

EWEP XIX

European
Workshop on
Efficiency and
Productivity
Analysis

June 16th – 19th, 2026
Munich, Germany

BOOK OF ABSTRACTS

Conference Programme

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13:30 - 15:00	Terra & Jupiter	Special plenary in honot of Knox Lovell
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09:00 - 10:30	Terra & Jupiter	Life-time Achievement Award to Erwin Diewert
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11:30 - 13:00	Terra Jupiter Venus 1 Mars 1 Mars 2	DEA Methods 4 Productivity 3 Justice 2 Education 2 Sustainability/Eco-efficiency 4
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Tuesday, June 16, 2026

09:15 - 10:15 | Terra & Jupiter | Plenary 1

Chair: Moriah Bostian

Title: WHAT IS LURKING IN THE SHADOWS? INTERPRETING ENVIRONMENTAL TRADE-OFFS IN DEA

Authors: [Prof. Mette Asmild](#)

Affiliation: University of Copenhagen

Data Envelopment Analysis (DEA) has become a standard tool for incorporating environmental externalities into productivity analysis, often through the use of shadow prices. However, these shadow prices are far from uniquely defined. They depend critically on modelling choices, such as how externalities are incorporated and the direction of projection onto the frontier, which determines the facet of the piecewise linear technology used for evaluation. Even within a single estimated facet, multiple implicit trade-offs coexist. Moreover, a given production process may generate multiple externalities. Thus, shadow prices are model-, direction-, and facet-specific, as well as multidimensional and heterogeneous. In this setting, speaking of the shadow price of an externality may be misleading. This talk explores these issues both conceptually and empirically using data where different externalities are present. A central theme is both the computation of such shadow prices and associated methodological challenges, and their interpretation and representation. When shadow prices vary across facets and dimensions, point estimates may obscure more than they reveal. The keynote therefore emphasizes distributional and geometric perspectives, along with visualization strategies that make variation, inconsistency, and environmental trade-offs explicit rather than hidden. The broader message is that incorporating, potentially several, externalities in DEA is challenging. Recognizing and engaging with this complexity opens new avenues for research and leads to more nuanced, policy-relevant insights into environmental performance and trade-offs.

10:45 - 12:15 | Terra | Agriculture 1

Chair: Federico Garcia Suarez

Title: CLIMATE-SMART AGRICULTURE AND TECHNICAL EFFICIENCY UNDER EXTREME WEATHER: A LATENT CLASS STOCHASTIC FRONTIER ANALYSIS OF SOYBEAN FARMS IN SÃO PAULO, BRAZIL

Authors: [Larissa Gui Pagliuca PhD¹](#); Dr. Marcelo José Carrer¹; Rodrigo Damasceno¹; Dr. Marcela de Mello Brandão Vinholis²

Affiliation: ¹ Federal University of Sao Carlos; ² Brazilian Agricultural Research Corporation

Climate-Smart Agriculture (CSA) comprises a set of practices and technologies, including crop rotation, no-till farming, and automated irrigation, aimed at mitigating climate-related risks to agricultural productivity. This study evaluates the relationship between CSA adoption and technical efficiency (TE) of soybean farms in São Paulo State, Brazil. Data were collected from a random sample of 152 farmers during the 2023/24 crop year, a period characterized by significant climatic stress: cumulative precipitation was approximately 26% below the historical average, while maximum temperatures diverged from long-term norms by +2.75 °C. This environmental context provides a strong basis to examine how CSA influences productive resilience under extreme weather conditions. The Stochastic Production Frontier (SPF) model with latent class controls was applied to identify heterogeneous groups of producers based on their degree of CSA practices adoption, enabling a comparative analysis of performance across distinct technological clusters. Preliminary results indicate that CSA adoption is associated with higher technical efficiency and greater climate resilience under adverse weather conditions. These findings suggest that CSA serves as a strategic driver not only for environmental sustainability but also for improved productive performance and climate adaptation within a sustainable intensification pathway.

Title: PREDICTORS OF EMISSION-ADJUSTED EFFICIENCY IN POLISH CROP FARMS: NONLINEARITIES, INTERACTIONS AND POLICY THRESHOLDS

Authors: [Dr. Jakub Staniszewski PhD](#); Prof. Bazyli Czyżewski; Prof. Anna Matuszczak

Affiliation: Poznań University of Economics and Business

Emission-adjusted efficiency (EAE) links farm production to greenhouse-gas (GHG) emissions by treating emissions as an undesirable output. Conventional driver analyses often impose linear effects and miss interactions among social, economic and natural factors. This study measures EAE for Polish field-crop farms and explores its associations with farm and policy characteristics while allowing for nonlinearities and heterogeneity. Using 2022 data for 2,107 small and medium holdings, EAE is estimated with a by-production DEA model under variable returns to scale. Machine-learning models are then trained to predict EAE and are interpreted with variable-importance rankings and accumulated local effects. Soil quality, farm size and subsidy structure are most strongly associated with variation in EAE, whereas most social characteristics show only marginal associations. Agri-environmental payments are associated with higher EAE up to a threshold; beyond it, a trade-off with economic performance is observed, and this association is weaker in regions with fragmented agriculture. Area-based and production-related support also display threshold patterns, becoming associated with higher EAE at higher levels of support. Land renting, hired labour services and investment loans tend to co-occur with higher EAE. These findings suggest that policy design should account for thresholds and regional heterogeneity when targeting emissions reduction without undermining output.

Title: TRADE-OFFS BETWEEN GOOD AND BAD OUTPUTS IN GERMAN DAIRY FARMS

Authors: [Dr. Fabian Frick](#); Prof. Dr. Johannes Sauer

Affiliation: Technical University of Munich (TUM)

Dairy producers not only operate under pressure of being profitable but also face increasing societal demands regarding their environmental (greenhouse gas emissions) and social (animal welfare) impacts. Using a unique representative dataset on dairy producers in Germany, we examine the relationships between good outputs (milk, animal welfare) and a bad output (greenhouse gas emissions). In a directional distance function approach, we identify trade-offs between those outputs and relate them to farm characteristics. Our results offer valuable insights into heterogeneity and determinants of sustainability performance of German dairy farms.

Title: TECHNICAL EFFICIENCY OF SEEMINGLY “RELATED” COW AND CALF PRODUCTION

Authors: [Dr. Federico GARCIA SUAREZ PhD](#); Camilo Alvarez García; Mercedes Motta

Affiliation: Universidad de la República

Animal protein is a major human nutrient. Production success depends heavily on the animal species choice, environment, labor, natural resources availability in order to establish the better system. Beef meat has been under scrutiny for its role on greenhouse gas emission. Grasslands provides a unique environment to produce a low-fat low-cost meat specially on the cow-calf stage. Ranchers should seek the highest number of calf possible, ideally a calf per cow per year. Cows has two possible outcomes, either produce a calf or being a product itself, in which case they are fattened and slaughter, being replaced by other female calf. Even when Uruguay has been improving its beef sector, the cow-calf production shows that the rate of calf per cow is around 0,65 when the literature suggest that a rate of 0,8 is possible with low cost technology. In this paper we estimate a seemingly unrelated regression given the relation between the cow-calf itself. After the estimation the inefficiency is recovered using the JLMS procedure. The analysis is performed at the smallest administrative level available, using size of each unit, precipitation, vegetation availability and the lagged amount of each category on the other dependent variable (i.e. lagged value of cows when estimating calf production, and viceversa). The data comes from the Agricultural Ministry and is provided at the smallest administrative census unit. Main results shows that cow efficiency is higher than in calf production.

10:45 - 12:15 | Jupiter | SFA methods 1

Chair: Christopher Parmeter

Title: INCORPORATING INTERMEDIATE OUTPUTS INTO SFA USING AN EQUATION SYSTEM APPROACH WITH APPLICATION TO TRANSPORT

Authors: [Dr. Trang Tran PhD](#); Prof. Dr. Phill Wheat; Dr. Alexander Stead; Prof. Dr. Andrew Smith

Affiliation: Institute for Transport Studies, University of Leeds

Stochastic Frontier Analysis is widely used to assess the performance of decision making units. But conventional models assume a single stage process in which inputs are transformed directly into final outputs. This ignores the role of intermediate outputs and obscures where inefficiencies arise within multi stage systems. Many production processes, especially in infrastructure industries, operate in two stages: the first generates intermediate outputs, which are then used to produce final outputs in the second stage.

While multi stage frameworks have been developed in Data Envelopment Analysis, similar progress in SFA has been limited. Existing network type SFA models are often complex and do not yield measures of overall efficiency. This study introduces a Network SFA approach that incorporates intermediate outputs to better identify the sources of inefficiency. The model estimates both stage level and overall efficiency, allows analysis of returns to scale at each stage, and accommodates different levels of data aggregation, making it suitable when input data are aggregated but output data are available by division. A simplified multi step estimation procedure is provided along with authors' written Stata package networkSFA. The model is then applied to a two stage road maintenance process to demonstrate its advantages over single stage analysis.

Title: INCORPORATING INTERMEDIATE OUTPUTS INTO STOCHASTIC COST FRONTIER MODELS

Authors: [Dr. Alexander Stead](#)¹; Dr. Trang Tran²; Prof. Phill Wheat²

Affiliation: ¹ Institute for Transport Studies, University of Leeds; ² University of Leeds

Recent work has incorporated intermediate outputs into stochastic production frontiers, enabling explicit modelling of multi-stage technologies. We develop the corresponding stochastic cost frontier framework, in which intermediate outputs are produced in a first stage and subsequently employed in the production of final outputs. We show that cost minimisation yields a system comprising two cost frontiers and an intermediate output equation, with the latter taking the form of a two-tier stochastic frontier in which stage-specific inefficiencies have opposing effects on the employment of intermediate outputs. This structure aids identification of overall cost inefficiency and permits recovery of stage-specific inefficiency components. By exploiting information contained in intermediate output data, the model also enables analysis of stage-specific technologies and cost structures.

We derive likelihood functions and efficiency predictors for the system and discuss approaches to estimation and recovery of underlying structural parameters. An empirical application uses historical data on tramways and light railways in Great Britain that generated their own electricity for traction and lighting, and estimates distinct inefficiency components associated with electricity generation and transport operations.

Title: THE COST OF REGULARITY: EMPIRICAL EVIDENCE ON MONOTONICITY, QUASI-CONCAVITY, AND FRONTIER FLEXIBILITY

Authors: [Pietro Sala](#); Maria Vrachlioli PhD; Dr. Fabian Frick; Prof. Dr. Johannes Sauer

Affiliation: Technical University of Munich (TUM)

Neoclassical production theory assumes monotonicity and quasi-concavity, yet these conditions are rarely imposed in parametric stochastic frontier estimation. This omission persists despite generating theoretically inconsistent frontiers and biased technical efficiency estimates, with practical consequences when such measures inform policy decisions. This paper examines the feasibility and implications of imposing regularity in unconstrained translog stochastic frontier models. Using Monte Carlo simulations, we compare regularization methods applied directly to the parameters of an unconstrained translog production frontier and evaluate their ability to ensure monotonicity and quasi-concavity. The results show that regional monotonicity does not generally imply quasi-concavity, and that local quasi-concavity alone does not ensure full pointwise regularity unless monotonicity also holds. By progressively extending local curvature constraints over larger subsets of observations, the simulations confirm a structural trade-off between flexibility and the likelihood of achieving full regularity. We also address inference challenges in constrained estimation using proximal bootstrapping to obtain consistent covariance matrices for adjusted parameters, including near the boundary of the feasible region. Finally, we characterize the levels local, pointwise, regional, and global at which regularity can be imposed and discuss their implications for reliable frontier estimation.

Title: DIFFERENCE-IN-DIFFERENCES WITH STOCHASTIC INEFFICIENCY

Authors: Prof. Dr. [Christopher Parmeter](#)¹; Dr. Samuele Centorrino²

Affiliation: ¹ University of Miami; ² International Monetary Fund

Difference-in-differences (DiD) methods are widely used to evaluate causal effects of policy interventions. When the outcome is generated by a stochastic frontier model, the treatment may affect both the production frontier (a direct, technology-shifting effect) and productive efficiency (an indirect effect through the distribution of inefficiency). We show that these two channels can be separately identified under a scaling-property specification for inefficiency, provided an auxiliary variable β shifts inefficiency without entering the frontier. The identifying variation comes from differences in the conditional means across values of β : ratios of these differences identify the shape of inefficiency heterogeneity from first moments alone, while the elasticity of inefficiency with respect to β is recovered either from a third-moment ratio at the baseline cell (when β is binary, under symmetric noise) or from an additional first-moment ratio across three or more values of β (when richer support is available). Once these inefficiency parameters are identified, the frontier parameters — including the direct treatment effect — are read off the conditional means at a reference value of β . The framework extends to staggered treatment adoption with fully heterogeneous cohort-specific effects. For estimation, we directly leverage the moment conditions implied by the model in a continuously updating estimator (CUE), which is well-defined whether the moment system is over-identified (binary β) or just-identified (non-binary β), robust to weak identification, and compatible with misspecification-robust inference; the closed-form solution that recovers the identification proof in sample arises as a special case used as a starting value. Monte Carlo simulations confirm that the estimator performs well in finite samples in both regimes, and the CUE J -statistic provides a formal specification test of the scaling restriction whenever the system is over-identified. We apply the method to Chinese manufacturing data around WTO accession, decomposing the effect of trade liberalization on exporting firms into a frontier contraction and an efficiency improvement.

10:45 - 12:15 | Venus 1 | Sustainability/Eco-efficiency 1

Chair: Carolin Canessa

Title: EVALUATING HEALTH, ENVIRONMENTAL AND CIRCULARITY TRADE-OFFS OF WASTE DERIVED FUELS IN THE CEMENT INDUSTRY

Authors: [Dr. Maria Michali PhD](#)

Affiliation: University of Bristol

Heavy industry, and cement plants in particular, is increasingly adopting waste co-processing to support decarbonization and landfill diversion. However, this creates complex trade-offs between climate mitigation, local health risks, and circular economy objectives. Cement facilities are often located near underserved communities and co-located with large waste streams used as alternative fuels. While this reduces fossil fuel use, the combustion process generates toxic pollutants such as heavy metals, dioxins, and particulate matter, strongly associated with carcinogenesis and underrepresented in environmental and social assessments. Reliance on waste-derived fuels also locks substantial material flows into energy recovery, a low-priority circular activity, limiting opportunities for higher-order strategies such as material reduction, reuse, and recycling. Using a Benefit-of-the-Doubt directional distance function Data Envelopment Analysis model, this study evaluates how co-processing in UK cement plants influences environmental efficiency, treating selected toxic pollutants as health related undesirable outputs. Monte Carlo simulations are used to assess how changes in waste fuel use affect environmental efficiency when climate performance, toxic emissions, and circular hierarchy positioning are considered jointly. The study supports the evaluation of alternative fuel strategies and more equitable and resilient decarbonisation pathways in heavy industries.

Title: NAVIGATING SUSTAINABILITY TRADE-OFFS: BENCHMARKING ORGANIC AND CONVENTIONAL DAIRY FARMS UNDER CARBON TAXATION

Authors: [Andreas Michael Wolff](#); Prof. Mette Asmild

Affiliation: University of Copenhagen

Denmark is set to introduce a carbon tax for agriculture in 2030. While intended to reduce CO₂ emissions, this policy risks disrupting the competitive balance between organic and conventional farming. This

paper investigates whether the upcoming regulation affects organic and conventional dairy farmers differently due to their specific production technologies. We apply Data Envelopment Analysis (DEA) within a meta-frontier framework to benchmark Danish dairy farms. First, we evaluate economic efficiency under current regulations to assess if existing subsidies and market conditions allow both systems to compete on equal terms. Subsequently, we simulate the 2030 tax regime by incorporating the tax on CO₂ e emissions as an input, thereby internalizing the negative externality. These emissions are derived indirectly from economic production data, mirroring the likely implementation of the tax. We utilize weight restrictions to ensure a proper incorporation of the tax, a realistic representation of the production technology and to appropriately account for inputs measured in different units. Given the heterogeneity of the sector, we focus on analysing structural shifts in efficiency patterns. By examining changes in rankings, efficiency scores, and shadow prices between the baseline and the tax scenario, we identify potential asymmetric impacts. By quantifying these effects, the paper assesses the compatibility of uniform carbon taxation with the dual objective of reducing emissions and supporting diverse farming systems.

Keywords: DEA, Agriculture, Carbon Tax, Environmental Economics

Title: HOW DOES RESTORATION SHIFT THE FRONTIER: THE ECO-EFFICIENCY OF SPECIES-RICH GRASSLANDS

Authors: [Moritz Leonhard Ptacek](#)

Affiliation: Technische Universität München

Although much debated, it is currently unclear how species-richness affects the economic performance of grasslands. Using a non-experimental, field-level dataset of grassland sites across Germany, we explore the relationship between economic and ecological output of grasslands. Applying Data Envelopment Analysis, we identify how species-richness shifts the frontier, if complementarity between outputs is possible, and if financial support is a good proxy for ecological output. Grassland restoration shifts the frontier outwards in the direction of ecological output, while the economic performance of species-rich grassland sites is competitive. Nevertheless, high heterogeneity, negative contribution margins, and low participation of farmers in restoration place a question mark behind the economic performance of species-rich grasslands. Complementarity between outputs suggests that extending both economic and ecological output is possible. This is not the case for conventionally managed sites, which face a trade-off at increasing levels of ecological output. Our results suggest that targeted funding of restoration and conservation may be more effective than the currently accelerating result-based schemes.

Title: FARMERS' OPPORTUNITY COSTS OF BIODIVERSITY PROVISION AND AGRI-ENVIRONMENTAL PAYMENTS

Authors: [Carolin Canessa](#); Philipp Mennig; Johannes Sauer

Affiliation: Technical University of Munich (TUM)

Agri-environmental-climate schemes (AECS) aim to improve the provision of environmental goods and services from agriculture by compensating farmers for implementing environmentally friendly management practices and achieving ecological outcomes. We contribute to the ongoing discussion on cost-effective AECS design by investigating the environmental efficiency of farms receiving AECS payments using a two-output DEA model. This model also allows us to estimate shadow prices for biodiversity and to assess whether current payments align with the opportunity costs of environmental provision in agriculture. The case study focuses on the Federal State of Bavaria, Germany, where a pilot result-based grassland conservation scheme was implemented between 2015 and 2022. In contrast to previous research, we uniquely measure farms' ecological performance using a farm-level biodiversity index to examine trade-offs between biodiversity provision and agricultural production. Our results indicate that there is potential to simultaneously improve both economic and biodiversity outcomes without additional financial compensation. A trade-off in the production of agricultural and environmental outputs, such as milk and biodiversity, was observed. Fewer than fifty percent of the examined farms are able to cover their opportunity costs (i.e., income losses) with the payments offered. Better farm targeting could reduce agri-environmental programmes' costs.

10:45 - 12:15 | Mars 1 | Regulation & Governance 1

Chair: David Saal

Title: IMPACT OF OPERATING SUBSIDIES ON SEWERAGE EFFICIENCY**Authors:** [Dr. Tomohiro Kitamura PhD](#)**Affiliation:** Otemon Gakuin University

In recent years, the operating situation for sewerage operation has become challenging in Japan because the volume of sewage treatment has been declined due to population reduction and the growing emphasis on water conservation, and there has been the need for capital investment to replace aged sewerage facilities and for natural disaster prevention measures. Therefore, efficient management is required in the sewerage industry. In Japanese sewerage companies, transfers from the general account are provided and allocated as subsidies to cover deficits. This may hinder efforts to reduce costs and may cause inefficient operation. This is called soft budget constraints problem.

In this study, we adopted panel data from Japanese public sewerage companies and estimated input distance function by stochastic frontier analysis. And we examined the relationship between inefficiency factors such as subsidies and technical efficiency from the estimates of coefficients.

