers may be only temporary. For example, we find that in a short-term view stock insurers are more successful in improving efficiency after endogenous turmoil (i.e., company rating downgrades). Different to previous studies focusing on the expense preference and efficient

structure hypotheses, we explicitly consider the dynamics of stock and mutual insurer's technology and efficiency.

Who is harvesting our grapes? Estimating the impact of the European migrant crisis on vineyard productivity in Southern Italy

Stefan Seifert* and Marica Valente

About half a million refugees and migrants have reached the Italian coasts in the aftermath of the 2011 Arab Spring uprisings, and the escalating Syrian civil war. 2016 Amnesty International Report estimates approximately 500.000 migrants to be irregularly employed as crop farm workers in Italy. The term "agromafia" represents this Italy-wide deep-rooted criminal activity. It operates through the so-called "caporalato" which consists in recruiting low-paid workforce under working conditions close to slavery. The estimated value of illegal business of agromafias and caporalato in Italy ranges from 14 to 17.5 bill. euros, profits obtained from the trade of crops and refined products like tomatoes, oranges, grapes and wine.

This study aims at estimating the causal effect of the migrant inflow with the European migrant crisis 2011 on Italy's vineyard productivity on regional level. Thereby, we focus on productivity in those regions receiving the greatest flows of migrants directly exploitable as low-cost labor inputs in grape harvesting, namely Sicily, Calabria and Apulia. In particular, we assume that illegal labor can influence productivity in several ways: Illegal labor can be used to replace legal labor, can be used as an additional input, or can be used as a substitute for capital inputs. Because the use of illegal labor is unobserved, productivity measures (and in particular labor productivity) are expected to be upward biased in all these cases, if illegal labor is used.

Our empirical analysis relies on the Synthetic Control Method, which builds a synthetic counterfactual by weighting units of a control group (all other Italian regions not directly affected by the coastal refugee inflow) for the pre-treatment periods in all the productivity-relevant characteristics, to resemble as much as possible the Southern region's productivity path. If the productivity path of the synthetic counterfactual is similar to the one of the treated regions prior to the migrant inflow, productivity differences after the shock are due to the abnormal migrant inflow itself.

Our paper contributes to the literature as a first attempt to identify the use of illegal migrant labor supply in Italian viticulture as well as its impact on productivity. Our paper expands the pre-existing literature as it shows how this method overcomes many limitations in building a reliable counterfactual when traditional assumptions fail, and, as in the case of agricultural productivity, the outcome variable presents large region-specific time-varying unobserved heterogeneity.

Is less really more? Academic performance of first-year students in Italy in the wake of two institutional reforms

Vania Sena*, Sergio Destefanis, Roberto Zotti and Cristian Barra

Between 2007 and 2008, the Italian government set sail to reduce the fraction of public resources allocated to the higher education system. As a result, higher education institutions (HEI) were asked to reduce the number of offered programmes, increase the average number of contact hours for a substantial share of the academic staff and slow down considerably the natural turnover of the academic staff in Italian universities. This paper uses Data Envelopment Analysis (DEA) to quantify the impact that these measures had on the academic performance of 53,159 first-year students in a large public Italian university. The analysis is articulated in two stages. The first stage decomposes students' academic performance into a student-level faculty effect directly influenced by the way teaching activities are organised at faculty level and a student-level within faculty efficiency score which is based on the comparison of the students' performance with their peers in the same faculty. In the second stage, we focus on the student-level faculty effects and on their evolution across the

different faculties. We find evidence that the reduction in the number of academic staff has an adverse effect on students' performance following the reforms.

Industrial concentration and technical inefficiency: A dynamic approach
Maman Setiawan*, Grigorios Emvalomatis and Alfons Oude Lansink

This research investigates the relationship between industrial concentration and technical inefficiency using a dynamic approach. Static relationship between industrial concentration and technical inefficiency is applied on the partial adjustment mechanism which results in a model associating the lagged industrial concentration with the technical inefficiency change. This research uses technical inefficiency estimation considering the adjustment cost coming from the investment. The model is applied to panel data of the subsectors in the Indonesian food and beverages industry over the period 1980-2014. The model also considers the endogeneity problem in the industrial concentration variable. The results suggest that lagged industrial concentration affects positively the technical inefficiency change. This implies that there is a short run effect of the industrial concentration on the technical inefficiency in the industry.

Efficiency in U.S. farm production and the role of distribution (structure and conduct) of farm programs: Evidence from a national survey
Saleem Shaik* and Hisham El-Osta

Technical efficiency and normal error is used a as proxy for performance and productivity, respectively, to examine the importance of farm program payment distribution (share and concentration) along with climate on agriculture production, efficiency and productivity. A heteroskedastic stochastic frontier production function equation with decomposed one-side inefficiency, u and random error, v is estimated using a) U.S. farm-level data from the lower 48 states based on the 2011 and 2014 Agricultural and Resource Management Survey (ARMS), and b) U.S. county-level data from a maximum of 3000 counties from 1970 to 2015. Results from ARMS reveal that the variables farm program payment share and top 25% concentration affect efficiency similarly across rural and urban counties but with different magnitudes. Similarly, the temperature and precipitation coefficient of variation affects efficiency with different magnitudes. Results using county data indicate differential importance of farm program payment distribution (share and concentration) on efficiency and productivity.