We revealed that the higher the proportion of subsidies from other accounts or the higher the level of staff salaries, the lower the technical efficiency of sewerage industry. Thus, there may be the possibility that the subsidies to cover deficits cause inefficient operation of sewerage companies and soft budget constraints problem has been occurred in Japanese sewerage industry.

Title: MODELING SPATIAL COOPETITION IN ENVIRONMENTAL EFFICIENCY: A NON-PARAMETRIC APPROACH FOR FAIR REGIONAL GOVERNANCE**Authors:** [Yunlong ZHANG](#)¹; [Emili Grifell-Tatjé](#)¹; Prof. Dr. [Zhiyang SHEN](#)²**Affiliation:** ¹ Universitat Autònoma de Barcelona; ² IESEG School of Management

Traditional environmental efficiency evaluations often treat regions as “isolated islands”, overlooking the spatial coopetition (cooperation and competition) shaping performance. This may lead to bias: “inefficient” regions are unfairly penalized for bearing cross-regional abatement costs, while “efficient” ones simply free-ride on external spillovers. This study develops a non-parametric by-production approach that internalizes spatial interactions, capturing two coopetition mechanisms: a resource-gain effect from collaborative spillovers and a benchmarking effect from competitive peer pressure. Through multi-scenario simulations, we decompose cooperation and competition’s contributions to efficiency, illustrating heterogeneous regional responses to varying degrees of spatial interdependence. Furthermore, shadow price analysis estimates the marginal costs of abatement under spatial constraints, offering insights into the economic legitimacy of interregional collaboration. We argue that regional efficiency represents a spatial equilibrium shaped by interregional interactions rather than a static individual attribute. By disentangling spatial dividends from intrinsic efforts, the approach challenges conventional outcome-based evaluation logic. Combining efficiency, spatial response elasticity, and shadow prices, it further proposes a three-dimensional policy typology to guide equitable performance assessment and differentiated governance across unbalanced regional economies.

Title: EFFICIENCY OF CENTRAL GOVERNANCE: A STOCHASTIC INPUT DISTANCE FUNCTION ANALYSIS**Authors:** [Dr. Nan Jiang PhD](#)**Affiliation:** Auckland University Of Technology

The conceptualization and empirical evaluation of public sector efficiency only began in the last decade or two, the underlying economic rationale is that central government manages public spending to maximize public welfare. This study is derived from a political rationale, in which the central government is assumed to manage public perceptions of its performance.

Stochastic input distance frontiers are estimated using a set of input-output measures, including government spending across five major functions, the World Governance Indicators, Human Development Index, Gender Development Index and material footprint, etc. The data includes 35 OECD countries from 1997 to 2022. Results show that the choice of functional form matters for distance elasticity estimates. The Cobb-Douglas functional form is rejected in favour of the translog. And the Hausman test rules out the random effects model in preference for the fixed-effects model. The implication is that a country is aware of its own inefficiency and the extent to which it can be reduced immediately without systematic reform is very limited.

The sample average efficiency ranges from 42% to 60%, parsimonious functional forms are associated with inflated efficiency scores. Although efficiency from the translog has a high correlation coefficient of 0.79 with those obtained from the Cobb-Douglas, distance elasticity estimates vary.

Keywords: stochastic frontier analysis; input distance function; central governance efficiency.

Title: A DEA BASED MODEL OF SEWAGE TREATMENT COSTS WITH MULTIPLE PLANTS AND SHARED OPERATIONAL MANAGEMENT

Authors: [Professor David Saal PhD¹](#); Professor Takayoshi Nakaoka²; Professor Tomoyasu Tanaka PhD³

Affiliation: ¹ Loughborough University; ² Doshisha University; ³ Kindai University

A substantial literature, with prevalent examples in electricity generation and sewage treatment, has measured the impact of pollution abatement on input requirements at the plant level. However, while sewage treatment operations often have distinctly identified plant specific inputs, only the very largest sewage treatment plants have dedicated operations management. Thus, the operation of multiple plants is commonly carried out by a team organised at firm level, thereby implying that plant level variable costs are shared across multiple plants. Moreover, while in some cases plant level accounting data on variable operating costs may be “available”, such data is often derived from an unspecified cost allocation method of inputs that are really managed by a multi plant team. This paper will therefore develop a DEA based model of sewage treatment operations that allows for plant specific inputs such as capital stocks, while modelling operational costs as a shared input. We then apply our shared input model to analyse the abatement costs of Japanese sewage treatment plants where we can closely observe the contaminant removal work carried out by sewage treatment plants given the availability of data for both influent and effluent pollutant concentration ratios.

10:45 - 12:15 | Mars 2 | Energy 1

Chair: Per J. Agrell

Title: EXPLORING CONDITIONAL DEA FOR DETERMINING REVENUE CAPS FOR NORWEGIAN ELECTRICITY DSOS

Authors: [Håvard Bergheim Holvik](#)

Affiliation: NVE-RME

The Norwegian Energy Regulatory Authority (RME) has, since 1997, applied DEA to determine revenue caps for electricity distribution system operators. Since 2013 a two-stage approach has been applied to account for geographical differences among DMUs.

For regional distribution grids, a four-output model is used. In recent years, the second-stage correction has been omitted due to a lack of statistically significant regression results. Industry consolidation has also reduced the number of DSOs, increasing issues related to slack and limiting the feasibility of a parametric second stage.

We explore the possibility of implementing moving from an unconditional to a conditional DEA model to account for the environmental factors. The motivation is twofold: CDEA may improve fairness and relevance by comparing firms operating in more similar environments without a second stage, and when the sample size is decreasing we want a model with less output dimensions.

We will present results on how efficiency scores and revenue caps could change when moving from our current DEA model to a possible conditional DEA implementation.

Title: THE EFFECT OF SMALL-SCALE ELECTRICITY GENERATION ON THE COST AND EFFICIENCY OF ELECTRICITY DISTRIBUTORS: A THRESHOLD RIDGE APPROACH

Authors: Fatemeh Jamhiri¹; [Prof. Kristofer Månsson PhD²](#); Prof. Pär Sjölander³

Affiliation: ¹ Persian Gulf University; ² Linnaeus University; ³ Jönköping University

The transition to a low-carbon economy introduces new challenges for electricity distributors. One such challenge is the increasing prevalence of small-scale renewable energy production, such as wind and solar

power. This paper investigates the effects of these factors by developing a new post-threshold ridge estimator. The proposed estimator is robust to multicollinearity between small-scale generation and the cost drivers. In addition, it performs variable selection, thereby addressing big data challenges arising from the growing number of factors that may influence electricity distribution costs. Finally, the study examines how small-scale production affects the efficiency of electricity distributors using stochastic frontier analysis.

Title: A CIRCULAR SLACKS-BASED METAFRONTIER PSEUDO-MALMQUIST INDEX FOR GROUP PERFORMANCE COMPARISON: APPLICATION TO GLOBAL PETROLEUM FIRMS

Authors: [Dr. Kwaku Ohene-Asare PhD¹](#); Emily Asaa Addison²; Dr. Eric D. Ofosu-Hene PhD³

Affiliation: ¹ University of Ghana Business School; ² Presbyterian University, Abetifi, Ghana; ³ Leeds Beckett Business School

Comparing performance across heterogeneous groups of decision-making units remains methodologically challenging when technologies differ and undesirable outputs are present. Conventional pseudo-Malmquist indices often face cross-group infeasibility, rely on radial measures, and blur the distinction between efficiency dispersion and structural technology gaps.

This paper develops a circular slacks-based metafrontier pseudo-Malmquist index (SMPM) that guarantees feasibility, satisfies transitivity, and incorporates non-proportional inefficiencies and undesirable outputs within a unified framework. The proposed index also enables a four-part decomposition into pure and scale efficiency spreads and pure and scale-related technology gaps. Interpretation rules are clarified under both constant and variable returns to scale. A Monte-Carlo study demonstrates that SMPM dominates the classical pseudo-Malmquist index and the circular pseudo-Malmquist index in terms of feasibility, ranking accuracy, and stability.

An empirical application to 58 global petroleum firms in 2024 shows that ownership differences are primarily efficiency-driven, whereas multinational advantages arise mainly from scale-related technology gaps. The framework provides a robust and operationally meaningful basis for benchmarking heterogeneous firms in sustainability-sensitive industries.

Title: STATIC AND DYNAMIC EFFICIENCY ASSESSMENT FOR EUROPEAN GAS TRANSMISSION: THE ACER STUDY

Authors: [Prof. Per J. AGRELL PhD](#)

Affiliation: UCLouvain, Louvain-la-Neuve, Belgium.

The European gas transport network is facing major challenges in the next decade. The European Green Deal is setting an ambitious timeline for the full decarbonisation of the sector, forcing the partial redeployment of assets to low-carbon gases such as biogas and hydrogen. In the short term, the radically lowered utilization of some segments since the Russian invasion of Ukraine in 2022 has led to steep tariff hikes in many countries. To put efficiency and effectiveness in focus for the European national regulators, the EU Agency ACER is charged with a mandatory period cost efficiency study for all gas transmission systems operators, starting in 2026. We review the structure, scope, methods and models for the project that will be the largest international regulatory cost efficiency study ever launched. The core is based on two models; an execution model with asset-based outputs to investigate cost effective use and investments for a given task; and a utilization model with exogenous outputs related to capacity and volume use, investigating the agility of operators facing variable and declining demand. The frontier methods are DEA and SFA depending on data generation process and availability. Several extensions to earlier models are presented for heterogeneous legacy investment costs, repurposing and decommissioned assets and neutrality to financial and operating models. Currently, the project is in a data collection phase with unprecedented data validation protocols.

13:30 - 15:00 | Terra | PhD Session 1

Chair: Herve Dakpo

Title: CONDITIONAL FRONTIER DIAGNOSTICS OF STRUCTURAL PRODUCTIVITY CONSTRAINTS UNDER CLIMATE STRESS: EVIDENCE FROM KENYAN SMALLHOLDER AGRICULTURE

Authors: [Denis Momanyi](#)

Understanding productivity under climate stress requires moving beyond average outcomes to examine how efficiently agents convert inputs into attainable performance. This paper develops and applies a frontier-based diagnostic framework to identify structural productivity constraints and persistent inefficiency in heterogeneous environments, using smallholder agriculture as an empirical case. We estimate non-parametric conditional quantile frontiers ($\tau = 0.90$) to benchmark attainable output conditional on observed production portfolios and compute normalized distance-to-frontier as a measure of structural productivity shortfall. Unlike conventional efficiency analysis, the framework explicitly distinguishes low productivity due to constrained frontiers from inefficiency relative to feasible performance. Distributional and spatial diagnostics are layered onto the frontier analysis to identify clusters of persistent underperformances. Applied to geo-referenced data from 569 smallholders in Western Kenya, results show pronounced context-specific productivity ceilings. Average distance-to-frontier is nearly three times larger in low-potential agroecological zones than in higher-potential zones, while differences across household types within zones are statistically negligible. A dual-threshold state classification identifies a subset of farms combining low output and large frontier gaps, indicating persistent low-productivity regimes. These regimes are spatially clustered, confirming that inefficiency is structurally embedded rather than idiosyncratic. A diagnostic-based targeting simulation demonstrates that policies focused solely on reducing mean inefficiency can increase within-group inequality and operate through channels other than observed input adjustments, highlighting limits of adoption-centric productivity strategies. The paper contributes a computationally transparent toolkit for productivity analysis under risk, with implications for efficiency measurement, spatial targeting, and performance improvement in climate-exposed systems.

Keywords: Productivity analysis, Conditional frontier, Structural inefficiency, Climate risk.

Title: UNDERSTANDING THE RELATIONSHIP BETWEEN U.S. AGRICULTURAL LABOR AND MACHINERY

Authors: [Linge Yang](#)

Affiliation: University of Connecticut, United States

This study analyzes the substitutability between labor and mechanization in U.S. agriculture using a translog cost function and county-level data from the 2002 and 2022 Census of Agriculture. We found that labor and mechanization are strong substitutes; thus, there is a general decline in substitutability at the national level in the past two decades. We also observe a declining own-price elasticity of labor, indicating reduced responsiveness of labor demand to wage change. Regional analysis highlights heterogeneity in substitution patterns, with areas like the West maintaining strong substitutability, while others exhibit mixed or complementary relationships. These findings offer insights for the design of subsidies and R&D funding in the agricultural sector.

Title: BY-PRODUCTION EFFICIENCY ANALYSIS UNDER A CAP-AND-TRADE FRAMEWORK

Authors: [Nicolas Marissiaux](#); Prof. Dr. Barnabé Walheer

Affiliation: Université de Liège

In the efficiency and productivity literature, many methods have been proposed to deal with undesirable outputs. Those were first treated as freely disposable inputs, then as a weakly disposable outputs under the null-jointness assumption, and, more recently, the by-production approach has been introduced to explicitly represent pollution-generating technologies as the intersection of two sub-technologies: one producing desirable outputs and another generating undesirable outputs.

Despite these advances, existing by-production models assessed with DEA generally evaluate DMUs in isolation and ignore the fact that some environmental policies like cap-and-trade systems often impose overall constraints on total emissions. In such a framework, pollution decisions by some DMUs affect pollution opportunities of other DMUs. Ignoring this zero-sum aspect may lead to inconsistent efficiency measures with the policy environment faced by firms.

This paper builds on the most recent by-production models, incorporating a zero-sum game (ZSG) structure for undesirable outputs. This new framework allows for the assessment of both technical and environmental efficiency under a new binding emission constraint. It provides an interesting tool for policymakers to evaluate firms' performances in regulated environments such as the EU ETS. Overall, this paper contributes to the literature by linking by-production efficiency analysis with zero-sum environmental regulation in a nonparametric framework.

13:30 - 15:00 | Jupiter | PhD Session 2

Chair: Frederic Ang**Title: META GREEN INNOVATION EFFICIENCY IN EUROPEAN REGIONS: SPATIAL SPILLOVERS FROM REGIONAL FINANCIAL DEVELOPMENT****Authors:** [PhD Student Myungjun Kim](#) [PhD Student](#)**Affiliation:** Seoul National University

This study investigates the impact of regional financial development on Green Innovation Efficiency (GIE) across 100 NUTS 2 European regions from 2011 to 2022. Recognizing the technological heterogeneity in the European landscape, this study utilizes a Stochastic Meta-Frontier (SMF) to derive Meta Green Innovation Efficiency (MGIE). This approach provides a heterogeneity-adjusted measure that enables a consistent and robust comparison of green innovation performance. The MGIE estimates are subsequently used as the outcome variable to examine whether regional financial development generates spatial spillover effects on green innovation efficiency. Based on diagnostic tests and model comparison, a Spatial Durbin Model (SDM) is employed to disentangle the complex spillover mechanisms. The empirical results, using the loan-to-deposit ratio (LDR) as a key proxy for financial development, reveal consistently positive and significant coefficients for both direct and indirect effects. The results imply that regional financial development creates a positive 'ripple effect' that enhances the green innovation of neighboring regions. This study contributes to the efficiency literature by integrating SMF with spatial econometrics, effectively linking technological heterogeneity and spatial externalities to regional financial development. Methodologically, the findings underscore the importance of jointly considering efficiency measurement and spatial dependence when evaluating regional green innovation performance in Europe. From a policy perspective, the results suggest that coordinated regional approaches to financial development can generate positive spillover effects in green innovation across European regions.

Keywords: Green innovation efficiency, Regional financial development, Meta-frontier, Spatial econometrics
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Title: ECONOMIES OF SCOPE IN CONVENTIONAL AND ORGANIC FARMING**Authors:** Arne Henningsen; Jakob Vesterlund Olsen; Michael Friis Pedersen; [William Louis Reingaard Vissing](#); Maria Tambour Rumberg; Henrik Neldeberg Fallesen Ravn**Affiliation:** University of Copenhagen, Department of Food and Resource Economics

Denmark has a political target of doubling its organic agricultural area by 2030 compared to 2018. However, in recent years, rising food prices and increased inflation have led to a notable decline in the demand for organic food products, particularly meat and other livestock products. As organic farms depend on synergies between crop and livestock farming, the recent decline in demand for organic livestock products could disrupt these synergies, challenging the growth of organic farming.

We investigate whether and how the level of economies of scope between crop and livestock production differs between organic and conventional farms by employing a Constant Elasticity of Transformation (CET) cost function. This functional form allows different shapes of transformation curves and varying returns to scale, which is essential for investigating potential economies of scope. The estimation of cost functions usually relies on the assumption of exogenously given output quantities, which is unrealistic in farm production. To avoid this, we rearrange the cost function to a specification similar to an output distance function, allowing the output quantities to be endogenous.

Based on an unbalanced panel data set of Danish farms from 2017 to 2024, our preliminary results do not support our hypothesis of substantial economies of scope in organic farming but indicate that both organic and conventional farms benefit more from specialisation than from integrated crop-livestock farming.

Title: TRANSITIONING FROM LIVESTOCK TO CROP PRODUCTION: A BAYESIAN STOCHASTIC RAY PRODUCTION FRONTIER ANALYSIS**Authors:** [Jeronya Mbiat Petnkeu](#); Prof. Arne Henningsen; Prof. Jørgen Dejgård Jensen**Affiliation:** University of Copenhagen, Department of Food and Resource Economics

The feasibility of the plant-based transition in Denmark, which aims to reduce livestock production to mitigate climate and environmental impacts, heavily relies on the ability of farms to shift production away from livestock without severe economic disruption. This paper evaluates farm-level production reallocation under livestock reduction using a Translog stochastic ray production frontier (SRPF). The Translog SRPF accommodates zero output quantities and allows for input–output non-separability as well as flexible substitution and transformation possibilities between livestock and crop production.

We estimate the production technology using Bayesian econometric methods to impose regularity conditions implied by production theory. These conditions are particularly important for the second part of our analysis, where we use the estimated production technology to simulate the effects of reducing livestock production (25%, 50%, and 100%), under short-run profit maximisation. Farms are allowed to adjust variable inputs and crop output while remaining constrained in quasi-fixed factors such as arable land, permanent grassland, and livestock-related capital goods (e.g., building for livestock farming). The resulting farm-level measures of crop expansion and profit changes quantify structural rigidities within the estimated production frontier.

13:30 - 15:00 | Venus 1 | PhD Session 3

Chair: Chris O'Donnell

Title: A COPULA-BASED FRAMEWORK FOR IDENTIFYING CONGESTION IN DATA ENVELOPMENT ANALYSIS

Authors: [Zakiatul Wildani](#)¹; Dr. Maria Michali¹; Dr. Bangdong Zhi²; Dr. Ming Luo²

Affiliation: ¹ University of Bristol; ² University of Bristol

Congestion is a well-known economic phenomenon in which an increase in inputs reduces the maximum possible output. Data Envelopment Analysis (DEA) has become the dominant approach for identifying congestion by examining the geometric features of the production frontier. However, existing DEA methods may lose economic meaning when congestion is not explicitly linked to overinvestment (input excess), limiting their usefulness for performance improvement. This study reconceptualises congestion as an asymmetric dependence phenomenon characterised by the joint occurrence of high input levels and low output realisation. To capture this mechanism, we propose a hybrid framework integrating DEA with copula modelling. At the decision-making unit (DMU) level, we combine DEA congestion frequency with copula-based risk signals to construct a four-classification system distinguishing confirmed congestion, hidden congestion undetected by DEA, false congestion, and non-congested units. Using a controlled framework with bivariate input–output pairs, the result shows congestion is predominantly a tail phenomenon. While symmetric dependence dominates the global dependence structure, strong asymmetric dependence is observed among DMUs experiencing confirmed and hidden congestion but is absent among non-congested and false alarms units. The results highlight that the asymmetric copula provides complementary information on overinvestment risk besides the congestion frontier-based approach.