Cross-country comparison of agricultural productivity between the United States, Canada and Australia: The superlative versus the quantity-only based index
Yu Sheng*, Xinpeng Xu and Eldon Ball

Recent studies that compare agricultural total factor productivity across countries use either the superlative index approach or the quantity-only based index approach, generating significantly different results. We demonstrate theoretically that the difference comes from measurement errors in implicit prices used by the quantity-only based index which differ significantly from market prices used by the superlative index. Using a novel dataset built upon a cross-country consistent production account for the United States, Canada and Australia, we show that the superlative index approach which uses both price and quantity information always outperforms the quantity-only based index approach which uses quantity information only, in terms of accuracy and consistency in aggregation. Our finding highlights the importance of collecting price data for performing international comparisons of agricultural productivity.

Output-specific inputs in DEA: An application to courts of justice in Portugal
Maria Silva*

This paper addresses the efficiency assessment of production units in cases where some characteristics of the production process are known. In particular we focus on the existence of direct linkages between inputs and outputs, where certain outputs are produced from specific inputs and not jointly produced from all inputs.

Our aim is to use and empirically compare alternative forms of reflecting the linkages between inputs and outputs. The alternatives to be compared to reflect the linkages between inputs and outputs are: the use of separate assessments; the use of ratios between linked outputs and inputs; and the use of differences between linked outputs and inputs. These alternatives are presented and contextualised within existing procedures for dealing with output-specific inputs, and results are discussed and illustrated empirically in the context of evaluating Portuguese courts' efficiency. Future avenues of research are suggested within the topic of evaluating courts efficiency in Portugal.

Central limit theorems for aggregate efficiency
Leopold Simar and Valentin Zelenyuk*

Applied researchers in the field of efficiency and productivity analysis often need to estimate and make inference about aggregate efficiency, such as industry efficiency or aggregate efficiency of a group of distinct firms within an industry (e.g., public vs. private rms, regulated vs. unregulated rms, etc.). While there are approaches to obtain point estimates for such important measures, no asymptotic theory has been derived for it--the gap in the literature that we fill with this paper. Specifically, we develop full asymptotic theory for aggregate efficiency measures when the individual true efficiency scores being aggregated are observed as well as when they are unobserved and estimated via DEA or FDH. As a result, the developed theory opens a path for more accurate and theoretically better grounded statistical inference (e.g., estimation of condence intervals and conducting statistical tests) on aggregate efficiency estimates such as industry efficiency, etc.

Is there a fair comparison of technical efficiency for conventional and organic dairy farms?
Timo Sipiläinen*

Several studies have compared productivity and technical efficiency of conventional and organic farms. Different parametric and non-parametric methods have been used. The results have been mixed but often organic farms are found to be less productive but more profitable. In this study, we take into account that production technologies may differ between conventional and organic farms and that there is both observed and unobserved heterogeneity between farms and farm groups. We apply PSM to account for observed heterogeneity with respect to size, location and time. The share of organic farms is less than 20 percent of the total sample. Therefore, PSM adjusted sample of conventional farms is used in the analysis.

We consider various definitions of outputs and inputs as well as returns and costs in the analysis. It is well known that there is a price premium for organic products but also input prices may differ. On the other hand, we do not have any producer price statistics for organic product. The direct subsidies per hectare are also differentiated which affects profitability of farming systems.

Panel data of 250 Finnish dairy farms for five years from 2008 to 2012 is utilized in the analysis. We separate persistent and non-persistent inefficiency in our stochastic frontier model. The results indicate that organic farms are more profitable than conventional dairy farms, productivities of inputs differ between farming systems and organic farms are technically less efficient than their conventional counterparts.

Productivity growth in German dairy farming using a dynamic inefficiency specification: A Bayesian approach
Ioannis Skevas*, Grigorios Emvalomatis and Bernhard Bruemmer

This article estimates and decomposes Total Factor Productivity (TFP) growth of German dairy farms for the period 2001-2009. The study period is characterized by steep milk price changes that took place towards the end of the period. Such a shock motivates the measurement of efficiency and TFP growth and their expected time variation. However, detection of efficiency and TFP growth shocks depends on the modelling approach followed. Most studies that have examined TFP growth have relied on models that specify inefficiency as a deterministic function of time. As a result, these models are unable to capture time-specific efficiency and TFP growth shocks. Additionally, models

that do not impose any time structure on efficiency, may be able to capture efficiency shocks, but are likely to produce very erratic results. We argue that a dynamic inefficiency specification that allows for inefficiency scores to be autocorrelated, allows for a more flexible time structure that can account for (persistent) efficiency shocks that may be induced by the high milk price volatility observed during the study period, without producing erratic results. In this study three models are considered: (a) a model that specifies the evolution of inefficiency as a deterministic function of time, (b) an unstructured model that allows for efficiency scores to evolve completely arbitrarily over time, and (c) a dynamic stochastic frontier model. The empirical findings reveal that all three models produce an average TFP growth rate above 1%. However, efficiency and TFP growth shocks are only captured by the unstructured and the dynamic stochastic frontier models with only the former producing very erratic results. Hence, the dynamic stochastic frontier model is not only able to capture efficiency and TFP growth shocks, but also to produce reasonable results. Furthermore, formal model comparisons are performed based on Bayes factors, and reveal that the dynamic stochastic frontier model is favored by the data when compared to the rest of the two models.

Derivation of netput shadow prices under different levels of pest pressure
Theodoros Skevas* and Teresa Serra

In this paper, we extend the study by Chambers et al. (2011) to the case of an event-specific shadow pricing approach. We propose a framework to derive agricultural netput shadow prices that recognize the effects of pest pressure on farmers' production environment. Our modeling approach is based on the dual representation of an event-specific data envelopment model. Shadow prices are computed to assign values to netputs in terms of their contribution to technical and environmental efficiency and applied to a panel dataset of Dutch arable farms. Results show that netput shadow prices vary significantly across pest pressure events, suggesting the relevance to consider the event-specific nature of the production technology when computing them. By revealing the relative importance of pesticides in terms of their contribution to environmental efficiency, this study provides a potential framework for constructing penalties aiming to internalize some portion of the social cost of pesticide use.