Title: EVALUATING TEACHING EFFICIENCY IN EUROPEAN UNIVERSITIES USING NONPARAMETRIC TECHNIQUES

Authors: [Andreea Monica Munteanu](#)

Affiliation: Bucharest University of Economic Studies

The higher education system plays an essential role in preparing students for the job market and in producing and disseminating scientific outcomes. Higher Education Institutions (HEIs) frequently encounter difficulties in optimally using their human, financial, and physical resources to produce educational or research outputs. The technological expansion of AI and automation, higher employability opportunities, and higher earnings are making students more interested in STEM and business fields of study. This research aims to investigate the teaching efficiency of public European HEIs oriented towards business and STEM fields of study during the 2022–2023 academic year using the ETER database. First, the dimensionality reduction technique proposed by Mouchart and Simar is applied, and second, efficiency estimates are obtained using the Data Envelopment Analysis (DEA) estimator. A comparative analysis of efficient and inefficient universities in teaching activities across various countries reveals interesting aspects of the performance of STEM-oriented and business-oriented universities in Europe. The distribution of high and low efficiency measures reveals

discrepancies across European countries.

Title: EVALUATING MULTIDIMENSIONAL PERFORMANCE IN THE EUROPEAN UNION: A COMPOSITE INDEX APPROACH TO EUROPE 2030

Authors: [JONATHAN ALULEA PEMBWE](#); Prof. Barnabé Walheer

Affiliation: University of Liège, Liège, Belgium

The mixed outcomes of the Europe 2020 Strategy prompted the European Union to reinforce its strategic framework through Europe 2030. This agenda prioritizes social, environmental, and digital goals, but progress assessments remain limited.

This paper builds a composite index to compare EU performance from 2014–2024 and evaluate countries' distance to Europe 2030 benchmarks.

The analysis uses standardized indicators included in a dataset that covers social, green, and digital aspects. Indicators are normalized using a direction-adjusted min-max method and combined through geometric means to reflect limited substitutability across policy areas. Sub-indices for each pillar are created and then put together to form an overall composite index.

A benchmarking exercise shows that, on average, EU Member States are still significantly away from selected Europe 2030 goals, with a normalized gap of about 40 percent. To test reliability, an alternative approach using entropy-derived weights is applied. The results show notable differences among EU Member States. Nordic countries and some Central European nations regularly rank as top performers, while other countries show significant disparities across policy areas. The results show that composite indicators can benchmark performance and guide policy within Europe 2030 framework.

Keywords: Composite indicators, Europe 2030 Strategy, entropy weighting, multidimensional performance.

15:30 - 17:00 | Terra | Organized session 1: Efficiency and Sustainability

Chair: Zhen Chen

Title: ENVIRONMENTAL PRODUCTIVITY MEASUREMENT USING SHADOW PRICES: AN APPLICATION TO DUTCH DAIRY FARMS

Authors: [Coco Wang](#)¹; Dr. Frederic Ang PhD²; Prof. Alfons Oude Lansink¹

Affiliation: ¹ Wageningen University & Research; ² University of Reading

The agricultural sector is crucial for food security, but is also a large source of greenhouse gas (GHG) emissions. Practices like manure management and fertilisation account for approximately 11% of European GHG emissions. With the European Climate Law targeting a 55% reduction in GHG emissions by 2030, the Common Agricultural Policy supports farmers in combating climate change and ensuring food security. Adjusting productivity measurement for GHG emissions is in this light important.

This study develops a productivity measure that rewards production and penalises GHG emissions and applies it to Dutch dairy farms. First, this study employs the by-production approach to determine the shadow prices of inputs, outputs, and GHG emissions. Second, using these shadow prices, this study computes a shadow-price-adjusted Fisher index.

This study uses the Dutch Farm Accountancy Data Network (FADN) for analysis. This study focuses on specialised dairy farms from 2006 to 2023, as the sector is widely recognised as an important contributor to GHG emissions. The dataset is unbalanced, consisting of 669 producers and 6,451 observations in total.

Title: INTEGRATING ECONOMIC, STRUCTURAL AND ENVIRONMENTAL DATA FOR MULTI-DIMENSIONAL EFFICIENCY ANALYSIS IN EUROPEAN AGRICULTURE

Authors: [Tamas Krisztin PhD](#)

Affiliation: International Institute for Applied Systems Analysis (IIASA)

Assessing productivity and environmental performance in European agriculture is complicated by the separation of economic and biophysical data. Farm-level accounts from FADN are not available below NUTS-2,

while biodiversity impacts and emissions are spatially differentiated at much finer scales. An integrated framework is therefore required to reconcile economic behaviour with environmental outcomes.

We construct 10×10 km grid-level “typical farms” that link FADN economic data with gridded structural information from the Farm Structure Survey and harmonised biophysical indicators. FADN farms are probabilistically allocated to grid cells using yield-similarity metrics, preserving observed inputs (land, labour, capital, intermediates and energy) while embedding farms in their agro-ecological context. Grid-level land use and management information is used to derive greenhouse gas emissions and biodiversity indicators, and structural and manager characteristics are assigned from the corresponding FSS layer.

Using these integrated production units for the EU around 2020, we estimate cross-sectional stochastic production frontiers to measure technical efficiency, treating energy as a standard input. Inefficiency is specified as a function of soil quality, farm structure, manager characteristics and CAP support intensity. Additional frontiers for emissions and energy intensity allow joint assessment of productivity, environmental and energy performance.

Title: A CROSS COUNTRY COMPARISON OF LONG AND SHORT TERM NON-RENEWABLE ENERGY USE EFFICIENCY OF THE EUROPEAN AGRICULTURE

Authors: [Hervé Dakpo](#)¹; Prof. Dr. Frederic Ang²; Prof. Dr. Wei Huang³

Affiliation: ¹ Université Paris-Saclay, INRAE, AgroParisTech, PSAE; ² University of Reading, UK; ³ Swedish University of Agricultural Sciences (SLU)

This study explores long- and short-term cross-country variation in non-renewable energy efficiency within European agriculture from 2004 to 2022, leveraging Farm Accountancy Data Network (FADN) information. Employing a four-component stochastic frontier model, the analysis distinguishes both transient and persistent inefficiency while accommodating farm-level heterogeneity. To address endogeneity in the input requirement technology relationship, a Generalized Method of Moments (GMM) estimator is adopted in a first step, ensuring robust parameter identification. By focusing on an energy input requirement technology, the research aims to quantify the potential for energy reduction and evaluate how diverse structural and technological factors influence efficiency outcomes. This approach allows for a nuanced understanding of energy use across varying production environments and management practices in European agriculture. The findings are expected to inform policy and managerial decisions aimed at enhancing energy efficiency and advancing sustainability goals. In particular, identifying drivers of inefficiency across different countries will shed light on the role of technology adoption, scale, and structural features in optimizing energy consumption. The methodological framework presented here provides a foundation for subsequent analyses of efficiency in other contexts, offering a valuable reference for future research on environmental and economic performance.

Title: TECHNOLOGICAL HETEROGENEITY AND HETEROGENEOUS SUBSIDY EFFECTS ON TECHNICAL EFFICIENCY: EVIDENCE FROM SWEDISH DAIRY FARMS

Authors: [Zhen Chen](#)¹; Dr. Ioannis Skevas²; Dr. Vivian Wei Huang¹

Affiliation: ¹ Swedish University of Agricultural Sciences; ² University of Macedonia

This paper integrates the random coefficient model into the stochastic frontier model and the determinants of technical inefficiency model to relax the assumption that farms operate under a common technology frontier and the effect of determinants of technical inefficiency are homogeneous across farms. The study focuses on Swedish dairy farms using FADN data from 2009 to 2023, we estimate random coefficients generalized true random effects models (GTRE) and investigate the heterogeneous impacts of subsidies on farm technical inefficiency within a Bayesian framework. The results show that the average of persistent and transient technical inefficiencies are 0.158 and 0.08, respectively. Moreover, the findings demonstrate that the total livestock subsidy, subsidy for less-favoured area and environmental subsidy have negative effects on transient technical efficiency, while only subsidy for less-favoured area exhibits a negative effect on farm's persistent technical efficiency performance.

Keyword: random coefficient model; GTRE; technological heterogeneity; heterogeneous effect

This paper is also part of the session titled ‘Efficiency and Sustainability in European Agriculture: Results from the AgEnRes Project,’ which is organized by Tamás Krisztin.

Chair: Victor Podinovski

Title: DEVELOPMENT AND APPLICATION OF A METHODOLOGY FOR ASSESSING THE EFFICIENCY OF SUSTAINABLE DEVELOPMENT USING DEA, SHANNON ENTROPY, AND MACHINE LEARNING

Authors: [Thomas E. Pappas](#); Prof. Dr. Roxani Karagiannis; Prof. Dr. Georgios Tsaples; Prof. Dr. Andreas C. Georgiou

Affiliation: Quantitative Methods and Decision Analysis Laboratory, University of Macedonia

This paper explores the integration of Data Envelopment Analysis (DEA), Shannon entropy, and machine learning models to construct composite indicators. DEA is utilized to reduce biases associated with subjective weight assignment, while Shannon entropy is examined as a complementary aggregation mechanism for incorporating multiple sustainability dimensions, providing a nuanced assessment of sustainability efficiency. Moreover, machine learning algorithms are applied to estimate the relative importance of the considered variables, thereby enhancing the interpretability of the results. The framework is illustrated as an empirical investigation that evaluates sustainability efficiency across 20 Eurozone countries, using data from Eurostat and the World Bank databases. Initially, the selected indicators are applied in the DEA stage to construct multiple sub-indicators corresponding to different dimensions of sustainability. Subsequently, Shannon entropy is employed to aggregate these sub-indicators into composite indices, while machine learning models identify key features. Based on the empirical findings, policy implications are discussed to support evidence-based decision-making. The paper concludes by outlining the advantages, limitations, and areas requiring further investigation regarding the combined DEA–Shannon approach.

This work is part of a project that has received funding from the University of Macedonia Research Fund under the Basic Research 2025 funding programme.

Title: GAIN–LOSS PORTFOLIO EFFICIENCY AND ASSET-PRICING BOUNDS: A DIRECTIONAL DISTANCE APPROACH

Authors: [Dr. Maryam Hasannasab PhD](#); Prof. Dimitris Margaritis PhD

Affiliation: The University of Auckland

We extend gain–loss (Omega) portfolio analysis by introducing shortage functions and directional distance measures. Portfolios are represented in a gain–loss technology defined by expected benchmark losses (downside) and expected benchmark gains (upside), allowing efficiency to be measured relative to target gain–loss levels. In finite-state settings, the resulting optimization problems can be solved by linear programming using positive-part linearisation. The dual formulation yields supporting pricing kernels, generating a direction-parameterized family of gain–loss good-deal bounds that rule out portfolios with excessively favourable upside relative to downside risk. We show that the gain–loss frontier admits an efficiency interpretation analogous to Data Envelopment Analysis frontiers, with pricing kernels emerging as supporting hyperplanes. The resulting geometry provides a downside-sensitive analogue of the mean–standard deviation restrictions of Lars Peter Hansen and Ravi Jagannathan, and relates to payoff-space distance-function asset-pricing results developed by Robert G. Chambers and Rolf Färe. We also discuss how the choice of direction affects portfolio efficiency rankings, following insights from Kristiaan Kerstens and coauthors.

Title: EVERY COIN HAS TWO SIDES: AN EXTENDED FRAMEWORK FOR MODELING BENEFICIAL AND HARMFUL BY-PRODUCTS

Authors: [PhD student Yunguo Mu PhD](#); Prof. Zhiyang Shen PhD; Prof. Michael Vardanyan PhD

Affiliation: IESEG School of Management, Univ. Lille, CNRS, UMR 9221 -LEM

By-products are unintended outputs produced alongside the main product in production which can have both positive and negative effects. A common oversight in the literature is the tendency to treat by-products solely as harmful in modeling. This paper proposes an extended framework that accounts for both beneficial and harmful by-products. We introduce a hybrid directional distance function to evaluate technical efficiency and conduct a scenario analysis to demonstrate the applicability of our approach. Our method also addresses a critical issue in traditional by-production models under variable returns to scale: the violation of the material balance principle. Applying this model to the agricultural sector in 27 European countries, we assess economic and environmental inefficiencies and trace changes in green productivity. We argue that our framework offers

a more holistic approach to by-product modeling, leading to more reliable efficiency evaluations and a better understanding of the trade-offs between economic and environmental outcomes.

Keywords: Data envelopment analysis, Environmental technology, Efficiency and productivity, By-products.

Title: ENHANCING FDH BY PRODUCTION TRADE-OFFS

Authors: Dr. Mahmood Mehdiloo; Dr. Grammatoula Papaioannou; [Professor Victor Podinovski](#)¹

Affiliation: ¹ Loughborough University

The use of production trade-offs and weight restrictions dual to them is a well-established methodology for convex constant and variable returns-to-scale (VRS and CRS) DEA models. Production trade-offs are interpretable as simultaneous changes to the inputs and outputs that are possible at any production unit in the technology. The dual weight restrictions identify limitations on the marginal rates of transformation and substitution between inputs and outputs on the production frontier. We show that production trade-offs can similarly be used in free disposal hull (FDH) models of technology. We also present theoretical results concerning the notion of consistency of production trade-offs in FDH.

15:30 - 17:00 | Venus 1 | Electricity

Chair: Kristiaan Kerstens

Title: DISTINGUISHING HIGH-IMPACT AND ATYPICAL OUTLIERS IN REGULATION: EVIDENCE FROM GERMAN ELECTRICITY NETWORKS

Authors: [Prof. Dr. Mohsen Afsharian](#)¹; Prof. Dr. Peter Bogetoft²

Affiliation: ¹ Leibniz-FH, University of Applied Sciences, Germany; ² Copenhagen Business School, Denmark

Benchmarking is a key tool in regulatory frameworks for assessing the efficiency of network industries. In this context, identifying outliers is crucial, as their presence can significantly distort benchmarking outcomes and the resulting firm incentives. This paper focuses on two types of performance-related outliers: influential units – firms that define the frontier and significantly affect the efficiency scores of others, and atypical units – firms that have unusual input–output profiles but little or no influence on the rest of the sample. Using the German electricity sector as a case study, we examine the methodology of the Bundesnetzagentur (BNetzA), a pioneer in regulatory benchmarking. We show that its reliance on standard dominance and super-efficiency analysis fails to distinguish between these two types, which may result in misaligned incentives. To address this gap, we propose two methodological refinements – a revised dominance measure and a radius-based super-efficiency approach – embedded in a transparent procedure tailored to regulatory benchmarking. The proposed approach is designed to support a more consistent and targeted application of performance-based rewards, while remaining fully compatible with existing regulatory procedures.

Title: TOTEX-BASED REGULATORY BENCHMARKING: EUROPEAN LESSONS FOR THE BRAZILIAN ELECTRICITY DISTRIBUTION FRAMEWORK

Authors: [Prof. Dr. Ana Lopes Ahn](#)¹; Prof. Dr. Bruno Vilela¹; Prof. Dr. Heinz Ahn Heinz²; Carolin Ladda²; Prof. Dr. Roberto Mesquita³; Roger dos Reis Alves⁴

Affiliation: ¹ Center for Performance Analytics & Regulation – CPR; ² Technische Universität Braunschweig; ³ Universidade do Estado de Mato Grosso; ⁴ CPFL Energia

The current Brazilian electricity distribution regulation treats OPEX and CAPEX through separate incentive mechanisms, creating opportunities for regulatory arbitrage and distorting efficiency signals. As OPEX is benchmarked independently from CAPEX, distribution system operators may overinvest in assets to reduce reported operational costs, increasing tariffs and masking inefficiencies. This misalignment highlights the need for regulatory approaches that jointly evaluate total expenditure (TOTEX) and address the trade-off between operational and capital costs. In this context, this study analyzes TOTEX-based regulatory models from Austria, Germany, and Norway to identify elements supporting a transition from OPEX- to TOTEX-based benchmarking in Brazil. The research combines bibliographic and documentary review with technical visits to European regulators, enabling direct observation of the practical application of TOTEX models. The analysis

shows that these countries operate mature TOTEX frameworks. Key mechanisms include alternative input specifications (calculated and standardized TOTEX), combined parametric and non-parametric benchmarking, systematic treatment of outliers, efficiency bottom lines, inefficiency-reduction targets, quality incentives, and differentiated CAPEX remuneration. Together, these practices provide guidance for designing a TOTEX-based efficiency framework for the Brazilian electricity distribution sector.

Title: OPTIMAL MERGERS AND SECTOR RESTRUCTURING

Authors: [Prof. Dr. Peter Bogetoft](#) [Dr. Merc.](#)

Affiliation: Copenhagen Business School, Denmark

This paper investigates optimal strategies for sector restructuring through consolidation. We address two key challenges: estimating potential gains from various mergers and solving the combinatorial problem of selecting the most advantageous merger combinations when certain choices preclude others.

Identifying value-creating mergers carries both firm-level and societal significance. Consolidation can reduce costs through information sharing and enhanced economies of scale and scope, improving the efficiency with which sectors serve consumers.

We demonstrate our approach using data from Denmark's electricity distribution sector. Danish policymakers and regulators—like their counterparts in other countries—seek to quantify consolidation benefits to inform regulatory policy. Our framework enables regulators not only to encourage best-practice adoption but also to calibrate allowed tariff revenues to reflect potential merger savings, thereby creating targeted incentives for efficiency-enhancing consolidation.

Title: FRONTIER REGULATION OF ELECTRICITY DISTRIBUTION: WHY ECONOMISTS ARE WRONG AND ENGINEERS ARE ONLY HALF RIGHT

Authors: [Prof. Dr. Kristiaan Kerstens PhD](#)¹; [Prof. Dr. Stefano Nasini PhD](#)²; [Prof. Dr. Miguel Alves Pereira PhD](#)³

Affiliation: ¹ Univ. Lille, CNRS, IESEG School of Management, UMR 9221 - LEM; ² IESEG School of Management, Univ. Lille, CNRS, UMR 9221 -LEM; ³ CEGIST, Instituto Superior Técnico, Universidade de Lisboa

FRONTIER REGULATION OF ELECTRICITY DISTRIBUTION: WHY ECONOMISTS ARE WRONG AND ENGINEERS ARE ONLY HALF RIGHT

Kristiaan Kerstens Stefano Nasini Miguel Alves Pereira

Frontier benchmarking is widely used in incentive regulation to determine RPI-X cost and other norms for electricity distribution firms. Almost universally, regulators and researchers rely on nonparametric frontier models, which impose either convexity or nonconvexity assumptions on the underlying technology. However, the physical laws governing electricity distribution, notably power flow equations, generate input-output relationships that may well depart markedly from both convex and nonconvex nonparametric frontier models. This paper is the first to empirically demonstrate the substantial divergence between these nonparametric frontier models and the true technology and cost function derived from engineering models. Using numerical simulations, we show that applying nonparametric frontier models introduces significant estimation error, potentially distorting efficiency scores and regulatory benchmarks. Among nonparametric frontier models, nonconvex models yield estimations that are closer to the engineering cost frontier than convex models. Furthermore, empirical results based on real-world data from Finland and Iran show that nonconvex cost frontiers provide a better fit with the data than traditional convex cost frontiers. These findings highlight the importance of aligning regulatory benchmarking tools with the actual technological constraints of electricity distribution systems and caution against overreliance on convex nonparametric frontier efficiency assessments.