The relationship between costs and travel time reliability of train operating companies
Andrew Smith* and Manuel Ojeda-Cabral

Travel time reliability is a key element of any transport system. In the railway sector, much has been discussed about the costs of delays to passengers, the demand side of the market. However, the cost of delays to the supply side of the market has received far less attention (Van Oort, 2016). In a vertically separated industry, the railway supply includes the infrastructure manager and train operating companies. This paper aims to fill this gap in the railway literature by studying the relationship between the costs of train operating companies and their degree of travel time reliability. Although there have been some attempts to measure this relationship (e.g. Civity, 2012), it has not been possible yet to establish a clear link between costs and reliability in the railway. First, we discuss and articulate the relationship between travel time reliability and train operator costs. Various factors are at play. Overall, we hypothesise, theoretically, the potential for a quadratic U-shaped relationship. This acknowledges that low reliability (e.g. more delays) could be associated with higher costs but, at the same time, high reliability could come at an extra cost too. Different underlying reasons for a company to be in either side of the curve are discussed. We then develop a cost model where the train operator costs are explained as a function of output, a set of input prices, and different measures of reliability. The model is applied on a panel data from all train operating companies in the UK over a period of fifteen years. The results allow us to expand our understanding of the mechanisms and incentives of companies to deal with reliability while keeping with tight cost efficiency objectives.

Robustness to outliers in stochastic frontier analysis: The Student's t-half normal model vs. the normal-half normal model

Alexander Stead*, Phill Wheat and William Greene

The presence of outliers in the data has serious implications for stochastic frontier analysis given that they may distort parameter estimates and, crucially, lead to an exaggerated spread of efficiency predictions. One way of increasing the robustness of the model to outliers is to alter our distributional assumptions about the two-sided error component such that it allows for thick tails. Several existing proposals specify thick tailed distributions for both error components in order to arrive at a closed form log-likelihood function, limiting the analyst's choice of efficiency distribution, however Stead et al. (2017) demonstrate that simulation methods may be used to pair a logistically distributed noise term with any of the canonical efficiency distributions, and that a far narrower range of efficiency predictions is obtained by doing so. We develop this further by proposing a Student's t distribution for the noise term, which generalises the normal distribution by adding a shape parameter governing the degree of kurtosis, therefore having the advantages of greater flexibility in the thickness of the tails and of nesting the normal distribution. We estimate a Student's t-half normal cost frontier for highways authorities in England, show that the model yields a significantly narrower range of efficiency predictions, and discuss testing against the standard stochastic frontier model.

An application of stochastic frontier analysis to measure the influence of weather on electricity distribution businesses: Evidence from developing economies

Karim Anaya Stucchi* and Michael G. Pollitt

This paper evaluates the influence of weather variables on the efficiency of electricity distribution companies that operate in Argentina, Brazil, Chile and Peru. The sample covers 82 firms representing more than 90 per cent of the distribution market of energy delivered for the period 1998-2008. Stochastic frontier analysis (SFA) is the method applied and a translog input distance function has been adopted. Two different approaches are evaluated: weather in the production function and weather in the inefficiency term (Battese and Coelli, 1995). The efficacy of one over the other is determined using nested models (Coelli et al., 1999). Weather data are collected from meteorological stations (429) and NASA (3,423 coordinates). A geographic information system (GIS) is used for locating the firms' service areas and their weather conditions. A combination of cost only and cost-quality models is proposed. We examine how technical efficiency estimates change in the face of the inclusion or non-inclusion of weather data. The influence of weather is analysed from three perspectives: a global level, a company-level and at ownership type-level. At the global level and for cost only models, the results suggest that on average there is a significant increase in measured efficiency when weather is incorporated in the production function. Under the cost-quality models, on average the effect of weather is much lower. This suggests that firms have internalised the effects of weather and have adapted their networks to the environment in which they operate. A company-level analysis indicates that across models a significant number of companies are affected by weather. Regulators are advised to make proper adjustments of efficiency scores when specific firms face important efficiency changes due to weather. Results from the ownership type-level analysis suggest that public firms tend to operate in less favourable weather conditions in comparison with the private ones and in areas with a lower human development index. However when including total costs and full quality variables, the effect of weather remains the same regardless of the type of firms.

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Input-specific managerial and program inefficiency in the Malaysian dairy industry: A multi-directional efficiency analysis

Nurul Aisyah Mohd Suhaimi*, Yann de Mey and Alfons Oude Lansink

Malaysia is currently trying to strengthening its local dairy production in order to meet growing domestic demand and through this increased self-sufficiency simultaneously boost food security. The existing literature on Malaysian dairy farming has identified great scope for improving technical inefficiency, yet no study to date has investigated the specific potential of improving the usage of inputs such land, labour and feed. The purpose of this study is to measure the input-specific technical inefficiency of Malaysian dairy farms by using multi-directional efficiency analysis and subsequently investigate its determinants. We make use of original data from 200 farms located in four regions with the most representative milk production to calculate both managerial and program inefficiency. Managerial and program inefficiency scores are presented for the two dominant production systems: the intensive and semi-intensive system. Managerial inefficiency is the inefficiency within a system whereas differences in inefficiency between systems is referred to as program inefficiency. Our results reveal marked differences in the inefficiency scores across inputs and between production systems. Intensive systems generally have the lowest managerial and program inefficiency scores. Results of the truncated bootstrap regressions for intensive systems show the following: the number of portable milking machines has a negative relation with technical inefficiency scores of land and other expenditure, age has a positive relation with labor inefficiency, and experience has a negative relation with other expenditure inefficiency. For semi-intensive systems, the number of portable milking machine has a negative relation with technical inefficiency scores of land and other expenditure and finance from government has a positive relation with the technical inefficiency score of feed. Our input-specific and production-system-specific results provide policy makers with valuable information to assist dairy farmers in Southeast Asia in improving their performance.