Keywords: Cost Frontiers, Convex, Nonconvex, Engineering models

15:30 - 17:00 | Mars 1 | Banking & Finance 1

Chair: Sayati Ghosh

Title: A GROUP-BASED PROFITABILITY GAP DECOMPOSITION MODEL: AN APPLICATION TO TAIWANESE AND CHINESE CITY BANKS

Authors: [Dr. Xiang Chen](#); Xisi Chen

Affiliation: Zhejiang University of Finance and Economics, China

Considering the technological heterogeneity among different groups of commercial banks, this study adopts this cross-group performance comparison model of Camanho and Dyson (2006) as its theoretical foundation, with the aim of analyzing the sources of profitability differences. This study incorporates profitability change model of Grifell-Tatje and Lovell (2015) into the group comparison model to propose a novel group-based profitability comparison model. The profitability gap can be decomposed in three stages, and present a more comprehensive and detailed analysis of the differences and sources of profitability performance across different groups. Using relevant data from 42 Chinese city banks and 36 Taiwanese banks during the period of 2015–2024, this study employs the proposed model to compare the profitability performance, and explains what factors contribute to the profitability gap. The empirical results show that the profitability of Chinese city banks is lower than that of Taiwanese banks, because of the contributions of Output mix effect and price effect in China are lower than that in Taiwan. Although the input mix effect between two bank groups is small, the contributions of Chinese city banks in Coastal and Inland regions present different results. In other words, Chinese coastal city banks have a lower input mix ability than Taiwanese banks, and Chinese inland city banks perform better ability than Taiwanese banks.

Title: THE EFFECT OF CORPORATE SOCIAL RESPONSIBILITY ON BANK PERFORMANCES: AN APPLICATION OF NETWORK STOCHASTIC FRONTIER ANALYSIS

Authors: [Dr. Chu-Nan Hu PhD](#)¹; Prof. Kuo-Jui Huang²

Affiliation: ¹ Chung-Hua Institution for Economic Research; ² National Ilan University

This dissertation divides the production process of commercial banking into two stages for describing the dual roles of deposits and corporate social responsibility (CSR) activities and for linking CSR with cost efficiency. In the first stage, banks expend a portion of their labor and physical capital inputs to collect deposits and engage in CSR; in the second stage, they employ their remaining labor and physical capital and two intermediate goods (i.e., deposits and CSR) to produce loans, investments, and noninterest income. Because the labor and capital inputs are utilized in both stages, we adopt the network stochastic frontier analysis (network SFA) model to evaluate bank efficiency, and investigate the relationship between efficiency and various CSR activities after controlling bank structures and their country-specific cultural factors. In addition, we also extend the findings of Huang et al. (2017) by incorporating environmental variables into the inefficiency term of the cost frontier, and we simultaneously estimate the parameter coefficients of the output distance function, cost frontier, and two cost share equations. We derive the joint probability density function of these four equations by applying the copula method. The incorporation of environmental variables substantially complicates the function, which is thus very difficult to estimate. We integrate the BankScope and Orbis Bank Focus databases to gather input-output data and CAMEL indices for 187 banks across 27 countries from 2003 to 2014. A collection of Corporate Social Responsibility (CSR) metrics is obtained from the Ethical Investment Research and Information Service (EIRIS) database, categorized into seven dimensions: employee, community, environment, governance, stakeholder, bribery, and ESG delivery. These scores are then rescaled for consistency. Furthermore, we incorporate four cultural indices established by Hofstede et al. (1991, 2010)—individualism, long-term orientation, uncertainty avoidance, and power distance—into the regression model to account for variations among countries. After controlling for banks' characteristics and their country-specific cultural factors, our empirical results reveal that banks devote themselves in "environment", "stakeholder", and "anti-bribery" activities would be beneficial for their efficiency performance. However, "employee", "community", "governance" and "ESG delivery" shows the negative relationship with banks' efficiency.

Keywords: Corporate social responsibility, Network SFA, Environmental variables, Copula

Title: ASSESSING THE EFFICIENCY OF EUROPEAN LISTED REGIONAL BANKS: A CONDITIONAL NONPARAMETRIC APPROACH

Authors: [Dr. Anamaria Aldea PhD](#)¹; Dr. Luiza Bădin PhD²; Dr. Carmen Lipară¹

Affiliation: ¹ Bucharest University of Economic Studies; ² Bucharest University of Economic Studies; "Gheorghe Mihoc - Caius Iacob" Institute of Mathematical Statistics and Applied Mathematics of the Romanian Academy

The coronavirus (COVID-19) pandemic was a game changer for the way companies and financial institutions worldwide run their daily operations to meet their performance objectives. The strong connection

between the companies active in one region and the European listed regional banks was scrutinized during the pandemic years (2020-2022). In times of high uncertainty, when individual and institutional investors were looking to maintain high liquidity to their investments, the commercial banks had to find available resources to finance companies that needed to restart their operations and implement additional healthy security measures after the lock down. In this paper we employ conditional efficiency analysis to assess and explain the impact of external factors such as stock volatility on the efficiency of European listed commercial banks. The approach is fully nonparametric and allows an insightful understanding of the compound impact of external factors (impact on the shape of the frontier and/or impact on the distribution of inefficiency). To estimate the conditional efficiencies, we apply the recent bootstrap-based method for bandwidth selection in conditional frontier models. We consider European listed commercial banks from FactSet database, as their activity stands for the primary function of banks, namely lending and borrowing financial resources and their usually associated lower risk makes them easier to manage.

Title: COST, OUTREACH AND GENDER: AN EMPIRICAL ANALYSIS OF SOUTH ASIAN MICROFINANCE INSTITUTIONS

Authors: [Sayati Ghosh](#); Prof. Dr. Simanti Bandyopadhyay¹

Affiliation: ¹ Shiv Nadar University

The paper has a threefold objective. First, to offer an assessment of the existence of mission drift phenomenon of Micro Finance Institutions (MFIs) by comparing the cost and outreach efficiencies. Second, to examine the impact of female participation at different hierarchical levels on the performances of the MFIs. Third, to explore whether a policy mandating female representation can impact the efficiencies of MFIs.

Using panel data on South Asian MFIs from MIX MARKET dataset during 2010-2019, we estimate stochastic cost and production frontiers. Results show that average cost efficiency of South Asian MFIs exceeds that of technical efficiency, indicating a prioritization of financial sustainability over outreach. Country-specific analyses from Indian, Bangladeshi and Pakistani MFIs yield similar patterns. The performance variations in these MFIs are due to variation in inefficiencies comprising gender specific variables.

India is the only South Asian country in our sample, with a gender-targeted governance provision under the Companies Act (2013) requiring at least one female board of director. Using a non-linear difference-in-difference (DID) in the second stage with frontier-based efficiency scores estimated in the first stage and a single stage linear DID on a set of cost and outreach indicators derived from the data, we find that female board members, managers and loan officers can improve efficiency, individually and jointly, following the Act's implementation.

15:30 - 17:00 | Mars 2 | Education 1

Chair: Oleg Badunenko

Title: FEED A COLD: NEW EVIDENCE ON THE IMPACT OF COVID-19 ON SCHOOL ATTENDANCE AND ACHIEVEMENT

Authors: [Dr. Kathy Hayes PhD](#)¹; Dr. Lori Taylor PhD²; Dr. Shawna Grosskopf PhD³; Dr. Laura Razzolini PhD⁴

Affiliation: ¹ Southern Methodist University; ² Texas A&M University; ³ Oregon State University; ⁴ The University of Alabama

A growing body of evidence documents the impact that COVID-19 pandemic had on learning outcomes and student attendance. Many of those analyses lack data on the extent to which student populations experienced face-to-face instruction during the pandemic. One problem is that attendance data do not differentiate between instructional modalities. One thing we know about virtual instruction: when students aren't in the building they aren't eating in the cafeteria. In this paper, we use Texas school-level records from the National School Lunch Program (NSLP) to refine existing measures of COVID impacts on attendance during the pandemic and associated learning loss. We address three research questions. First, we use frontier analysis to measure the effect of going to school on learning outcomes. Second, how does the incorporation of NSLP data refine existing measures of COVID impact on student attendance? Finally, to what extent would improved measures of COVID attendance explain differences across schools and students with respect to student learning outcomes. The results will aid our understanding of COVID-related losses that would help

better target compensatory resources. Our methodology provides a strategy that researchers in other states could use to explore these important issues.

Keywords: Frontier analysis, measurement and productivity, school attendance, learning outcomes

Title: ZERO INEFFICIENCY AND LATENT CLASS STOCHASTIC FRONTIER MODEL AND ITS APPLICATION

Authors: [Prof. Yi-Wun Chen](#)

Affiliation: National Chung Cheng University

The traditional stochastic frontier model assumes that all observations are inefficient. The inefficiency term is continuously distributed in this model, implying zero probability (i.e., impossibility) of an observation with full efficiency. However, fully efficient observations may exist under a competitive market. Estimation of the production technologies and technical efficiencies or inefficiencies of these observations through the traditional stochastic frontier model is thus invalid. Moreover, when a single stochastic frontier model is used to estimate parameters for heterogeneous observations with different production technologies, bias emerges. This paper presents an econometric model developed to solve these problems. In the empirical study, I analyze the operating cost efficiency of universities in the United States by the proposed model. The results suggest that considering the multiple-regime model and fully efficient observations are necessary when observations are heterogeneous and market conditions are competitive; otherwise, the estimated technical efficiency indices for each observation would be biased and inconsistent.

Title: TWO DECADES OF PUBLIC SPENDING EFFICIENCY IN EU COMPULSORY EDUCATION

Authors: [Dr. Giovanni Antonini](#); Prof. Tommaso Agasisti

Affiliation: Politecnico de Milano

Compulsory education in the EU is largely publicly funded, yet average learning outcomes have weakened in recent years. This study measures how efficiently EU education systems transform public resources into learning and equity outcomes, and how efficiency evolves over time. We build an original national panel for the 27 EU countries (2000–2024). Inputs are public expenditure per student and the teacher–pupil ratio; outputs combine harmonised achievement scores from international large-scale assessments (PISA, TIMSS, PIRLS) and an equity indicator given by the share of low achievers in PISA. To reflect the cumulative nature of schooling, for each output year we use the three-year average of inputs observed in the previous three years. Efficiency is estimated with input-oriented DEA under variable returns to scale and bias-corrected via bootstrap procedures to obtain confidence intervals. Changes over time are examined through productivity indices. In a second stage, bootstrap-corrected regressions relate efficiency to contextual factors (income, demography, human capital, teacher pay, private enrolment and governance proxies). Preliminary results show marked cross-country heterogeneity: Northern European systems tend to be persistently closer to the frontier, while Southern and Eastern countries remain further away, suggesting scope for improving the conversion of spending and staffing into both achievement and equity.

Title: NETWORK DEA MODEL FOR EFFICIENCY ANALYSIS OF THE UNIVERSITIES IN THE UK

Authors: Dr. Akram Dehnokhalaji¹; [Dr. Oleg Badunenko PhD](#)²

Affiliation: ¹ Aston Business School; ² Brunel University of London

In this study, we develop a network DEA model to evaluate the efficiency of the universities in the UK across several years. We develop a two-stage DEA model with a combination of series and parallel components. We consider three nodes, the cost node in the first stage where the resources are transformed into the academic and non-academic staff and two nodes in the second stage, the teaching node and the research node and calculate the efficiency of each university for each of these three dimensions. The overall efficiency score is also calculated and the relationships between the overall efficiency and stages efficiencies has been established. We look at the yearly results for overall efficiency, cost efficiency, teaching efficiency and research efficiency of universities using visualization techniques. This analysis supports a deeper understanding of dynamics and structural differences across higher education institutions. We interpret the findings in the context of the UK higher education.

Wednesday, June 17, 2026

09:00 - 10:00 | Terra & Jupiter | Plenary 2

Chair: Spiro E. Stefanou

Title: FINANCING AGRICULTURAL PRODUCTIVITY GROWTH IN TIMES OF GLOBAL DISORDER

Authors: [Johan Swinnen](#)

Affiliation: Director General of the International Food Policy Research Institute (IFPRI)

Since the mid-2010s, decades of remarkable improvement in food security and poverty reduction worldwide have stalled or reversed. This problematic trend coincides with falling growth rates in global GDP and agricultural productivity. Agrifood systems meanwhile face a slowdown in R&D expenditure and an uptick in climate shocks, conflict, and other disruptions which have joined to create an era of global disorder. It is therefore urgent for governments and development partners to increase public and private investments in agricultural productivity. Reversing the decline in productivity growth will require revamping the global agri-food aid and investment architecture. This change will involve not only revising the traditional models of investment, finance, and aid but also revisiting the source structures, including a shift in geopolitics, a larger role of the private sector, and more effective use of scarce public and private financial resources. At the same time, the evolving donor landscape and shifting political economy of aid suggest that future financing models will likely incorporate a more diverse set of instruments and partnerships.

10:30 - 12:00 | Terra | Special session: Index numbers

Chair: Christopher Parmeter

Title: ON THE THEORY AND PRACTICE OF PROPER INDEXES

Authors: [Erwin Diewert](#)

Title: PROPER QUANTITY INDEXES FOR COHERENT PRODUCTIVITY COMPARISONS

Authors: [Christopher O'Donnell](#)

10:30 - 12:00 | Jupiter | Agriculture 2

Chair: Subal C. Kumbhakar

Title: HOW CAP SUBSIDIES AFFECT TECHNICAL EFFICIENCY: EVIDENCE FROM HUNGARIAN DAIRY FARMS USING AN ENDOGENEITY-CORRECTED DYNAMIC BAYESIAN SFA

Authors: [Lajos Baráth](#)¹; Dr. Andrzej Pisulewski; Imre Fertő; Jerzy Marzec

Affiliation: ¹ ELTE KRTK

This paper analyzes the effects of Common Agricultural Policy (CAP) subsidies on the technical efficiency of Hungarian dairy farms using an endogeneity-corrected dynamic Bayesian stochastic frontier model. Technical efficiency is allowed to evolve dynamically and key subsidy instruments are treated as fully endogenous. Using an unbalanced panel from the Hungarian FADN database for 2004–2018, we find strong persistence in technical efficiency, with around 79% of efficiency carried over between periods. The results reveal heterogeneous effects across policy instruments: decoupled payments and Less Favoured Area (LFA) subsidies significantly reduce technical efficiency, while agri-environmental scheme payments improve it. Coupled subsidies show no significant effect once endogeneity is accounted for. Moreover, the results highlight the importance of treating agricultural subsidies as endogenous when assessing their effects on technical efficiency.

Title: IS BIO-INPUT ADOPTION ASSOCIATED WITH TECHNICAL EFFICIENCY? EVIDENCE FROM SOY-BEAN FARMS IN BRAZIL

Authors: Rodrigo Damasceno¹; [Dr. Marcelo José Carrer PhD¹](#); Prof. Hildo Meirelles de Souza Filho PhD¹; Dr. Marcelo de Mello Brandão Vinholis PhD²; Larissa Gui Pagliuca PhD¹

Affiliation: ¹ Federal University of Sao Carlos; ² Brazilian Agricultural Research Corporation

Expanding the use of bio-inputs across an additional 13 million hectares is one of the key strategies in the Brazilian government's ABC+ Plan (2020-2030) for promoting low-carbon agriculture. Despite this policy emphasis, empirical studies using farm-level data to assess farmers' adoption of biological products and their impacts remain scarce. This article assesses the determinants and impacts of bio-input adoption on technical efficiency and technological gap of soybean farms in Brazil. Primary microdata was collected from a random sample of 152 farms in the state of São Paulo during the 2023/24 crop year. The empirical strategy combines propensity score matching with stochastic production frontiers corrected for sample selectivity and a meta-frontier framework. Adoption of bio-inputs is associated with farmers' participation in cooperatives, degree of risk aversion, innovativeness, cultivated area, access to credit, farmer age, and income from non-agricultural activities. The average technical meta-efficiency of adopters (0.65) is eight percentage points higher than that of non-adopters (0.57), a difference that is statistically significant at the 1% level. This performance gap is driven by superior managerial efficiency rather than by differences in production technology. The findings provide evidence that bio-input adoption lowers input costs without reducing soybean yields. These results may support the sustainable transition of Brazilian agriculture.

Keywords: bio-inputs, low-carbon agriculture, technology adoption, technical efficiency.

Title: A SYSTEMATIC REVIEW OF THE NET CONTRIBUTION OF PESTICIDES ON AGRICULTURE: ACCOUNTING FOR ECONOMIC, ENVIRONMENTAL, AND SOCIAL EFFECTS

Authors: [Dr. Xiaojie Wen](#); Prof. Dr. Niklas Möhring

Affiliation: Uni Bonn

Pesticides are a key input in modern agriculture, yet their contribution to agriculture remains unclear once environmental and social effects are considered. Therefore, this study introduces the concept of the net contribution of pesticides, defined as the aggregate balance between pesticide-induced economic benefits and environmental and social costs, extending conventional productivity toward an integrated, unit-based assessment. Building on this framework, the study presents the first global systematic literature review combined with meta-analysis, synthesizing 278 estimates from 66 empirical studies. Results reveal a strong disciplinary bias: more than half of the estimates focus solely on economic outcomes, and meta-regression analysis shows that such studies systematically report significantly larger and more positive elasticity estimates than those accounting for environmental or social dimensions. Methodologically, Data Envelopment Analysis is associated with significantly smaller elasticity estimates relative to econometric approaches, while Stochastic Frontier Analysis does not produce estimates that differ significantly in magnitude. Estimation specifications, including indicator measurement, fixed effects, and classification, further shape reported results. Overall, the findings highlight systematic overestimation risks in the assessment and underscore the need for integrated productivity and efficiency approaches to evaluate the net contribution of pesticides.

Title: A PROXY-VARIABLE INPUT DISTANCE FUNCTION FOR MULTI-OUTPUT PRODUCTION: EVIDENCE ON FERTILIZER AND PESTICIDE REDUCTION IN EU AGRICULTURE

Authors: Prof. Lukas Cechura PhD; Dr. Zdenka Zakova Kroupova; Jiri Vacek; [Prof. Subal C Kumbhakar PhD](#)

Affiliation: Czech University of Life Sciences Prague

This study contributes to the theoretical development of a proxy-variable approach for modelling multiple-input, multiple-output production technology and provides empirical evidence on the relationship between input-use intensity, particularly fertilizers and pesticides, and economic viability. The proxy-variable framework addresses endogeneity of variable inputs while allowing decomposition of output growth into components attributed to quasi-fixed inputs, variable inputs, and productivity change. The novelty of the approach is three-fold. First, it extends the proxy-variable literature by incorporating a flexible representation of a multi-input, multi-output production process, ensuring consistent estimation of production technology and productivity in the presence of endogenous inputs. This provides an operational strategy for identifying and estimating a

translog input distance function with three outputs, three variable inputs, and three quasi-fixed inputs. Second, it advances multiple-output proxy-variable modelling by more directly addressing productivity and efficiency, thereby narrowing the gap between proxy-variable methods and stochastic frontier analysis. Third, it delivers new empirical evidence on productivity dynamics and the role of capacity constraints in shaping short-run production responses across European farms, with particular attention to agrochemical inputs.

10:30 - 12:00 | Venus 1 | SFA methods 2

Chair: Artem Prokhorov

Title: STANDARD STOCHASTIC FRONTIER ANALYSIS FRAMEWORK WITH DEPENDENCY BETWEEN INEFFICIENCY AND NOISE

Authors: [Dr. Zangin Zeebari PhD¹](#); Prof. Scott Hacker

Affiliation: ¹ Jönköping University

In standard stochastic frontier analysis, noise and inefficiency are assumed independent to ensure identification and tractable maximum likelihood estimation, so the composed error is obtained via convolution and asymmetry is attributed to inefficiency. However, this independence assumption is strong and may not reflect empirical reality, as unobserved shocks and inefficiency can plausibly be correlated in practice. Although some studies introduce dependence via joint parametric distributions, thereby departing from the usual setup (e.g., symmetric mean-zero noise and non-negative inefficiency), the more prevalent approach relies on copula-based models. In this paper, we retain the standard distributional assumptions, i.e., mean-zero normal noise and half-normal inefficiency, but allow them to be (at least linearly) dependent, then we find the conditional inefficiency scores, and present both a simulation study and an empirical application.

Title: INCORPORATING INTERMEDIATE OUTPUTS INTO SFA USING AN EQUATION SYSTEM APPROACH: AN EXTENSION TO PANEL DATA

Authors: [Prof. Dr. Phill Wheat PhD](#); Dr. Trang Tran PhD; Dr. Alex Stead PhD

Affiliation: University of Leeds

This paper contributes to the growing literature on systems of stochastic frontier (SF) equations by further developing existing Network SF models to extend its application to panel data. Network SFA frameworks model multi-stage production processes through a system of SF equations. This approach offers significant advantages, including explicit measurement of efficiency at each stage and a simple multi-step estimation procedure. However, its applicability is constrained by a cross-sectional specification, which limits insights into dynamic performance and may introduce bias when applied to panel data. To address these limitations, we develop a four-component panel model that separates time-variant and time-invariant efficiency, providing richer understanding of firm behaviour over time. In addition, we adapt the original multi-step estimation method to accommodate the panel structure while preserving its computational simplicity, supported by an author-developed Stata package. Finally, the applicability of our extended model and the validity of the proposed estimation method are demonstrated by an empirical example of English road maintenance.

Title: PUBLIC SUBSIDY AND COST EFFICIENCY IN FINNISH THEATRES

Authors: Prof. Christopher Parmeter PhD¹; [Dr. Marta Zieba PhD²](#)

Affiliation: ¹ University of Miami; ² University of Limerick

Public subsidies in the performing arts are justified by market failures, social objectives, scale economies, and employment concerns. Critics, however, argue that subsidies may weaken cost discipline and create soft budget constraints. Despite the sector's well-known exposure to Baumol's cost disease, the relationship between public funding and cost efficiency remains unsettled. This study examines this relationship using official panel data on 60 Finnish public-law theatres from 2006–2023. A generalized true random effects stochastic cost frontier reveals substantial cost-saving potential: total expenditures could be reduced by up to 19% if theatres operated on the frontier, with persistent inefficiency accounting for a larger share of the gap than transitory inefficiency. Public subsidies are positively and significantly associated with higher cost efficiency, contradicting the soft budget constraint hypothesis. Municipal subsidies have a stronger marginal

effect than state subsidies, consistent with closer local oversight and accountability. The findings underscore how subsidy design and governance shape efficiency outcomes.

Title: SHAPE-AWARE DEEP LEARNING FOR MODELS OF PRODUCTION

Authors: [Professor Artem Prokhorov PhD¹](#); Dr. Zheng Wei; Prof. Huiyan Sang; Yu Ma

Affiliation: ¹ University of Sydney Business School, CEBDA, CIREQ

The stochastic frontier model (SFM) is widely employed in the analysis of productivity and efficiency, yet strict parametric forms, such as the Cobb-Douglas and Translog functions, are often assumed for modeling production, leading to potential misspecification issues. While semi- and nonparametric SFMs offer greater flexibility, they face challenges in imposing monotonicity and concavity to maintain the desirable economic interpretation. We develop a framework which enforces these properties within deep neural networks (DNNs). The stochastic frontier model we develop (DNN-SFM) leverages the flexibility and predictive power of DNNs while preserving key properties of a production function, such as free disposability and diminishing marginal product. Additionally, we demonstrate how to use Shapley values to measure and interpret global and local effects of individual inputs on the production frontier in cases when model parameters do not admit a simple interpretation. The performance of the proposed method is assessed using simulations; a real-world application to rice production in the Philippines illustrates empirical relevance of the proposed method.

Keywords: Deep neural networks, Stochastic frontier models, Shapley values

10:30 - 12:00 | Mars 1 | Manufacturing 1

Chair: Magdalena Kapelko

Title: SIZE THRESHOLDS AND THE ADOPTION OF AI-BASED TECHNOLOGIES: EVIDENCE FROM SPANISH MANUFACTURING FIRMS

Authors: [Dr. Luis Orea¹](#); Dr. Inmaculada Álvarez²; Dr. Christopher Parmeter³; Dr. Desiderio Romero⁴

Affiliation: ¹ Universidad de Oviedo; ² Universidad Autónoma de Madrid; ³ University of Miami; ⁴ Universidad Rey Juan Carlos

This paper investigates why some firms adopt AI-based and other Fourth Industrial Revolution (4IR) technologies while others do not. Our empirical approach is inspired by Bresnahan and Reiss (1991). While a growing literature examines AI and robot adoption using structural production models or reduced-form regressions, we are not aware of work applying their threshold-based framework to technology adoption. We model adoption intensity as an ordered outcome governed by profitability cutoffs, allowing us to infer adoption constraints without fully specifying demand or cost functions. We extend this framework by introducing size thresholds: the firm size required to adopt a technology, intensify its use, or adopt multiple AI-based technologies. These thresholds summarize the net profitability of adoption, capturing both its drivers and barriers. Using panel data on Spanish manufacturing firms from 2017–2023, we find that the average size threshold is two to three times that of a representative firm. We also document substantial heterogeneity across firms, subsectors, and technologies. Conditional on adoption, greater intensity increases per-unit profitability beyond the additional fixed costs of intensification. The results highlight the importance of policies that lower adoption thresholds and incentivize AI uptake.

Title: FROM FUNDS TO FRONTIERS: HOW PON E&C SHAPES EFFICIENCY IN ITALIAN MANUFACTURING SECTOR

Authors: [Dr. Marco Alberto De Benedetto PhD](#); Prof. Camilla Mastromarco PhD; Dr. Anna Rita Dipierro PhD

Affiliation: UNIVERSITY OF CALABRIA

This paper evaluates the causal impact of the EU-funded Programma Operativo Nazionale Imprese e Competitività 2014–2020 (PON E&C) on the technical efficiency of Italian manufacturing firms. Using linked administrative and balance-sheet data over 2014–2023, we implement a staggered difference-in-differences design, complemented by propensity score matching on pre-treatment financial, demographic, and locational characteristics. The results show that PON interventions significantly boost efficiency, with the largest gains among small, young, and Southern firms—groups facing tighter financial constraints and structural disadvan-

tages. Further analyses reveal that project features, including funding intensity and investment orientation, shape the magnitude of gains. These findings suggest that EU cohesion policy can enhance firm-level productive performance, particularly when targeted toward resource-constrained firms, underscoring the potential of place-based industrial interventions to foster regional convergence in technological and organizational capabilities.

Title: PARETO KOOPMANS EFFICIENCY AT THE UNIT AND THE INDUSTRY LEVEL: AN APPLICATION TO INDIAN MANUFACTURING

Authors: [Professor Subhash C Ray](#)

Affiliation: University of Connecticut

In most empirical applications unit level data are used to measure radial input- or output-oriented technical efficiency of firms from an industry. A measure of group level efficiency is typically obtained as an average (arithmetic or geometric) of the individual efficiency measures. Even the directional distance function looks at the maximum proportional contraction of all inputs and expansion of all outputs. This leaves any potential input and output slacks out of consideration. Yet it is well known that a production unit is not fully efficient unless it is Pareto efficient. Any unrealized potential increase in any output and/or possible reduction in any input signifies inefficiency. The non-radial Russell measures do take explicit account of slacks in inputs or outputs depending on the orientation of projection of an inefficient input-output bundle. The so called slack based measure (SBM) (also known as an enhanced Russell measure or a Pareto-Koopmans measure) projects any inefficient input-output bundle onto the strongly efficient subset of the frontier. Also, to measure Pareto-Koopmans efficiency for the industry the individual input contraction and output expansion factors need to be weighted by the share of the unit in the industry total of the relevant input or output.

Key words: Pareto-Koopmans Efficiency; DEA, Aggregation of Efficiency; Indian Manufacturing

Title: COMPARING PERFORMANCE USING ADDITIVE MODELS BASED ON REGRESSION SPLINES: AN APPLICATION TO FIRMS IN MAJOR EUROPEAN COUNTRIES WITHIN THE MEAT MANUFACTURING INDUSTRY

Authors: Prof. Juan Aparicio¹; Dr. Victor J. España¹; [Prof. Magdalena Kapelko PhD²](#)

Affiliation: ¹ Miguel Hernandez University of Elche; ² Wroclaw University of Economics and Business

This study has two main objectives. Firstly, it aims to develop an innovative performance evaluation framework to compare efficiency and technological gaps among groups of firms over time. The proposed framework integrates: (1) frontier machine learning technique based on multivariate adaptive regression splines, and (2) efficiency, productivity and technology indices designed to enable comprehensive performance comparisons across groups. Secondly, the framework is applied to assess the performance of meat processing firms in five EU countries — France, Germany, Italy, Poland and Spain — using data from 2013 to 2022. The findings reveal that over this period, German meat processing firms consistently exhibited the highest performance, with Polish firms showing the lowest performance levels. These differences are predominantly influenced by variations in technological capabilities, with the technological edge of German firms driving their superior performance. Additionally, the analysis shows some convergence in performance over time, narrowing the performance disparities among some of the countries and over the years studied. At the same time, some differences in performance have been detected between the pre-COVID and post-COVID periods. Our results appear reasonably robust when compared with a standard framework based on Data Envelopment Analysis and when different directional vectors are applied.

10:30 - 12:00 | Mars 2 | Health

Chair: Gabriel Rosero

Title: WHEN PARALLEL NETWORK DEA MEETS AGGREGATED DATA: LIMITS OF PROCESS-LEVEL DIAGNOSIS IN PUBLIC HOSPITALS

Authors: Marta Abreu; [Miguel Pereira](#)

Affiliation: Instituto Superior Técnico, Universidade de Lisboa

Parallel network Data Envelopment Analysis (DEA) is increasingly used to disentangle process inefficiency from resource misallocation in multi-activity organisations. Its empirical application, however, typically relies on the availability of process-level inputs, outputs, or observed internal allocations - conditions that are often violated in contemporary healthcare systems. This paper evaluates the empirical limits of parallel network DEA when such information is entirely unavailable. Using Portuguese public hospitals following the 2024 reorganisation of the National Health Service into Local Health Units, we apply a parallel network DEA framework that decomposes inefficiency into process-level performance, within-unit resource misallocation, and system-wide allocation inefficiency. Because administrative data report only hospital-level aggregates, the network models are embedded within a Monte Carlo simulation procedure that reconstructs feasible process-level quantities consistent with observed totals. The results show that aggregate benchmarking at the hospital and industry levels remains numerically stable under extreme informational constraints. However, when internal quantities are generated as proportional transformations of aggregates using common baseline shares with limited variability, strong collinearity across processes emerges. As a consequence, relative differences across hospitals are mechanically preserved across processes, cross-process trade-offs become rare, and reallocation signals are difficult to interpret as evidence of genuine internal misallocation. These findings delineate a clear empirical boundary for the use of parallel network DEA: while suitable for aggregate efficiency measurement under data scarcity, meaningful process-level diagnosis requires at least partial, unit-specific information on internal allocations or activity by speciality.

Keywords: Parallel network DEA; Hospital efficiency; Resource misallocation; Data scarcity □ Corresponding author: miguelalvespereira@tecnico.ulisboa.pt

Title: THE MANAGERIAL USE OF EFFICIENCY INFORMATION IN PUBLIC HOSPITALS

Authors: Prof. Paul Rouse PhD¹; Dr. Ajit Arulambalam PhD²; [Prof. Dimitris Margaritis PhD¹](#)

Affiliation: ¹ The University of Auckland; ² Director Population Health, & Consultant Performance Strategy and Projects

This study explored how hospital service managers use efficiency-related performance information to improve service delivery in a large publicly funded hospital with secondary and tertiary level services. Managers of the hospital's eleven major service areas were split into two groups: one receiving routine performance reports and the other receiving additional efficiency-focused reports using Data Envelopment Analysis (DEA). Efficiency scores improved for the DEA group with no improvement in scores for the routine report group. A qualitative case study found that targeted, contextual performance information enhanced managerial engagement and strategic action. Thematic Analysis revealed four key themes: direct leadership, operational feedback, performance signal, and management development, highlighting behavioural and organizational factors influencing performance improvement.

Title: A MULTI-FRONTIER APPROACH TO SUSTAINABILITY: PRODUCTIVITY ANALYSIS IN ECONOMIC, ENVIRONMENTAL, AND SOCIAL DIMENSIONS

Authors: [Wenzhuo ZHOU PhD](#); Prof. Zhiyang Shen; Prof. Michael Vardanyan

Affiliation: IESEG School of Management, Univ. Lille, CNRS, UMR 9221 -LEM

While a growing body of literature has incorporated environmental considerations into productivity analysis, the social dimension of sustainability remains underexplored, particularly in intertemporal contexts. This limitation is primarily due to the methodological challenges of jointly assessing economic, environmental, and social performance and the lack of consistent data. This study develops an extended multi-frontier sustainability framework that explicitly incorporates social performance into sustainability evaluation. Using data from a group of advanced economies, we select representative social indicators across three key domains: human development, healthcare outcomes, and social governance. A multidimensional sustainability performance indicator is proposed to decompose changes in productivity over time into three distinct components: economic productivity, environmental performance, and social progress. The first two components can be further decomposed into efficiency change and technological change. Furthermore, natural capital, proxied by forest area, is included as a non-substitutable control variable to ensure consistency with the principle of strong sustainability. This integrated framework offers a more comprehensive and policy-relevant approach to evaluating sustainable development across countries.

Keywords: Data envelopment analysis; Sustainability performance indicator; Social progress; Multiple Frontiers.

Title: MAPPING DIET EFFICIENCY GAPS: A SLACK-BASED BENCHMARKING APPROACH**Authors:** [Dr. Gabriel Rosero PhD](#); Prof. Dr. Liesbeth Colen PhD**Affiliation:** University of Göttingen

Diet quality has become a pressing public health issue in high-income countries, driven by economic pressures and evolving food environments that lead households toward inexpensive, calorie-dense, and nutrient-poor foods. This contributes to increasing obesity and diet-related diseases, disproportionately impacting low-income and less-educated groups. We employ Slack-Based Measure Data Envelopment Analysis to evaluate how effectively individuals convert their food intake into overall dietary quality and to identify the main factors that influence this efficiency. Using nationally representative dietary intake data from the German National Nutrition Survey II, we construct ten components of the Healthy Eating Index. Components associated with adequate intake are considered desirable outcomes, whereas those related to moderate intake are considered undesirable outcomes. Our findings suggest that dietary efficiency in Germany is generally low: individuals achieve about 50% of the dietary quality under comparable energy-intake conditions. Slack decomposition reveals notable deficiencies in adequate intake components, particularly whole grains and vegetables, as well as systematic surpluses in undesirable components, including sodium, refined grains, and added sugars. These patterns offer a comprehensive overview of deviations from established guidelines and identify areas where improvements are most achievable, providing valuable insights for targeted policy interventions.

13:30 - 15:00 | Terra | Organized session 2: Agricultural TFP and environment

Chair: Simone Pieralli**Title: THE PERSISTENCE OF CLIMATE SHOCKS ON GLOBAL AGRICULTURAL PRODUCTIVITY GROWTH****Authors:** [Ariel Ortiz-Bobea](#); Yurou He; David B. Lobell**Title: AN ENVIRONMENTAL EXTENSION OF THE FARM ACCOUNTANCY DATA NETWORK USING GE-LOCATIONS: A CASE STUDY ON FARM CLIMATE VULNERABILITY****Authors:** [Ana Klinnert](#); Kevin Schneider**Title: MEASURING THE EXTREME EFFECTS OF WEATHER ON FRENCH AGRICULTURE****Authors:** [Dr. Simone Pieralli](#)**Affiliation:** Joint Research Centre, European Commission

This paper measures the effects of extreme weather on French agriculture. This paper considers the case in which sub-technologies are not completely separable with a specific emphasis on the impact that weather has had on French field crop agriculture between 1990 and 2015. We collect finely-spaced gridded data on daily temperatures (minimum, maximum) and on daily precipitation. Lastly, we collect interpolated yearly soil variables at the department level in France on soil carbon and soil pH. We match these data with a representative unbalanced panel farm accountancy data set of 30,958 observations of field-crop specialists over 26 years (with more than 1000 farms every year on average).

To quantify that impact a transitive climate indicator under non-separable sub-technologies is constructed using a directional output distance function. This provides an empirical, non-parametric, measure of the positive or negative impacts of climatic variables on French field-crop agricultural production. The climate index correctly characterizes the effects of droughts and flooding events. Negative effects are evidenced when too much or too little rainfall is accumulated. Negative effects are also clear when too much heat is accumulated during the year.

13:30 - 15:00 | Jupiter | DEA Methods 2

Chair: Juan Pablo Henao Henao**Title: EXTENSIONS OF DEA-MARKOV MODELS WHEN TARGETS, PLANNING HORIZON AND DMUS**

ARE CO-DESIGNED

Authors: [Prof. Andreas Georgiou PhD¹](#); Prof. Emmanuel Thanassoulis PhD²; Prof. Konstantinos Kaparis PhD¹; Dr. Georgios Tsaples PhD¹

Affiliation: ¹ University of Macedonia; ² Aston University

This paper advances the DEA-Markov framework by introducing complementary extensions that enhance its capacity to support dynamic decision-making in evolving systems. First, the Dual-Frontier model treats both recruitment policies and target structures as synchronized, co-designed elements. Aspirational targets form their own convex frontier, allowing the model to identify efficient policy-target pairs that jointly satisfy Markov balance relations. This enables managers to distinguish between attainable and desirable evolution paths and to analyse how different target configurations interact with feasible interventions. Second, the Open-Time Control model adopts the time horizon as a decision variable. Therefore, instead of assuming a fixed number of transitions, the model determines the optimal duration required to reach a target structure under Markovian dynamics. By combining DEA-based efficiency measures with stepwise system evolution, the framework evaluates the trade-off between transition speed, policy effort and target attainment. Both extensions preserve linearity and interpretability while transforming DEA-Markov models from static evaluators into dynamic design instruments capable of generating efficient trajectories in multi-period environments.

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Keywords: DEA-Markov models, dual frontier, dynamic trajectories, efficiency

Title: NONPARAMETRIC PRODUCTION APPROACH TO HEDONIC PRICE FUNCTIONS

Authors: [Dr. Kassoum AYOUBA](#); Prof. Hervé LELEU

Affiliation: INRAE, CESAER , France

We introduce a nonparametric production approach to hedonic price functions in this paper. Inputs and outputs differentiation and heterogeneity are embodied in a global set of attributes which is included in an extended definition of a production possibility set. Then, by developing a short run economic model of profit maximization with incomplete (buyers and sellers) information, hedonic price functions for each output/input and firm-specific implicit values for

attributes emerge from duality. This requires no prior assumptions about the functional form describing the hedonic price functions or the production technology and represents the main contribution of the paper. We also propose a production model approach to estimate implicit “market values” for attributes, as an alternative to traditional hedonic first stage regressions, assuming that firms operate in a competitive environment. The proposed methodology is then applied to estimate the marginal willingness to pay for Protected Designation of Origin (PDO) milk using a sample of French dairy farms located in the Burgundy-Franche-Comté region.

Title: WINDOW-BASED DYNAMICS IN CHANCE-CONSTRAINED DATA ENVELOPMENT ANALYSIS MODEL WITH OPTIMAL CONTROL THEORY PRINCIPLES: A TOTAL COST EFFICIENCY MODEL

Authors: [Prof. Dr. Paulo Nocera Alves Junior PhD¹](#); [Prof. Dr. Isotilia Costa Melo PhD²](#)

Affiliation: ¹ Universidad Catolica del Norte (UCN); ² ICN Business School, Université de Lorraine, CERE-FIGE

Evaluating performance in multi-period settings under uncertainty is challenging in operations and supply chain management, particularly when inventories are inter-period link measures. We propose a Dynamic Stochastic Data Envelopment Analysis (DEA) model that embeds Optimal Control Theory (OCT) principles to enforce consistent state-transition relationships among costs related to demand (exogenous disturbance), ordering/production (control), and inventories (state). Uncertainty is handled via chance constraints converted to deterministic equivalents using a normal curve, with a covariance matrix computed from cost data. To capture temporal probability evolution, the method is combined with window analysis, computing window-specific moments and efficiency scores that reflect both dynamics and stochastic behavior. The model is formulated in total-cost terms to avoid distortions arising from unitary cost assumptions and to work directly with accounting reports. An empirical application with 15 public companies from the stock market deemed as Decision-Making Units (DMUs) and annual windows is used to compare deterministic and stochastic settings. Incorporating uncertainty can change frontier status while remaining stable overall. The framework prevents

projections that violate demand–supply–inventory balance across periods.