Estimation of cost efficiency in restoring biodiversity loss at hydropower plants in Sweden

Wondmagegn Tafesse Tirkaso*

A number of investment projects intended to mitigate the negative ecological impacts of hydro power plants has been implemented in different parts of Sweden, such as restoration of fish habitats and spawning ground. Meanwhile, it is not clear whether these spending’s were made in line with cost minimization principle. Therefore, we have estimated the cost efficiency level of different mitigation measures, construction of fish paths and instream biodiversity restoration. A stochastic frontier cost function is estimated with costs of measures as response variable and prices of inputs, project duration and ecological effects as explanatory variables. The estimates are based on survey data from 111 projects in Sweden that were implemented between 1985 and 2015. The data contain expert judgments on the effects of measures on different ecological indicators; on the target for the measures which for most measures is increase in the population of salmon trout, effects on other fish species, effect on mussels, and other ecological effects. Estimated result indicated that there is a significant cost efficiency loss, 35%, when targeted fish species constitutes the ecological output. The corresponding loss is smaller for effects on mussels, and amounts to 19%. We also found that projects managed by private sector are relatively more efficient than when managed by public and non-governmental organizations. Further, there is an evidence of improvement in average efficiency score on projects which started in the later period in the sample.

A formula for efficiency based on DEA scores
Chris Tofallis*

We show how to generate a formula which expresses efficiency scores in terms of input and output values. The formula has the same form as that used to obtain the DEA scores, be it a ratio of linear expressions or a multiplicative form. The parameters in the formula are estimated using the Automatic Democratic Method, i.e. the DEA scores are regressed on the underlying data.

Regression allows a best fit to the DEA scores, which are treated as upper bounds. This provides a compact efficiency formula which avoids the often unrealistic input and output weights arising in DEA with the consequent lack of discrimination. It also permits a direct ranking of units.

Size and productivity: A conditional efficiency approach for the Italian pharmaceutical sector
Pierluigi Toma* and Camilla Mastromarco

In this study we use an appropriate nonparametric two-step approach on conditional efficiencies to investigate how size and time affect the performance of companies. Using a dataset of Italian manufacturing firms over the period 2007-2015, we explore the effect of dimension on the attainable production set (input-output space) and on the efficiency distribution. We conducted the study on one sub sector of the manufacturing sector, following NACE Rev. 2 methodology and nomenclature, which is currently adopted by the European Union. The selected sub sector is the 21 named Manufacturers of basic pharmaceutical products and pharmaceutical preparations. The choice of this sub sector is founded on the need to test the effect of dimension in contexts strongly characterized by technological innovation and R & D traction. The results obtained represent a step forward in management policy and for the choice of the optimal business dimension to achieve better economic performance.

Efficiency-based system configuration assessment: The case of micro-grids
Taylan Topcu, Konstantinos Triantis* and Matthew Robinson

The ability to differentiate between system configuration alternatives that address community needs has been a primary concern for the discipline of systems engineering. This research proposes an interdisciplinary approach by employing DEA on a system configuration selection problem. A hypothetical design scenario of installing a Micro-grid (MG) infrastructure is assumed and possible MG configurations are generated using a trade-space exploration approach. A stochastic weather simulation is built based on the atmospheric observations of the National Renewable Energy Lab. The production behavior of the generated MG configurations under uncertainty are investigated based on this simulation. The ability of DEA to holistically handle multiple system attributes concerning various stakeholders in a dynamically changing environment is demonstrated through an example of abstractly represented MGs. Formulation of the DMU black-box is established using the performance goals set by policy makers and the configurational requirements of the alternatives. Relative efficiency scores of the MG configurations are calculated. The DEA results are compared with the traditional systems engineering approach to configuration selection (multi-attribute utility) and value based assessment rooted in micro-economic theory. This research claims two primary contributions to the literature. First, it demonstrates the extended use of DEA outside usual application areas by providing an example from the fields of design of complex engineered systems and decision making under uncertainty. As a second contribution, our approach provides the Systems Engineering community with a nonparametric alternative to the widely applied weighted decision making and value based approaches.

Informing enterprise operational assessment through a complex adaptive systems efficiency measurement approach
Konstantinos Triantis*, Glen Lyddane and Oscar Herrera-Restrepo

Managerial policies act as guidelines for enterprise operations. They direct enterprises toward the achievement of operational goals. When enterprises operate in a network (e.g., network of social

service chapters; network of bank branches; etc.) they might coordinate actions. For example, they may decide to share information among themselves or learn best practices from others. We view coordination as exhibiting connectivity, feedback, and adaptation, which are features of complex adaptive systems (CAS). By considering enterprise networks as CAS, we study managerial policies that enhance the coordination among enterprises. Our premise is that different managerial policies that impact coordination will have an effect on technical efficiency at both the individual enterprise and network levels. To operationalize our concept of coordination, we consider flocking behavior from natural ecosystems that is studied in the CAS literature and use it as a proxy to represent different managerial policies. To study the relationship of managerial policies, coordination and technical efficiency performance, we conduct agent-based simulations. This approach takes into account individual enterprise decisions, collective influences from enterprises that constitute the network, and network goals. The proposed experimental design informs when and how managerial policies enhance the coordination among enterprises and allows for the investigation of the relationships that exist between individual enterprise decisions and collective influences. For some data sets, these relationships result in an emergent goal seeking network behavior with respect to the goal of achieving technical efficiency.