Title: A THREE-STAGE NETWORK DEA APPROACH FOR MODELING RESILIENCE AND DYNAMIC EFFICIENCY UNDER EXTREME CLIMATE EVENTS

Authors: [Juan Pablo Henao Henao](#); Maria Vrachioli PhD; Dr. Roberto Villalba; Prof. Dr. Johannes Sauer

Affiliation: Technical University of Munich (TUM)

Increasing climate variability, and in particular the growing frequency and severity of droughts, poses major challenges for agricultural production systems that must operate under resource constraints. Technical efficiency is widely recognized as a key determinant of productive performance. However, most existing efficiency analyses are static and treat extreme events as exogenous disturbances. For example, conventional stochastic frontier analysis (SFA) and standard data envelopment analysis (DEA) models typically provide average efficiency measures and do not explicitly account for the sequential nature of production decisions before, during, and after a climatic shock. As a result, they offer limited insight into where inefficiencies arise during adaptation periods. This paper develops a novel three-stage network DEA framework to evaluate dynamic efficiency in the presence of climatic shocks. The proposed model represents the production process as a series of interconnected stages: pre-shock preparation, within-shock operation, and post-shock recovery. Intermediate variables link stages, enabling the decomposition of overall efficiency into stage-specific components while preserving the internal structure of the decision-making units. The proposed model provides a general and flexible tool for analyzing dynamic production processes subject to external shocks, with potential applications in a wide range of operational and environmental contexts.

13:30 - 15:00 | Venus 1 | Energy 2

Chair: Brita Engen Finne

Title: EFFICIENCY MEASUREMENT THROUGH NON-PARAMETRIC AND PARAMETRIC TECHNIQUES: ACCOUNTING FOR SAMPLE HETEROGENEITY AND CONTEXTUAL VARIABLES IN EUROPEAN ELECTRICITY DSO

Authors: [Dr. Rui Rita PhD](#)¹; Dr. Vitor Marques¹; Dr. Diogo Bárbara

Affiliation: ¹ Portuguese Energy Services Regulatory Authority

This study presents a benchmarking analysis performed by the Portuguese Energy Services Regulatory Authority (ERSE) to support the decision on efficiency targets for the electricity distribution activity for regulatory period from 2026 to 2029 (The collaborative process between ERSE and its European counterparts allowed to set an European sample of electricity DSO).

To achieve the study's aim, we applied two non-parametric methodologies, Data Envelopment Analysis (DEA) and Malmquist Index, and one parametric methodology, the Stochastic Frontier Analysis (SFA), in particular, the Ray Frontier Production Model. The efficiency analysis models included two outputs: supply points and energy distributed. Regarding inputs, total expenditures (TOTEX) and operating expenditures (OPEX) are considered in different models. In addition, a contextual variable was used - the system average interruption duration index (SAIDI) for low-voltage electricity distribution activity.

For analysing the companies' efficiency performance and set the goal efficiency for the Portuguese DSO, ERSE followed three procedures: i) assessed data comparability; ii) estimated the efficiency values using the SFA and DEA models; iii) defined efficiency groups based on the global scores percentile ranges, iv) applied the efficiency of technological progress (from the Malmquist Index Analysis) to the most efficient group.

Title: PERSISTENT AND TRANSIENT PRODUCTIVE INEFFICIENCY IN THE SWISS HYDROPOWER SECTOR

Authors: [Samuel Schenk PhD](#); Prof. Massimo Filippini

Affiliation: ETH Zurich

This paper analyzes cost efficiency in the Swiss hydropower sector by decomposing overall inefficiency into persistent (structural) and transient (time-varying) components. Using an unbalanced panel of 56 hydropower

plants observed over the period 2011–2021, we estimate a translog total cost function under two stochastic frontier specifications: the multi-step random-effects model of Kumbhakar (2014) and the one-step simulated maximum likelihood (GTRE) approach of Filippini and Greene (2016).

The estimated parameters are statistically significant and consistent with prior evidence, and both models indicate the presence of economies of scale. Mean transient efficiency ranges from 0.70 (GTRE) to 0.74 (Kumbhakar), while persistent efficiency varies between 0.80 (Kumbhakar) and 0.91 (GTRE). Overall efficiency is similar across specifications, amounting to 0.60 (Kumbhakar) and 0.64 (GTRE), respectively.

Although transient efficiency rankings are broadly comparable across models (Spearman correlation: 0.704), the correlation for persistent efficiency is substantially lower (0.429), suggesting that assessments of long-term structural inefficiency are sensitive to the chosen econometric specification. By distinguishing between structural and short-run inefficiency, the analysis provides policy-relevant insights into the cost structure of the Swiss hydropower sector.

Title: THE EFFECTS OF SETTLEMENT STRUCTURES AND WIND PARK PLANNING ON THE EFFICIENCY OF ELECTRICITY DISTRIBUTION IN SWEDEN

Authors: [Dr. Maria Nieswand](#)

Affiliation: Leibniz-Institut für ökologische Raumentwicklung

The infrastructure required for distributing electricity to end consumers is incrementally intertwined with spatial planning and the development of cities and regions (urban and regional development). For example, this becomes apparent in situations where settlements grow fast and unsystematically or where wind parks are planned (and realised) to increase renewable power generation. In both cases, electricity distribution system operators (DSOs) are affected and may incur additional costs because they are obliged to deliver power to any type of settlement structure and to connect wind parks.

In this paper, I investigate the effects of settlement structures and wind park projects on the (cost) efficiency of DSOs. I use data on Swedish DSOs in the time period between 2019 and 2024 and estimate a four-components-model proposed by Badunenko and Kumbhakar (2017). For the mentioned variables of interest, I use spatial measures applied in urban and regional planning and combine them to the actual operating areas of the DSOs.

The novelty of my approach is that the measurements come from spatial science and practices and differ from those that are usually applied in regulatory analyses. This provides new insights on the effects of planning activities on DSOs costs and efficiencies.

Title: COST WEIGHTS AS MODEL OUTPUT IN A WORLD OF RAPID AND ASYMMETRIC PRICE INCREASES

Authors: [Brita Engen Finne](#)

Affiliation: NVE-RME

In 2014 the Norwegian Energy Regulatory Authority (RME) created a cost weight scheme in which different grid components are given different weights, based on the price of the components. The approach is similar to the NormGrid as implemented in pan-European TSO benchmarks. The cost weights developed by RME are used as output in a DEA model used to calculate revenue caps for the regional distribution system operators (DSOs).

The cost weights are static and do not account for changes in market prices over time. Yet exact precision is not important if the relative price changes are accounted for. If component prices change asymmetrically, the cost weights will give a lower quality comparison. Norwegian DSOs have reported substantial asymmetrical cost increases in recent years, accelerating since 2022. This has possible implications for efficiency comparisons and revenue cap outcomes.

We show how static cost weights can distort comparative efficiency results. Our analysis highlights the model's sensitivity to outdated weights and indicates how recalibration may be needed to preserve accuracy.

13:30 - 15:00 | Mars 1 | Country analysis 1

Chair: Mateusz Wojniak

Title: MEASURING AND EXPLAINING RESOURCE IMPACTS ON GLOBAL INNOVATION PERFORMANCES**Authors:** [Prof. Dr. Barnabe Walheer PhD](#)**Affiliation:** Universite de Liege, Belgium

This paper develops a multidimensional nonparametric framework to assess and explain cross-country differences in global innovation performance. Using data for 118 countries from 2013 to 2022, we construct annual global innovation sets and evaluate two complementary dimensions: innovation effectiveness, measured through scientific, creative, and economic outcomes; and innovation efficiency, defined as the ability to convert human capital, financial sophistication, and infrastructure into these outcomes. While efficiency levels remain relatively high and stable, effectiveness exhibits persistent gaps. A resource impact ratio further reveals a shift from widespread resource scarcity toward growing disparities in the quality of resource use. A second-stage analysis links these performance measures to structural determinants. Government efficacy, education expenditure, financial development, and ecological sustainability are strongly associated with higher effectiveness and efficiency, whereas political stability shows a negative relationship. Our findings highlight the importance of institutional capability, sustainable development, and financial depth in shaping national innovation trajectories.

Keywords: national innovation systems; innovation efficiency; innovation effectiveness; resource allocation.

Title: SPATIAL SPILLOVERS AND PROVINCIAL ECONOMIC EFFICIENCY IN VIETNAM: EVIDENCE FROM A SPATIAL STOCHASTIC FRONTIER APPROACH**Authors:** [Prof. Dr. Thanh Viet Nguyen PhD¹](#); Michel Simioni²**Affiliation:** ¹ University of Akureyri; ² MOISA, INRAE, University of Montpellier and Toulouse School of Economics, France

Vietnam has achieved rapid economic growth over the past three decades, yet this expansion has relied largely on factor accumulation rather than sustained productivity gains. This paper examines provincial economic efficiency in Vietnam while explicitly accounting for spatial spillovers across regions. Using panel data for 63 provinces over the period 2010–2023, we estimate alternative stochastic frontier models that allow for spatial dependence in output, random noise, and technical inefficiency. The empirical results show strong evidence of spatial clustering in inefficiency, indicating that provincial performance is influenced by neighbouring regions rather than determined solely by local production conditions. Model comparison based on likelihood ratio tests and information criteria suggests that a spatial stochastic frontier with dependence in the inefficiency term provides the best balance between explanatory power and parsimony. Institutional quality and human capital are found to reduce inefficiency, while the impact of foreign direct investment varies across provinces, pointing to uneven absorptive capacity and heterogeneous spillover effects. By integrating spatial dependence into the stochastic frontier framework, this study demonstrates that ignoring interprovincial linkages can lead to biased efficiency estimates and misleading policy conclusions. The findings underscore the importance of coordinated regional policies, improvements in subnational governance, and investments in human capital to support Vietnam's transition toward productivity-driven growth. More broadly, the paper illustrates the value of spatial stochastic frontier methods for analysing efficiency dynamics in emerging and transitional economies.

Keywords: Spatial stochastic frontier, Technical efficiency, Spatial spillovers, Vietnam

Title: FRONTIER ANALYSIS OF ECO-EFFICIENCY GAPS: EVIDENCE FROM EUROPEAN COUNTRIES**Authors:** [Dr. Golnaz Amjadi PhD¹](#); Dr. Charles-Henri Di Maria**Affiliation:** ¹ STATEC Research

This study estimates and compares eco-efficiency across European countries from 2000–2018. The study derives eco-efficiencies from the ratio of gross domestic product to greenhouse gas emissions and identifies eco-efficient countries as those that maximize their production of goods and services per unit of greenhouse gas emissions. Specifically, it identifies Sweden, Denmark, Italy, Norway, and Luxembourg as the most eco-efficient countries. Moreover, the paper investigates technological and policy factors that explain variations in eco-efficiency across countries. Countries with stricter environmental policy and higher energy tax revenue per unit of greenhouse gas emissions tend to be more eco-efficient. However, gains in eco-efficiency diminish as policy stringency and taxes increase.

JEL classification: C01, E23, L60

Keywords: Eco-efficiency; Greenhouse gases; Gross domestic product.

Title: MEASURING PRODUCTIVITY GROWTH USING MACHINE LEARNING. AN APPROACH BASED ON EFFICIENCY ANALYSIS TREES APPLIED TO OECD COUNTRIES

Authors: [Mateusz Wojniak](#)¹; Prof. Magdalena Kapelko PhD²; Prof. Juan Aparicio PhD³; Dr. Marta Zieba PhD⁴

Affiliation: ¹ University of Limerick; ² Wroclaw University of Economics and Business; ³ University Miguel Hernandez of Elche ; ⁴ Univerisity of Limerick

Evaluating country-level productivity growth is important for many reasons, as a country's economic performance determines the standard of living and, hence, the well-being of its citizens. This paper examines the productivity performance of OECD countries over 1990–2023 in an aggregated cross-country framework using a novel machine-learning-based frontier approach that does not suffer from the overfitting problem commonly associated with Data Envelopment Analysis. This paper develops new measures of productivity growth, building on the recently proposed Convexified Efficiency Analysis Trees approach. We construct the Malmquist Productivity Index and decompose it into pure technical efficiency change, scale efficiency change, pure technological change, and the change in scale of technology. The analysis uses data from Penn World Table 11. We measure output as real GDP in constant international dollars, and inputs include the capital stock, human capital, and the labour force. The empirical results indicate positive pure technical efficiency gains of 3.3% on average, suggesting a gradual movement toward the frontier. Overall, productivity growth across OECD countries is driven primarily by changes in pure technical efficiency and scale efficiency, while technological change and changes in the scale of technology contribute to a lesser extent.

13:30 - 15:00 | Mars 2 | Regulation & Governance 2

Chair: Alexandre Nunes Almeida

Title: BEYOND EVALUATION SUITES FOR LLMs: ROBUST PARTIAL-FRONTIER COST-EFFECTIVENESS USING TOKEN PRICES AND USER PREFERENCES

Authors: [Mr Simone Di Leo PhD](#)

Affiliation: Sapienza Università di Roma

This research proposes a cost-effectiveness assessment for Large Language Models (LLMs). This evaluation relies on a paradigm shift: text generation and coding performance are measured based on marginal usage costs (euro per million input and output of tokens), rather than on technical benchmarks. The study combines OpenRouter cost data (January 2026) with quality scores from LLM Arena user preferences for text and code tasks (ELO scores, data release December 2025). Using 157 LLM models, I estimate an efficiency frontier with a partial robust (order-m) output-oriented approach, using $m = 127$ to limit the influence of outliers and identify super-efficient observations. The results reveal a varied landscape: models with max 500k tokens of context are distributed along the frontier; intermediate-context models (1M) show efficiency close to unity but are fewer in number; the few models with large context (2M) are close to the frontier, suggesting a future meta-frontier estimation as the number of models increases. Among the super-efficient models, US and Chinese providers stand out (e.g., Gemini/Gemma, Claude, DeepSeek, Qwen), while Europe is under-represented, with Mistral among the few players close to the frontier. Future work will integrate model latency, throughput and task code specificity (such as SVG code generation) in the frontier estimation. This framework supports the operational choices of users and companies by integrating perceived quality and cost of use.

Title: WHY TAX ADMINISTRATIONS DO NOT FULLY ENFORCE: A RATIONAL INEFFICIENCY APPROACH

Authors: [EBRAHIM REZAEI](#); Dr. Josef Jablonsky PhD

Affiliation: Prague University of Economics and Business

This paper develops a rational inefficiency framework for tax collection and tax administration. While the existing literature typically interprets inefficiency as a manifestation of institutional weakness or managerial failure, this study argues that part of observed tax collection inefficiency is an optimal and deliberate outcome

of tax administration decisions. Building on the generalized inefficiency model, we endogenize enforcement effort and administrative adjustment costs, showing that full enforcement and frontier efficiency are generally not optimal. We formally distinguish between rational inefficiency, arising from optimal trade-offs between revenue gains and enforcement costs, and wasteful inefficiency, associated with avoidable administrative and organizational failures. The proposed framework nests standard stochastic frontier models as a special case and provides a structural interpretation of persistent tax gaps. Empirically, the model allows inefficiency to depend on both cost-related and governance-related factors, enabling the identification of optimal and excessive inefficiency. The results offer a new theoretical foundation for evaluating tax administration performance and caution against policy prescriptions that implicitly assume zero inefficiency as a benchmark.

Keywords: Rational Inefficiency, Wasteful Inefficiency, Tax Administrations, Generalized Inefficiency Model

Title: POLITICS, REVEALED PREFERENCES AND LOCAL SPENDING PERFORMANCE: A BENEFIT OF THE DOUBT APPROACH

Authors: Lorenzo Catalano¹; [Prof. Giovanna D'Inverno PhD²](#); Prof. Dr. Kristof De Witte¹

Affiliation: ¹ KU Leuven; ² University of Pisa

This paper examines how municipal spending efficiency in the Flemish region of Belgium evolves in response to electoral dynamics at both the local and federal levels. Using panel data for nearly 300 municipalities over 1999-2019, we construct a composite indicator of spending performance based on a directional distance function Benefit-of-the-Doubt (BoD) model, which endogenously weights growth rates across ten major expenditure categories and allows for heterogeneous local priorities. The results show that efficiency scores are highly robust to alternative weight restrictions. Moreover, the optimal weights reveal systematic shifts in spending priorities over time, and rightward federal vote shifts are associated with adjustments in both revealed priorities and efficiency levels. Municipalities reallocate relative importance across spending domains across electoral cycles, with notable changes in the shares devoted to mobility, social care, safety, and general administration.

Keywords: Composite Indicator, Local government performance, Revealed preferences, Optimal budget shares

Title: CONSUMPTION EFFICIENCY AND POPULATION AGING: EVIDENCE FROM EXPENDITURE FRONTIERS IN BRAZIL

Authors: [Prof. Alexandre Nunes Almeida PhD¹](#); Prof. Carlos R. Azzoni PhD²; Prof. Subal C. Kumbhakar PhD³

Affiliation: ¹ Luiz de Queiroz College of Agriculture - University of Sao Paulo; ² School of Economics, Business and Accounting, University of Sao Paulo; ³ Binghamton University, State University of New York

CONSUMPTION EFFICIENCY AND POPULATION AGING: EVIDENCE FROM EXPENDITURE FRONTIERS IN BRAZIL Brazil's rapid demographic transition has substantially increased the share of elderly individuals, reshaping household composition and consumption needs. These households allocate a considerable portion of their budgets to health services and pharmaceuticals, which can affect the financial stability of the entire family. Using pooled cross-sections from the Brazilian Household Budget Surveys for 1996, 2003, 2009, and 2018, this study estimates expenditure frontiers using Stochastic Frontier Analysis separately for elderly- and non-elderly-headed households. Preliminary results show that income and household size increase food and health expenditures in both groups, but elasticities are systematically lower among elderly-headed households. In the total expenditure frontier, higher budget shares for food, housing, and health are associated with lower total expenditure for both groups, while transport and education shares increase total expenditure only among non-elderly households. Inefficiency patterns also differ: they are significantly related to age, education, labor market participation, and credit use for non-elderly households, but are weakly linked to observable characteristics for elderly-headed households. The results indicate different patterns of consumption efficiency, with important implications for welfare and public policy. Further analysis is underway to refine these findings.

Keywords: Population aging, Consumption efficiency, Stochastic frontier analysis, Household expenditure

15:30 - 17:00 | Terra | Organized session 3: Composite indicators

Chair: Giannis Karagiannis

Title: A GENERALIZED DIRECTIONAL DISTANCE BENEFIT OF THE DOUBT MODEL FOR INTERVAL INDICATOR DATA

Authors: [Prof. Nicky Rogge](#)¹; Prof. Marijn Verschelde²; Prof. Raluca Parvulescu²; Achmed-Youssef Oukassou

Affiliation: ¹ KU Leuven; ² IESEG School of Management, Univ. Lille, CNRS, UMR 9221 -LEM

This study measures and benchmarks nurses' performances in a large Belgian home care nursing organization. The multidimensional nature of the home care nurse services, with nurses performing a wide range of nursing tasks, such as general care, wound care, giving injections, placing enemas, administering infusions, etc., and the disparate working conditions of the nurses, call for a reconciliatory performance evaluation framework, for which this study advocates the conditional benefit-of-the-doubt (BoD) method. Based on the composite performance scores best practice nurses are identified so they can be emulated by peers. In addition, the impact of the disparate working conditions of the nurses on their care service performances is examined. Overall results show that older nurses perform less care services on monthly basis. As to the working conditions, results show that contractual regime and the region of activity relate strongly to nurses' care service performance.