Objectives and incentives: Evidence from the privatisation of Great Britain's power plants
Thomas Triebs* and Michael Pollitt

Does privatisation increase firm productivity because the owner's objective changes or because a private owner is better able to control management? And is privatisation sufficient to improve productivity or is it only effective in combination with competition? We answer these questions for Great Britain's electricity industry privatisation. We separate the effects of changes in objectives from changes in incentives by assuming that the former only affect labour but not non-labour inputs like fuel. As effective competition was only introduced several years after privatisation, we are able to analyse the separate effect of competition. We find that privatisation increased labour but not fuel productivity; evidence for the importance of objectives. However, the onset of effective competition increased both input's productivities. Only strong competition makes plants fully productive.

Economies of scale: A meta-analysis on the scale of hospitals
Bart van Hulst* and Jos Blank

There is an abundant supply of studies that examine the cost structure of hospitals. The numerous efficiency and productivity studies have led to several systematic review studies These reviews discuss the quality and reliability of the productivity and efficiency analysis, including in-depth analysis of modelling choices such as specification and estimation strategies. The focus of both review and empirical studies is mainly on efficiency and productivity; results on scale, are often neglected. At the same time, all productivity studies implicitly deal with scale, because a decision has to be made about the presence or absence of scale effects (either constant returns to scale or variable returns to scale).

This paper applies a meta-analysis on the optimum scale of hospitals. The paper includes separate analysis for parametric studies and non-parametric studies, since both type of studies generate different results on scale. We identified 41 parametric studies that generate 95 model results. For the parametric studies the scale- elasticity is regressed on the model characteristics and the size where the scale elasticity applies. From the regression results, that most model characteristics have no influence on results. Only the number of inputs modelled and the choice between a long-run cost function and a short-run function seem to have an impact. Specification has no significant impact, however since we found that the scale elasticity varies with size, a Cobb–Douglas specification is less suitable, especially if there is a wide variation in size in the sample. For a reference study, based on the most common characteristics, the optimum is 320 beds. For parametric frontier studies the optimum is 239 beds. We identified only 19 non-parametric studies that had usable results on scale.

Non-parametric studies generate direct results on the optimum scale. Therefore an optimum scale can be computed as a weighted average, resulting in an estimate for the optimum scale of 220 beds. Regression analysis reveals that for non-parametric studies, the optimum heavily depends on the context.

Temporal perception as a source of productivity measure distortion
Fabian von Schéele* and Darek Haftor

This paper shows how a worker's perception of time produces hidden and dramatic distortion of worker productivity measures. Firstly, the paper addresses the practice that reported time records in service organizations are based on self-assessments of time made by human agents. This is a crucial source of time perception distortion that introduces errors in productivity metrics. Secondly, the paper demonstrates that the use of linear calculus as an acceptable assessment of curve linear mathematical expressions, as a practice of standard economic literature, leads to large errors in the calculations of worker productivity. The misjudgment of time in curve linear mathematics generates large leverage effects on productivity metrics. To remedy these limitations, the paper presents a mathematical model of productivity that incorporates time distortion with a following mathematical expression of curve-linear logic. The here proposed productivity addresses production capacity in terms of time volume, with changes of cost level and accounting for time leakage as well as the curve linear mechanism between time and economy during a predefined time period. The proposed model gives rise to several novel conclusions, including (1) that the unintentional misjudgment of time has large leverage effect on the productivity measure, (2) that the time distortion is unconditionally prevalent in all productivity metric and its influence on the metrics is so dominant that it must not be ignored, and (3) that the leverage effect in productivity metrics is partly depending on contract mode and the profit margin assumed by the firm. The overall message here is that some of the fundaments of productivity analysis should be modified with regard to the measurement of time and value in workload and profit. The here introduced model for productivity analysis may have significant impact for managers as well as researchers of performance and performance metrics.

Measuring capital value: A distance function approach
John Walden*, Rolf Färe and Shawna Grosskopf

Establishing capital value for a firm or industry is important for assessing capital user cost and investment between time periods. Unfortunately, data do not always exist to measure capital value and associated changes through time using standard approaches such as the Perpetual Inventory Method (PIM). In this study, we utilize a method for calculating capital value based on an input distance function, publicly available sale price data, and non-parametric programming methods. The distance function model yields shadow prices for physical attributes which are used to derive an estimate of capital value. This method is applied to a group of fishing vessels using sale price data from the years 2000-2013 along with data on vessel physical characteristics and permits held. Shadow prices for vessel attributes returned by the distance function are used to estimate a total value for currently permitted vessels in the northeastern United States, and to construct a capital value index based on the Lowe quantity index for vessels active in the squid, mackerel and butterfish (SMB) fishery between 1996 and 2016. The overall capital value for all permitted vessels was estimated to be approximately $628 million ($U.S.). Trends in the capital index for the SMB fishery show disinvestment over the 20 year time horizon covered by the index.

A flexible estimator for dynamic panel stochastic frontier models
Hung-Jen Wang*, Yu-Fan Huang and Sui Luo

Recent developments on dynamic panel stochastic frontier models have attract attentions from empirical as well as theoretical researchers. In this paper, we propose a feasible estimation method for a dynamic panel stochastic frontier model where the dynamic arises from the composed error of the model (rather than specific components of the error). The method can be easily applied to

models where the unobserved individual effect may be fixed, random, or correlated random. The key of the estimation method lies in using the panel fully aggregated estimator (PFAE) of Han et al.~(2014) for the correlation parameter. We show how to include the PFAE estimator in the likelihood function of the model and estimate all of the model parameters in one step. The method avoids the incidental parameters problem and circumvents the inconsistency issue of the correlation parameter. Furthermore, the method does not rely on first-difference or within-transformation of the model, thus allows for flexible distribution assumptions on the composed error of the model.

Energy efficiency and stochastic frontier analysis using the Box-Cox transformation functional form
Thomas Weyman-Jones*, Júlia Mendonça Boucinha and Catarina Feteira Inácio

There is wide interest in measuring energy efficiency and an important contribution is the work on stochastic demand frontier analysis of Filippini and Hunt. In this paper, we extend the application of this approach in three ways. We firstly incorporate into the measured energy efficiency analysis the interaction with the production of greenhouse gas emissions since one of the objectives of increases in energy efficiency is to reduce emissions, and we do this by developing a production function and dual cost function approach that treats emissions as an essential input to the production of energy. Secondly, we generalise the functional form that has been used in previous work, chiefly log-linear and translog specifications, to enable an approach based on the Box-Cox Transformation (BCT). This yields nonlinear elasticity functions as opposed to the constant elasticities or linear elasticity functions of the log-linear and translog approaches and we derive these functions. Thirdly, we suggest that the BCT models can incorporate components for inefficiency and idiosyncratic error familiar from standard stochastic frontier analysis by making use of quasi-maximum likelihood estimation (QMLE). While most of the current literature has focused on aggregate or residential energy efficiency, we apply these ideas to data on energy consumption in industry. We wish to know if the long-term changes in energy consumption at these different levels reflect continuous improvement in energy efficiency as anticipated in the engineering literature. Alternatively, improvements in the efficiency of producing energy may be associated with initially increased consumption as suggested by the literature on the rebound effect that has been supported empirically.

We use a panel data sample of the 28 member states of the EU from 1990 to 2014 at different levels of aggregation including industrial gas and electricity usage. We consider different specifications including the input requirement function, input distance function and conditional input demand function.

We find initially that there is an interaction between energy efficiency and emissions but that it is complex since there is evidence of energy saving in parts of the EU accompanied by worsening emissions in other parts. A second finding is that specifications from the log-family i.e. double log, inverse and translog functional forms, are strongly rejected in favour of more general Box-Cox functional forms. This has an important bearing on elasticity estimates and consequently on policy making since the implied elasticities are highly nonlinear.

Allowing for outliers in stochastic frontier models: A mixture noise distribution approach
Phill Wheat*, Alexander D. Stead and William Greene

Whist the innovation of stochastic frontier analysis (Aigner et al, 1977 J Prod Anal) was allowance for random noise into technical and economic efficiency measurement, many practical datasets include observations which appear within the tails of the efficiency distribution and in many application contexts are implausibly low. The ‘problem’ can be conceptualised as one of hetroscedasticity in the noise error, however a priori there is no obvious measured variable to model the heteroscedasticity, since the mis-reporting/inconsistent reporting of the dependent variable (particularly in a cost function) is essentially random. In this paper we propose a model which is as the cost function variant of Aigner et al but with the noise error comprises a mixture of two normally distributed mean zero random variables. We show that this model yields estimates that can capture noise as

having thicker tails than relying on a normally distributed noise term. The result is that the condition mean efficiency predictor does not penalise observations with outlying residuals as much as a normal distribution since they are implicitly allocated to the noisy class. We investigate the properties of this model using both simulation and empirical application.

Dimension reduction in nonparametric models of production
Paul W. Wilson*

It is well-known that the convergence rates of nonparametric efficiency estimators (e.g., free-disposal hull and data envelopment analysis estimators) become slower with increasing numbers of input and output quantities (i.e., dimensionality). Dimension reduction is often utilized in non-parametric density and regression where similar problems occur, but has been used in only a few instances in the context of efficiency estimation. This paper explains why the problem occurs in nonparametric models of production and proposes three diagnostics for when dimension reduction might lead to more accurate estimation of efficiency. Simulation results provide additional insight, and suggest that in many cases dimension reduction is advantageous in terms of reducing estimation error. The simulation results also suggest that when dimensionality is reduced, free-disposal hull estimators become an attractive, viable alternative to the more frequently used (and more restrictive) data envelopment analysis estimators. In the context of efficiency estimation, these results provide the first quantification of the tradeoff between information lost versus improvement in estimation error due to dimension reduction. Results from several papers in the literature are revisited to show what might be gained from reducing dimensionality and how interpretations might differ.

Measuring scale efficiency of farms across regions - A Bayesian stochastic metafrontier approach
Stefan Wimmer* and Johannes Sauer

The structure of farms differs across regions due to both historical reasons and distinct production conditions. Even within a single country, we observe a large variation in average farm size across different regions. In Germany, for example, average farm size varies from 34 ha in the federal state of Bavaria to 286 ha in Mecklenburg-Vorpommern. The objective of this work is to analyse to what extent technological differences explain this variation. For this purpose, we estimate stochastic production frontiers for German crop farms located in different regions and test whether the production technologies are identical or not. It is shown that technologies significantly differ from each other, so we construct a metafrontier developed by Battese and Rao (2002), Battese, Rao and O'Donnell (2004) and O'Donnell et al. (2008). This metafrontier envelopes all individual production frontiers and allows to compare the performance of firms operating in heterogeneous production environments. Its parameters are obtained from the estimated parameters of the production frontiers using linear programming (LP). Therefore, this technique does not directly produce standard errors for the metafrontier parameters. To facilitate statistical inference, we estimate the production frontiers applying Bayesian techniques. In this framework, LP is done for each draw from the posterior distributions and thus credibility intervals for the resulting parameters can be calculated. The Bayesian framework also enables us to impose regularity conditions on the production frontiers as required by economic theory (O'Donnell und Coelli 2005).