Keywords: Home care nursing; Benefit-of-Doubt; Composite Indicators; Benchmarking; Conditional order-m.

Title: SUSTAINABLE RURAL DEVELOPMENT IN SEMIARID REGIONS: A STUDY OF THE CAATINGA BIOME IN BRAZIL

Authors: Jefferson Staduto¹; Prof. Hermilio Vilarinho PhD²; Prof. Andreia Zanella PhD³; [Prof. Ana Camanho PhD](#)⁴

Affiliation: ¹ Universidade Estadual do Oeste do Paraná; ² INEGI, Faculdade de Engenharia, Universidade do Porto; ³ Universidade Federal de Santa Catarina; ⁴ Faculdade de Engenharia, Universidade do Porto

This study aims to assess sustainable rural development in Brazil's Caatinga biome. Semi-arid regions such as the Caatinga face persistent environmental and socioeconomic pressures, making them limiting cases for sustainability analysis due to high climate vulnerability, strong resource dependence, and structural constraints. Sustainable rural development is evaluated using a composite indicator that integrates economic, social, and environmental dimensions. The indicator is constructed using a robust Benefit-of-the-Doubt approach based on Directional Distance Functions, and performance changes over time are examined using the Malmquist index, drawing upon a dataset of 1,148 municipalities from the two most recent Brazilian Agricultural Censuses. The results reveal that regions with stronger agricultural bases and local infrastructure exhibit higher performance. The Malmquist index indicates an overall improvement in rural sustainability over the period, primarily driven by gains in performance rather than by shifts in the technological frontier, which exhibits signs of stagnation or retraction across most of the region. Although performance gains are observed across diverse territorial contexts, technological progress remains spatially concentrated, underscoring the role of local governance and context-specific policies in promoting sustainability.

Title: UNVEILING COMPANY READINESS FOR INDUSTRY 4.0 USING BENEFIT-OF-THE-DOUBT MODELS

Authors: [Prof. Hermilio Vilarinho PhD](#)¹; André Guimarães²; Dr. Eduardo e Oliveira PhD¹; Prof. Teresa Pereira PhD¹

Affiliation: ¹ INEGI, Faculdade de Engenharia, Universidade do Porto; ² University of Beira Interior

Digital maturity assessments are essential for guiding industrial firms through their transformation towards Industry 4.0. This study proposes a composite indicator to evaluate digital maturity using a Benefit-of-the-Doubt (BoD) approach grounded in robust and conditional efficiency techniques. Leveraging a dataset of 490 Portuguese firms that completed a self-assessment, following the IMPULS model adapted to Portugal, we constructed firm-specific scores that account for environmental factors. The empirical results show that digital transformation remains at an early stage for most firms, especially SMEs, and that firms exhibit low maturity in Smart Infrastructure, Smart Products, and Data-Driven Services, while Human Resources emerges as the most developed dimension. This work applies Generalized Additive Models (GAMs) to explore the non-linear influence of contextual variables, such as firm size, sector, and region, on the BoD scores. We find that conditional BoD scores differ significantly from the standard BoD and the fixed-weight IMPULS adapted

index. Moreover, firm age, category, and sector exert effects on digital maturity, whereas financial productivity indicators do not. This use of GAMs provides richer insights than traditional methods, uncovering complex interactions that affect firms' digital maturity. The integration of BoD and GAMs yields a more context-sensitive assessment of digital maturity, strengthening the evidence base for Industry 4.0 decision making.

Title: A ROBUST CONDITIONAL ASSESSMENT OF PERFORMANCE TRENDS IN EDUCATION AND TRAINING SYSTEMS OF EUROPEAN REGIONS

Authors: [Fernando Osório](#)¹; Prof. Ana Camanho PhD¹; Prof. Flávia Barbosa PhD²; Prof. Giovanna D'Inverno PhD³

Affiliation: ¹ INESC TEC, Faculdade de Engenharia, Universidade do Porto; ² INESC TEC, Faculdade de Economia, Universidade do Porto; ³ University of Pisa

This paper proposes a robust conditional approach based on a range directional 'Benefit-of-the-Doubt' (BoD) model to monitor the evolution of performance from 2020 to 2023 in the education and training systems of 200 European regions, including 180 at NUTS2 level. The methodological framework first establishes an 'ideal' performance point, representing the most ambitious level between empirically observed best practices and aspirational benchmarks identified by experts or policymakers. Subsequently, we propose a decomposition of the Malmquist Productivity Index under a BoD setting that isolates temporal and contextual effects while monitoring performance trends. The results revealed that Europe is progressing at uneven speeds, with notable disparities both within and across countries. While numerous regions exhibited marked improvements driven by significant gains at the best-practice frontier, others experienced notable performance declines, primarily due to efficiency setbacks.

Keywords: Data envelopment analysis, Directional distance function, Robust Conditional modelling, Evolution of Performance

Title: AN INTERVAL SCALE BENEFIT-OF-THE-DOUBT MODEL

Authors: [Dr. Roxani Karagiannis PhD](#); Prof. Giannis Karagiannis PhD

Affiliation: University of Macedonia

The radial DEA model with a single constant input, referred to as the Benefit-of-the-Doubt (BoD) model, has several uses, including ratio analysis, in which ratios may take on positive values for some DMUs and negative values for others. Many researchers used data transformations to convert all negative values to positive values. The BoD, an input-oriented model, fails to satisfy the property of output translation invariance because it lacks a convexity constraint in its specification. Thus, any data transformation will affect the efficiency scores of the inefficient DMUs, even though their classification as efficient or inefficient remains unaffected. A promising alternative is to split the variables underlying the interval variables into an output and an input. In addition to the vector of one's capturing the single constant input in the original BoD formulation, an additional set of variables should also be treated as inputs. We apply the above framework to construct a Financial Performance Index for a sample of Greek hospitals, based on three financial ratios: gross profit margin (interval-scale data), asset turnover ratio, and owner's equity turnover ratio. We compare and contrast our findings with those obtained by translating the data at the outset using a positive value large enough to convert the interval-scale data to positive, and by normalising all the ratios using the minimum-based re-scaling formula.

Keywords: BoD, Interval scale variables, Translation-invariance

Title: A COMPOSITE PERFORMANCE INDICATOR FOR COURTS OF JUSTICE

Authors: Prof. Giannis Karagiannis PhD¹; Prof. Stavros Kourtzidis²; [Dr. Panagiotis Ravanos](#)³

Affiliation: ¹ University of Macedonia; ² University of Dundee; ³ European Commission DG JRC

The performance of courts of justice is a multidimensional phenomenon monitored by various indicators, each of which represents a different aspect of the court's ability to carry out its mandates and most frequently provides a different ranking of the courts. A comprehensive measure summarizing the different aspects of court performance is therefore needed to adequately inform policy decisions. In this paper we use the Benefit-of-the-Doubt (BoD) model to develop a composite performance indicator for courts of justice capturing court productivity, judge performance, and timeliness in case resolution by means of three well known indicators,

namely the clearance rate, the disposition time and judge productivity. We use a special form of the Benefit-of-the-Doubt (BoD) model which accounts for the reverse nature of indicators to obtain our composite performance index. We use the proposed framework to develop a composite performance indicator for a sample of Greek first-instance courts for the period 2018-2019.

Keywords: courts of justice, court performance, composite indicator, Benefit-of-the-Doubt model.

Title: EVALUATING THE EUROPEAN PILLAR OF SOCIAL RIGHTS: A BENEFIT-OF-THE-DOUBT APPROACH WITH COMMON WEIGHTS

Authors: [Prof. Dr. Laura Carosi PhD¹](#); Prof. Dr. Giovanna D’Inverno¹; Davide Zucchini

Affiliation: ¹ University of Pisa

The European Pillar of Social Rights Programme was launched in 2017 by the European Commission for a fairer and more inclusive European Union. A set of headline indicators have been set to monitor the European countries’ actions related to the three areas of the pillar: Equal opportunities and access to the labour market, Fair working conditions and Social protection and inclusion. In this paper we propose an innovative procedure to evaluate the strengthening of social rights and the improvement of working and living conditions across European countries. We construct a composite indicator with a common system of weights where both forward and reverse indicators are considered using a Benefit of the Doubt approach. In addition, a new intertemporal analysis is performed by extending the Overall Malmquist Index with a common system of weights to the composite indicator framework. In this context, we assess the 27 EU member states over the period 2015-2024 to analyse the evolution of their performance and ranking positions.

15:30 - 17:00 | Jupiter | Agriculture 3

Chair: Raushan Bokusheva

Title: MANAGEMENT CONTROL SYSTEMS AND PRODUCTIVE PERFORMANCE OF SPANISH AGRI-FOOD SMES

Authors: Beatriz García-Cornejo; José Antonio Pérez-Méndez; [Alan Wall](#)

Affiliation: University of Oviedo

Agri-food companies in Europe operate under increasingly stringent traceability and food safety requirements and face increasing institutional pressure from EU sustainability agendas. This study examines the impact of Management Control Systems (MCS) - which can be defined as formal, information-based routines and procedures used to monitor and influence organizational activities - on the productive performance of these firms. We use a novel panel data set of 202 Spanish agri-food small and medium-sized enterprises (SMEs) observed over the period 2019-2024 which combines survey data on the use of MCS with firm-level financial information from the Iberian Balance Sheet Analysis System (SABI) database, allowing managerial variables to be combined with verified accounting data. Using stochastic frontier analysis, and taking into account measures of environmental and social sustainability, we estimate the relative effects on firm performance of the following managerial variables: (i) the interactive use of MCS (i.e., dialogue-oriented and forward-looking use of control systems); (ii) a transformational leadership style (i.e., leadership that promotes change and organizational learning); (iii) measures aimed at integrating environmental objectives into strategic business planning; and (iv) the use of data analytics (systematic use of data to support managerial decision-making).

Title: BALANCING ENVIRONMENTAL, SOCIAL, AND ECONOMIC SUSTAINABILITY GOALS: TRADE-OFFS FACED BY SMALLHOLDER FARMERS IN CHINA

Authors: [Gaofei Yang](#); Maria Vrachioli; Johannes Sauer

Affiliation: Technical University of Munich (TUM)

Agriculture is receiving increased attention for transitioning toward more sustainable food and agriculture systems to achieve Sustainable Development Goals (SDGs) by 2030. As a result, there has been growing interest in how to systematically monitor and evaluate agricultural sustainability including environmental, social, and economic dimensions. However, empirical evidence on the relationships between these three dimensions remains scarce. Therefore, we construct a composite indicator of agricultural sustainability (CIAS)

grounded in a hierarchical framework at farmer level. Using nationally representative survey data from 2020 in China, we estimate dimension-level and overall composite indicators via the Benefit-of-the-Doubt (BoD) model that avoids imposing prior weight structures across heterogeneous farms. An overall CIAS reaches 0.79, driven primarily by social sustainability (0.84), followed by economic (0.83) and environmental (0.71) dimensions. Latent Class Analysis identifies two distinct profiles: economically oriented farmers (39%) and socially oriented farmers (61%), with older farmers significantly more likely to belong to the latter group. Current policy instruments such as subsidies and online training lift economic and environmental sustainability performance among the former group, but often at the cost of the social dimension, a pattern invisible in the CIAS performance analysis. In addition, economically oriented farmers require stronger social inclusion and rural services, while socially oriented farmers could benefit from improved financial access and market integration, and both groups need targeted environmental policies such as soil conservation practices, where the two classes are statistically indistinguishable. This study demonstrates that agricultural sustainability assessments systematically obscure the trade-offs that any sustainability transition must confront.

Title: SENSITIVITY OF FARM RESILIENCE TO ALTERNATIVE DROUGHT THRESHOLDS: THE CASE OF SMALLHOLDER FARMING IN MALAWI

Authors: [Carlos Böke Pascual](#)¹; Dr. Fabian Frick; Prof. Dr. Johannes Sauer

Affiliation: ¹ Technical University Munich

Studies examining the effects of droughts on farm performance often use standardized climatic indexes and arbitrary shock thresholds to separate affected from non-affected farms without testing the significance of these thresholds. Using panel data on Malawian farmers, we show that widely used thresholds differ substantially from actual breakpoints in land productivity responses to shock severity. We then use the empirically determined alternative thresholds to assess the sensitivity of farm resilience to the choice of threshold. Results of a continuous Difference-in-Difference framework, which combines binary drought separation between affected and non-affected farms, and drought severity as treatment dose, suggest that marginal effects of increased dosage are sensitive to the choice of drought threshold. Furthermore, characterizing resilient farms based on land productivity relative to both baseline performance and other farms, shows that the largest differences to non-resilient farms relate to fertilizer use and production value. However, characterization is sensitive to changes in the composition of the sample of resilient farms arising from the application of alternative thresholds. These findings imply that estimates of climatic shock impacts should rely on more careful selection of thresholds and consider spatial heterogeneity in shock severity. Policies seeking to improve farm resilience may otherwise be misinformed by an arbitrary definition of drought-affectedness.

Title: IDENTIFYING THE IMPACTS OF CLIMATE AND WEATHER ON ARABLE FARMS' PERFORMANCE

Authors: [Prof. Dr. Raushan Bokusheva PhD](#)

Affiliation: Zurich University of Applied Sciences

Agriculture is a sector that is particularly vulnerable to weather shocks and climate change, with droughts, extreme temperature events, and floods directly impacting farming outcomes. This paper investigates the effects of climate and weather on arable farm productivity. We define a model that allows production technology parameters to vary across a set of distinct climates and current-period weather in addition to conventional inputs to explain the variation in production output. We anticipate farm technical inefficiency to vary with both climate and weather shocks. If some farms systematically fail to adapt their technologies to prevailing climate in their location, they may regularly underperform compared to frontier farms in their climate. We also hypothesize that less adapted farms are more vulnerable to climatic shocks and, thus, expect technical inefficiency demonstrating higher variation for periods with adverse weather events compared to periods with relatively favorable weather conditions. To test our hypotheses, we estimate production technology parameters using a Bayesian finite-mixture model using French FADN farm data for 2004-2020 and relevant historical weather observations and use its residuals to investigate heteroskedasticity sources in persistent and transient technical efficiency components.

Keywords: latent-class production technology model, climate change impact, adaptation, technical efficiency.

Chair: Amer Ait Sidhoum

Title: ANALYSING PRODUCTIVITY AND EFFICIENCY IN THE NORWEGIAN AQUACULTURE INDUSTRY: A METAFRONTIER DEA APPROACH

Authors: [Prof. Dr. Yajie Liu PhD](#)

Affiliation: UiT The Arctic University of Norway

This study examines the efficiency and productivity of the aquaculture industry in Norway. The Norwegian aquaculture sector faces significant challenges in enhancing productivity, profitability, and sustainability while maintaining its comparative advantage. Using a metafrontier Data Envelopment Analysis (DEA) framework, we evaluate the performance of various aquaculture farm groups, taking into account technological heterogeneity across these groups. The analysis enables the assessment of relative efficiency within each group, while the metafrontier approach provides a unified benchmark across all groups. Our findings reveal variations in efficiency and productivity levels among groups, underscoring the influence of technological disparities and operational practices. The results indicate that while some farms operate close to the efficiency frontier, others exhibit potential for improvement in both efficiency and productivity. These improvements can be achieved by optimizing production scales or refining the use of specific inputs. The insights from this study contribute to the strategic development of the Norwegian aquaculture industry, fostering sustainable growth and enhancing its competitiveness in the global market.

Title: VALUING WATER QUALITY AND QUANTITY TRADE-OFFS FROM IRRIGATION: AN INTEGRATED BIO-PHYSICAL - PRODUCTIVITY APPROACH

Authors: [Prof. Tiho Ancev](#)¹; Prof. Morian Bostian²; Akash Ghokale¹; Prof. Francisco Rosas³

Affiliation: ¹ University of Sydney; ² Lewis and Clarke; ³ ORT Uruguay

Greater interannual rainfall variability is increasing reliance on supplemental irrigation in historically rain-fed agricultural regions. Irrigation development—often coupled with greater fertiliser use—can worsen water quality through nutrient loading and reduce water availability through additional withdrawals. This study evaluates ex ante the economic–environmental trade-offs associated with irrigation and fertilisation intensification in the San Salvador Basin (Uruguay) by integrating outputs from a calibrated Soil and Water Assessment Tool (SWAT) model with a productivity and efficiency framework based on directional distance functions (DDFs). Using SWAT-simulated data for multiple scenarios, we estimate inefficiency measures and shadow prices for undesirable outputs—nitrate (NO₃) and phosphorus (P) runoff—via an output-oriented DDF, and for irrigation water use via an input-oriented DDF. Average directional distances indicate scope for performance improvements that varies across scenarios and space. Estimated shadow prices indicate substantial heterogeneity in trade-offs: NO₃ shadow values range 1–3 \$/ha, while P shadow value ranges 0.034–0.109 \$/ha). The shadow value of irrigation water costs ranges from 0.072–0.113 \$ per \$, suggesting positive but uneven marginal value from irrigation water use. Spatial patterns highlight less favorable trade-offs in areas close to the river and stream channels, supporting spatially-targeted rather than uniform irrigation development.

Title: EVALUATING IRRIGATION WATER PRODUCTIVITY, SHADOW PRICES, AND PER-HECTARE WATER VALUATION IN VINEYARDS USING STOCHASTIC FRONTIER ANALYSIS

Authors: [Dr. Carlos Bopp Dr.](#)¹; Roberto Jara-Rojas; Boris Bravo-Ureta; Alejandra Engler

Affiliation: ¹ Universidad de Talca

Analyzing agricultural water use efficiency and shadow prices is key to informing policies aimed at improving sustainability under increasing water scarcity. This study examines how irrigation water use and irrigation technology affect output in Chilean wine grape farms. To address potential selection bias in irrigation choice, we apply propensity score matching and estimate Stochastic Production Frontier models using data from 371 growers. The results show that pressurized irrigation systems achieve higher output across all levels of water use, with stronger effects at lower application levels. Estimated shadow prices are 0.026 USD/m³ for pressurized irrigation and 0.033 USD/m³ for gravity systems, and vary substantially with water use intensity. Average technical efficiency is 70.4%, with no significant differences between irrigation methods. A post-estimation analysis combines irrigation volumes and shadow prices to derive implied per-hectare water costs, which are approximately 4.4 times higher under gravity irrigation than under pressurized systems. Overall, our findings suggest that substantial water savings can be achieved without reducing output, offering valuable implications

for agricultural sustainability while also contributing to policy debates on agricultural water management and volumetric pricing.

Title: LINKING SUSTAINABILITY EFFICIENCY TO FARMERS' WILLINGNESS TO ADOPT IMPROVED WASTEWATER MANAGEMENT: EVIDENCE FROM COLOMBIAN COFFEE FARMS

Authors: [Dr. Maria Vrachioli¹](#); [Dr. Amer Ait Sidhoum PhD²](#)

Affiliation: ¹ Technical University of Munich (TUM); ² Natural Resources Institute Finland (Luke)

A recurring concern in empirical efficiency research is that uptake of innovative practices is seldom random: producers who are already better managed or less constrained may be more likely to engage, so “adoption effects” can be confounded by endogenous self-selection. We address this issue by linking frontier-based efficiency measurement to stated willingness to adopt improved practices. Using a 2024 survey of 84 Colombian coffee farms, we estimate technical, social, and environmental efficiency in a linked (by-production) DEA framework. Desirable outputs include market output and a composite social output index, while the undesirable output captures emissions associated with mineral nitrogen use. The efficiency results indicate that farms perform comparatively better on the social and environmental dimensions than on technical performance, suggesting scope to raise productive efficiency without necessarily worsening sustainability outcomes. We then use a discrete choice experiment to elicit farmers’ willingness to adopt improved on-farm wastewater management options that differ in private and environmental attributes. Interacting choice parameters with DEA-based efficiency measures shows limited evidence that baseline efficiency systematically shapes willingness to adopt or the associated attribute trade-offs. Overall, the findings suggest that demand for improved wastewater solutions is broad-based rather than concentrated among farms that are already more efficient.