The group- and metafrontiers are then used to decompose productivity growth into its components technical efficiency, technical change, and scale efficiency. We call scale efficiency with respect to the group frontier firm-related scale efficiency (FSE) and scale efficiency with respect to the metafrontier technology-related scale efficiency (TSE). The former indicates how close the individual farm is operated to the optimal scale of production given the technology of the actual location, whereas the latter compares this point to the optimal scale of production on the metafrontier. Thus, we can infer to what extent different production environments explain the variation in farm size and how productive farms in different regions are at their optimal scale of production. Preliminary results show that productivity of farms operating in small-scaled agricultural areas is indeed

maximized at a smaller point of scale compared to farms that are located in large-scaled regions, while the most productive farms are found in the latter. These results have important policy implications for addressing the trend towards fewer but larger farms.

Stationary points for parametric stochastic frontier models
Ian Wright* and William Horrace

The results of Waldman (1982) on the Normal-Half Normal stochastic frontier model are generalized using the theory of the Dirac delta (Dirac, 1930), and distribution-free conditions are established to ensure a stationary point in the likelihood as the variance of the inefficiency distribution goes to zero. Stability of the stationary point and "wrong skew" results are derived or simulated for common parametric assumptions on the model. Identification is discussed.

Iterative nonparametric S-shape estimation
Daisuke Yagi*, Andrew L. Johnson and Hiroshi Morita

A production function satisfying the Regular Ultra Passum (RUP) law is characterized by increasing returns to scale followed by decreasing returns to scale along any expansion path. Although there are existing nonparametric estimators imposing the RUP law, they impose additional strong assumptions such as: deterministic model and homotheticity. This paper proposes an iterative algorithm to estimate a function that satisfies the RUP law while relaxing these other assumptions. We use Monte Carlo simulations to show the performance of our estimator with different data generation processes. We also analyze Japanese manufacturing data using the proposed estimator by computing marginal productivity, marginal rates of substitution and most productive scale size.

Nerlovian profit efficiency of small-sized, owner-operated sugarcane farms in the Northeastern region of Thailand
Suthathip Yaisawarng* and Thanaporn Athipanyakul

Sugarcane, a major raw material for sugar, grows well in certain climate. Brazil is the largest sugar producer as well as the sugar exporter in the world market. Thailand is the second largest sugar exporter mainly because of the low domestic consumption. Thailand is among the top world sugarcane producers and should have a bright prospect for sugar export since the global sugar market is growing. Unfortunately, sugarcane production in Thailand is inefficient as evidenced by low yield and high average cost. Its yield currently stands at about the world's average. Thai Government has initiated several policies directed toward increase sugarcane yield. Average cost of production is marginally lower than the ex-factory sugarcane price where the growers are price takers, and in recent years the average cost slightly exceeds its price. How will sugarcane farmers benefit from their production and become sustainable?

This paper explores ways to improve efficiency of sugarcane production in Thailand. We use DEA technique to compute Nerlovian profit efficiency for a sample of small-sized, owner-operated sugarcane farms in the northeastern region of Thailand in 2014/15 crop year. Our model includes one output (quantity of sugarcane produced) and several inputs (e.g. cultivated land, different types of labor, sugarcane seeds, fertilizer and other inputs). The Nerlovian profit efficiency is decomposed into technical and allocative components to identify causes and explore possible ways to improve farmers' profit efficiency. Case studies of selected efficient and less efficient farms will be included to complement our quantitative results. Our findings will be put in the context of existing public policies and future policy recommendations.

Risk preference and efficiency in Chinese banking
Ning Zhu*, Yanrui Wu, Bing Wang and Zhiqian Yu*

Departing from earlier efficiency studies considering banking risk preference, this paper employs a multi-directional efficiency analysis approach to measure technical efficiency of 49 Chinese commercial banks during 2004-2012. This approach allows for endogenous classification of three risk

preferences, namely the conservative, moderate and aggressive risk modes, by changing direction vectors. Banking efficiency is hence estimated on the basis of optimal risk preference. The findings show that the moderate risk preference is the most appropriate strategy to achieve technical efficiency in the Chinese banking sector. It is also shown that low risk costs, compulsory credit spreads and scale expansion played a critical role in promoting the development of Chinese banking sector in earlier years, but their effect decreased rapidly. The findings also imply that the average technical efficiency scores of joint stock commercial banks and city commercial banks were higher than those of state-owned commercial banks under the optimal risk preference, and that efficiency mainly shows a trend of improvement over time.

Technical efficiency in the nursing home sector in Ireland – A stochastic frontier input distance function approach

Marta Zieba, Declan Dineen and Shiovan Ni Luasa*

We estimate an input-oriented technical efficiency (TE) in Irish nursing homes using the stochastic frontier input distance function approach. We collected primary data on patient days, length of stay, nursing and non-medical staff, and the number of beds, for 59 public and 93 private nursing homes in Ireland during the period 2008-2009. The average TE score is around 0.90 for both private and public nursing homes, indicating that Irish nursing homes should decrease their inputs by 10 percent and still produce the same output level. Furthermore, we compare the results with our published TE scores using non-parametric and semi-parametric bootstrap DEA approaches. We find that the latter methods underestimate the TE scores as they do not account for data noise. Moreover, we investigate the relationship between efficiency and its possible determinants. We use a comprehensive set of 15 explanatory variables directly parameterising the variance of inefficiency. As well as ownership and other characteristics such as size, age and location, we examine how the quality of care (staffing mix and staff flexibility), case mix and the working environment affect the TE scores of Irish nursing homes. To our knowledge, this is also the first paper which compares SFA with bootstrap DEA using long-term care data.

Environmental productivity change in world air emissions: A new Malmquist-Luenberger index approach

Jose L. Zofio*, Juan Aparicio, Javier Barbero, Magdalena Kapelko and Jesus Pastor

Over the last twenty years an accelerating number of studies have relied on the standard definition of the Malmquist-Luenberger index proposed by Chung et al. (1997) [J. Environ. Manage., 51 229-240], to assess environmental sensitive productivity change. While recent contributions have shown that it suffers from relevant drawbacks related to inconsistencies and infeasibilities, no one has studied systematically the performance of the original model, and to what extent the existing results are unreliable. This paper introduces the optimization techniques that allow implementing the first model solving these problems, and using a country level database including air pollutants, systematically compares the results obtained with both approaches. We discuss the relative number, magnitude and significance of the disparities that researchers should expect if resorting to the original model. Results show that inconsistencies and infeasibilities in the original model are increasing in the number of undesirable outputs included, reaching remarkable values that seriously question the reliability of results, and compromise any policy recommendation based on them.

Technical efficiency and household human capital: A data envelopment analysis (DEA)

Emanuele Zucchini*

Technical inefficiency (TI) is one of the main problem in the agricultural sector of many Sub-Saharan African (SSA) countries. It entails a loss in output production with a negative impact on agricultural development of SSA countries. The immediate determinant of TI is inadequate use of traditional inputs which thus stimulates policy makers to promote programmes facilitating the access to agricultural inputs such as fertilizers, seeds, etc. However, a more fundamental cause of TI is low level of human capital which in turn can determine the mismanagement of agricultural inputs and/or

the lack of access to them. Thus, in this paper, we analysed the impact of household human capital on technical efficiency (TE) of five crops using a recent LSMS-ISA dataset from Malawi. We employed a two-stage approach. First, we estimated TE through the Data Envelopment Analysis (DEA) approach testing the separability assumption of education. Second, we regressed some explanatory variables, i.e. household and agricultural characteristics, on DEA TE scores using the Fractional Regression Model (FRM) to explain differences in TE. We also tested the appropriate model specification, one-part vs. two-part and the functional specification of FRM. Results suggest that human capital, i.e. education, explains differences in TE although traditional inputs as fertilizers remain an important determinant.

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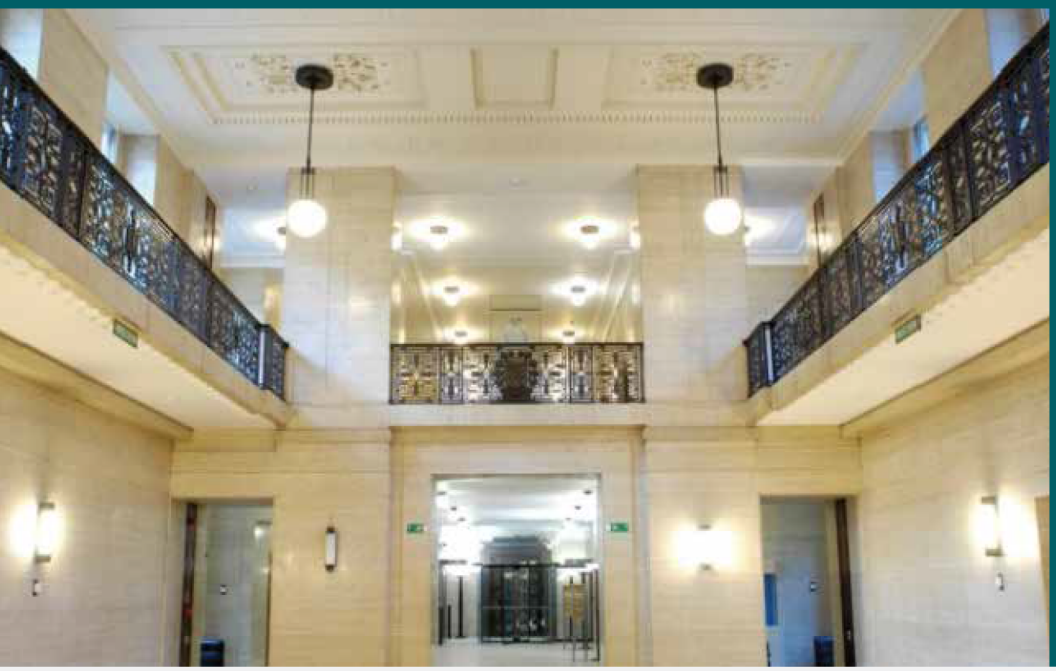

CONFERENCE SCHEDULE

MONDAY 12 JUNE 2017
Early career researcher day

TUESDAY 13 – THURSDAY 15 JUNE 2017
The main conference

CONFERENCE VENUE

Senate House, Malet Street,
London, WC1E 7HU

SOCIAL EVENTS

TUESDAY 13 JUNE 2017
Welcome evening reception at Senate House

WEDNESDAY 14 JUNE 2017
Conference dinner* Grand Connaught Rooms,
61-65 Great Queen Street, London, WC2B 5DA
**conference dinner is an optional registration item*

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