15:30 - 17:00 | Mars 1 | Productivity 1

Chair: Hideyuki Mizobuchi

Title: INTANGIBLES IN TANGIBLE PRODUCTIVITY DISCREPANCIES

Authors: [Charles-Henri DiMaria](#)

INTANGIBLES IN TANGIBLE PRODUCTIVITY DISCREPANCIES Charles-Henri DiMaria In the early 2020s, the OECD highlighted two key insights: intangible investment in the United States proved more resilient and recovered faster after the global financial crisis than in European countries, and intangible assets have become an increasingly important driver of productivity growth across OECD economies. This presentation explores a central question: do countries that, on average, invest more in intangibles than the U.S. achieve higher productivity growth? After a critical review of intangible investment data from EUKLEMS (LUISS consortium) indicating some unavoidable shortcomings, our findings suggest a positive relationship. However, not all intangible assets contribute equally. We show that organizational capital emerges as the primary driver of productivity performance, while other intangible categories exhibit no significant impact on growth.

Keywords: Intangible, GDP per capita growth, organizational capital.

Title: STATISTICAL INFERENCE FOR CONSUMER PRICE INDICES

Authors: [Prof. Valentin Zelenyuk PhD¹](#); [Prof. Shirong Zhao²](#)

Affiliation: ¹ University of Queensland; ² Dongbei University of Finance and Economics,

This paper develops asymptotic results for commonly used price indices within the economic approach to index number theory. We establish central limit theorems for the Lloyd-Moulton index—the exact cost-of-living index under CES preferences—as well as for widely used indices such as Laspeyres, Paasche, Fisher, Tornqvist and Sato-Vartia indices. These results enable the construction of asymptotic confidence intervals for each index. Using Monte Carlo simulations, we evaluate the finite-sample performance of these intervals and examine how well the traditional indices approximate the true cost-of-living index. This work contributes to the price index literature by further bridging the economic and stochastic approaches and providing statistical tools for evaluating the precision of inflation measures used in policy and practice.

Title: MAKING INFERENCES ABOUT DIFFERENCES IN PRODUCTIVITY ACROSS GROUPS IN NON-

PARAMETRIC, CROSS-SECTIONAL SETTINGS**Authors:** [Prof. Paul Wilson](#)**Affiliation:** Clemson University

In non-parametric, dynamic settings, Malmquist productivity indices are often used to assess changes in productivity across time when firms are observed in two or more periods. In non-parametric, cross-sectional settings, where each firm is observed only once, one can compare mean efficiencies of different groups of producers, but until now there have been no results enabling researchers to estimate and make inferences about differences in productivity across different groups of firms except in trivial cases with only one input and one

output. This paper develops a Malmquist-type index to to assess differences in average productivity between groups of firms. Theoretical, asymptotic statistical results are developed in order to enable statistical inferences about differences in mean productivity across groups of producers. Results are given for cases (i) where the production sets are convex for both groups, and (ii) where the production set for one or both groups is non-convex. Simulation results indicate that the methods developed in the paper work well in finite samples.

Title: SATO-VARTIA PRODUCTIVITY INDEX**Authors:** [Dr. Hideyuki Mizobuchi PhD¹](#); [Dr. Valentin Zelenyuk²](#)**Affiliation:** ¹ Doshisha University; ² The University of Queensland

Sato–Vartia price and quantity indices are widely used in empirical applications because of their desirable theoretical properties and empirical tractability. However, to the best of our knowledge, they have not been applied to productivity measurement, and no formal theoretical justification for such an application has been established.

In this paper, we propose a productivity index constructed from the Sato–Vartia quantity index. We demonstrate that, under a homothetic multi-output CES production function, the proposed index coincides exactly with the rate of Hicks-neutral technological change. This result provides a clear production-theoretic interpretation of the index and establishes its theoretical consistency within a well-defined structural framework.

To evaluate its empirical relevance, we apply the proposed index to the U.S. industry production account and compare it with several widely used productivity measures, including the Laspeyres, Paasche, Fisher, and Törnqvist indices. The empirical results indicate that the Sato–Vartia-based productivity index produces estimates broadly comparable to those obtained from these established measures.

The comparison further clarifies the conditions under which the Sato–Vartia productivity index yields results similar to, or distinct from other standard indices, thereby shedding light on its practical usefulness for applied productivity analysis.

15:30 - 17:00 | Mars 2 | Energy 3**Chair:** Anatoliy Goncharuk**Title: IS SPAIN'S ENERGY VOUCHER LIGHTING THE WAY FOR THE POOR? A MICROECONOMIC EVALUATION OF THE BONO SOCIAL ELÉCTRICO****Authors:** [Prof. Dr. Ana Rodriguez-Alvarez PhD¹](#); [Dr. Manuel Llorca PhD²](#)**Affiliation:** ¹ Oviedo University; ² Copenhagen School of Energy Infrastructure (CSEI)

This paper analyses the effectiveness of the Bono Social Eléctrico, a Spanish social electricity voucher aimed at alleviating energy poverty among vulnerable households. Departing from a microeconomic theoretical framework and applying a Stochastic Frontier Analysis (SFA) approach, the study evaluates the gap between observed and potential energy poverty levels. The empirical analysis employs Spanish household panel data, capturing key household characteristics and subsidy information. The findings indicate that, while the BSE contributes to reducing energy poverty, its effectiveness is constrained by insufficient coverage and lack of impact on the poorest households. Education and computer access play an important role in addressing energy poverty. The study suggests policy recommendations to enhance the voucher's targeting

mechanisms and explores strategies for more effective interventions to tackle energy poverty.

Title: CARBON MITIGATION COST WITH MARKET DISTORTIONS: EVIDENCE FROM POWER PLANTS IN CHINA

Authors: [Prof. Chunbo Ma PhD](#)

Affiliation: The University of Western Australia

Conventional approaches to the estimation of pollutants' mitigation costs typically assume that firms minimize production costs in response to market prices. However, the prevalence of environmental regulations could cause firms to depart from their optimal input-output mixes, leading to additional costs. In this paper, we develop an extended generalized cost function to estimate the effect of environmental regulations on firms' production costs. We then apply this approach to a dataset of China's large power plants from 2005 to 2015. The results indicate that a 1% regulatory-related decrease in CO₂ emissions increases production costs by 1.57%. Carbon regulations triggered substantial substitution of capital for labor and energy. The estimated regulatory demand elasticities of carbon mitigation for capital, labor, and energy are -0.79, 0.19, and 0.28, respectively. Because of regulatory distortion, the average adjusted marginal abatement cost for CO₂ is 359.06 CNY/ton, significantly higher than costs estimated by conventional frontier-based approaches using the same data. A back-of-the-envelope calculation indicates that despite the high mitigation costs, China's carbon regulation efforts for the power sector remain cost-effective.

Keywords: regulatory cost distortions; marginal abatement costs; generalized cost function; China S-

Title: BALANCING OUTPUT GROWTH AND ENERGY EFFICIENCY GOALS IN INDIAN MANUFACTURING: SOME ALTERNATIVE SCENARIOS

Authors: [Dr. Kankana Mukherjee PhD](#)

Affiliation: Babson College

In 2014, the 'Make in India' initiative was launched by the Government of India which aimed at increasing the share of manufacturing in the Indian economy to help propel economic growth and create millions of jobs. These goals were further extended in the National Manufacturing Mission (2025-26) introduced in the Union Budget. But an increasing manufacturing production places very large demand on energy and poses a challenge since India is striving to achieve energy efficiency in all sectors of the economy. As most industries in India still use traditional sources of energy, they are big contributors to overall greenhouse gas emissions. The goals of increasing manufacturing production and employment while at the same time reducing energy use conflict with each other. This study investigates these tradeoffs by examining data from the Annual Survey of Industries, Government of India for the manufacturing sector across the states in India over the period 2013-14 to 2023-24. Utilizing Data Envelopment Analysis and distance functions, several alternative models are considered for reconciling the conflicting goals in Indian manufacturing. Results show that significant potential for simultaneous increase in output and reduction in energy use exists in several states. The results from the empirical analysis should be helpful in providing policy directions for the government as well as strategic insights for firms across the states in India.

Title: INTEGRATING EXERGY INTO DEA: A THERMODYNAMICALLY CONSTRAINED EFFICIENCY BENCHMARK

Authors: [Prof. Anatoliy Goncharuk Dr.¹](#); [Dr. Biresh Sahoo PhD²](#)

Affiliation: ¹ NLA University College; ² XIM University

This study integrates exergy analysis into data envelopment analysis (DEA) to build a thermodynamically constrained efficiency frontier. Conventional DEA measures technical efficiency without considering energy quality or the second law of thermodynamics. We propose two models (a directional distance function (DDF) model and a slack-based measure (SBM) model) that incorporate fuel exergy as an input and explicitly account for exergy destruction. The models yield dual performance scores: conventional technical efficiency and new exergy-efficiency measures. In an empirical application to 71 Indian coal-fired power plants (using inputs like fuel and exergy content, outputs, and CO₂ emissions), we found a consistent gap between conventional and exergy-based efficiency scores: average exergy efficiency is substantially lower than technical efficiency, revealing hidden thermodynamic losses. Moreover, we identify a technical–thermodynamic performance paradox: some plants that are technically efficient are exergy-inefficient, and vice versa, and plant size

influences these efficiency constraints. By embedding the second law into the frontier, our approach establishes a more physically grounded benchmark for energy and environmental performance, with implications for designing sustainable efficiency standards and energy policies.

Thursday, June 18, 2026

09:00 - 10:00 | Terra & Jupiter | Plenary 3

Chair: Johannes Sauer

Title: THE COST OF CAPITAL IN REGULATED NETWORKS: HAVE WE MADE ANY PROGRESS?

Authors: [Prof. Dr. Christoph Kaserer](#)

Affiliation: Technical University of Munich (TUM)

Since the introduction of grid regulation, the question of how to determine an appropriate cost-of-capital allowance has been highly contested. This talk begins by providing an overview of the regulatory framework governing German electricity networks and by explaining why the regulated return on equity (RoE) falls short of market-implied returns by approximately 250 basis points, according to our own estimates. Notably, this estimate is derived from an agnostic perspective regarding the appropriate cost-of-equity model. In the second part, we take a more fundamental perspective and discuss why assessing the cost of capital remains inherently challenging. Despite extensive debate in both academia and practice over the past two decades, several core issues remain unresolved. In light of the unprecedented level of investment required in electricity networks over the coming decades, regulators should carefully consider these challenges, as they may significantly affect the sector's ability to attract sufficient private capital to finance the necessary capital expenditures.

10:30 - 12:00 | Terra | DEA Methods 3

Chair: Cinzia Daraio

Title: ENDOGENEITY IN NONPARAMETRIC PANEL DATA ESTIMATION: APPLICATION TO CONDITIONAL PRODUCTION FRONTIERS

Authors: [Prof. Dr. Camilla Mastromarco PhD¹](#); Prof. Dr. Léopold Simar²; Prof. Dr. Anne Vanhems Anne Vanhems³

Affiliation: ¹ UNIVERSITY OF CALABRIA; ² UCLouvain, Louvain-la-Neuve, Belgium.; ³ TBS Business School, Toulouse, France

This paper develops a nonparametric panel data framework for production frontier estimation in the presence of endogenous environmental variables. In frontier models, endogeneity does not only bias

conditional mean relationships but may distort identification of the production boundary itself through violations of boundary independence. We address this problem by proposing a fully nonparametric control-function approach that restores identification of the conditional frontier under endogeneity. Exploiting the time structure of panel data, we show that lagged outcomes and controls can be used to construct internal instruments within a nonseparable framework. This allows inputs and output to be “purged” of endogenous external factors prior to frontier estimation. The resulting transformed variables define a production technology that is orthogonal to endogenous controls, ensuring consistent estimation of both full

and robust order-m (quantile) frontiers. We establish consistency and asymptotic normality of the proposed estimators. An empirical application to Italian listed firms (2014–2023) shows that sustainability shifts the frontier outward across the firm size distribution, while digital finance has heterogeneous effects, reducing the frontier for smaller firms but increasing it for larger ones. These findings highlight the importance of accounting for endogeneity in productivity analysis.

Title: SINGLE INDEX MODELS FOR NONPARAMETRIC CONDITIONAL FRONTIERS**Authors:** Prof. Catherine Cazals¹; Prof. Jean-Pierre Florens¹; [Prof. Léopold Simar PhD²](#)**Affiliation:** ¹ Toulouse School of Economics,; ² Université catholique de Louvain

In production theory, a lot of attention has been paid in the literature to the analysis of the effect of environmental variables on the efficiency of firms. The usual and natural way to investigate this issue is to consider conditional frontier models. For nonparametric approaches, this can create serious problems if the number of these potential environmental factors increases, exacerbating the curse of dimensionality characteristic of nonparametric models. In this paper, to address this issue, we investigate whether Single Index Models (SIM) could be used for modeling the effect of these variables on the production process. We propose a test for the SIM hypothesis and analyse the asymptotic properties.

If the SIM model is not rejected, we obtain better rates of convergence of the conditional efficiency estimates. The paper investigates, through some Monte-Carlo experiments, the finite sample properties of the proposed test and the properties of the resulting estimates of the SIM when it is not rejected. We illustrate the method with a real data set from the French national postal operator in charge of universal service.

Title: GUIDING INTO THE NEW SPACE ERA: AN EFFICIENCY EVALUATION OF ITALIAN SPACE FIRMS**Authors:** [Prof. Pierluigi Toma PhD¹](#); DR. Anna Rita Dipierro²**Affiliation:** ¹ University of Salento; ² LUM university

As a promising environment, the Italian space industry is drawing increasing attention from the government. This study evaluates the efficiency of Italian firms operating in the sector over the 2014–2023 period. After outlining the historical, and technical evolution that brought the space economy into its new era and reviewing the main literature, we identified a gap in firm-level efficiency assessments in this field. To address it, we apply a bootstrap-Data Envelopment Analysis (DEA) approach, an effective nonparametric method for evaluating the relative efficiency of the decision-making units. Findings suggest an increasing trend in the efficiency distribution of firms over time, by however leaving a room for improvement. In addition, we explore the relationship between efficiency and corporate governance dimensions among the sampled firms, uncovering notable patterns within the industry. Being the very first efficiency analysis of the sector, the work opens up for further applications and produce results of interest for researchers, practitioners and decision-makers.

Title: COMBINING MULTICRITERIA METHODS WITH EFFICIENCY ANALYSIS: A CONICAL FDH DIRECTIONAL LUENBERGER APPROACH INCLUDING TIME-VARYING PREFERENCES**Authors:** [Prof. Dr. Cinzia Daraio PhD¹](#); Prof. Dr. Thyago C. C. Nepomuceno PhD²; Prof. Dr. Leopold Simar PhD³**Affiliation:** ¹ Sapienza University of Rome; ² Federal University of Pernambuco; ³ UCLouvain, Louvain-la-Neuve, Belgium.

This paper develops a multidimensional directional approach to measure strategic paradigm shifts in efficiency and productivity analysis under time-varying preferences. We integrate conical Free Disposal Hull (FDH) estimators of directional distance functions with a Luenberger productivity indicator defined for general nonconvex technologies. Managerial priorities and policy goals are allowed to evolve over time and are embedded directly in the specification of the directional vectors. Within this setting, we propose a Luenberger-type Strategic Paradigm Shift index that decomposes performance change into two components. The first, Directional Efficiency Change, captures operational adaptation evaluated under period-specific preferences. The second, Preference Change, isolates the pure effect of shifting priorities while holding production possibilities fixed. The conical FDH structure accommodates general returns to scale and heterogeneous production environments without imposing convexity. The resulting Luenberger-based measure is additive, fully directional, and consistent with evolving evaluation criteria. By disentangling operational improvements from changes induced by redefined strategic objectives, the proposed approach provides a more accurate assessment of performance in policy-driven and mission-oriented organizations operating in dynamic environments. An empirical illustration shows the usefulness of the approach.

Chair: Erik Enstad

Title: PERSPECTIVES FOR BRAZILIAN SOCIOBIODIVERSITY PRODUCTION: A REGIONAL ANALYSIS FOR THE PERIOD 2008-2025

Authors: [Luísa Fancelli Coelho](#); Prof. Humberto Francisco Silva Spolador PhD

Affiliation: "Luiz de Queiroz" College of Agriculture - University of São Paulo

The OECD bioeconomy agenda aims to expand biotechnology-based initiatives by 2030, integrating biological knowledge, renewable biomass, and cross-sector applications. In this context, the bioeconomy framework creates opportunities for regional socioeconomic development in biodiversity-rich countries such as Brazil. Accordingly, Brazil has developed public policies to foster bioeconomy supply chains, including the Brazilian National Program for Sociobiodiversity, implemented in 2009 to preserve traditional knowledge and forest and biodiversity conservation. However, empirical evidence on productive performance is limited. To fill this gap, this study estimates technical efficiency in a stochastic production frontier model applied to municipal-level data (2008-2025), covering 18 sociobiodiversity products and incorporating climatic control variables. Average technical efficiency is 54%, varying across products, indicating structural constraints beyond policy mechanisms. Oil palms such as macaúba and babaçu show the highest technical efficiencies while baru has the lowest technical efficiency among the products. Maximum temperature is the only climatic variable with a statistically significant negative effect on production. These results support the design of targeted public policies to improve efficiency and producer well-being, thus promoting sustainable use of sociobiodiversity resources in Brazil.

Keywords: Forest-based products, SFA, Technical efficiency, Sustainability.

Title: ECONOMIC AND ENVIRONMENTAL EFFICIENCY IN EUROPE: A BY-PRODUCTION DEA ACROSS INDUSTRY SECTORS.

Authors: [Rodrigo Cestau PhD \(c\)](#); Pablo Arocena

Affiliation: Universidad Pública de Navarra

The objective of this paper is to estimate and compare economic and environmental performance across European industry sectors at the country level, using a sector–country panel.

We implement an extension of the by-production technology proposed by Zhou et al. (2025), which links the economic and emissions sub-technologies through common energy use and generates economic and environmental performance measures. The production function relates capital, labour, and energy as inputs to produce value added as the desirable output and greenhouse gas emissions as the undesirable output. We then apply the Simar and Wilson (2007) double-bootstrap truncated regression procedure to relate the estimated scores to ISO 14001 intensity and a set of contextual covariates.

Preliminary results point to a systematic gap between the two performance dimensions. The distance to the frontier is modest for the economic component, while the environmental component accounts for most of the overall shortfall. In the second step, ISO 14001 is more strongly associated with an improvement in environmental performance.

The gap between economic and environmental efficiency indicates that most sector units fall short primarily in emissions performance rather than in value creation. This shifts the policy focus from broad competitiveness agendas to measures that directly affect emissions, such as cleaner energy inputs, fuel switching or upgrades in production processes.

Title: PROBABILISTIC EFFICIENCY ANALYSIS USING INTERPRETABLE ARTIFICIAL INTELLIGENCE: ASSESSING THE ROLE OF ENVIRONMENTAL VARIABLES

Authors: [Ricardo González-Moyano](#)¹; Dr. Juan Aparicio Baeza¹; Dr. José Luis Zofio Prieto²

Affiliation: ¹ Miguel Hernández University of Elche; ² Autonomous University of Madrid

This study proposes a machine-learning approach to assess the technical efficiency of decision-making units operating under heterogeneous external conditions. The objective is to model the full space of characteristics within a probabilistic framework that explicitly incorporates uncertainty, generalize the efficiency frontier to reduce sample-related overfitting, and provide technological insights, including variable importance and

counterfactual explanations that guide inefficient units toward efficiency. We introduce a two-stage framework that incorporates contextual variables (Z) directly into the efficiency assessment. In the first stage, efficiency-based labels are obtained by applying Conditional Data Envelopment Analysis, classifying units as efficient or inefficient. In the second stage, supervised classification models—such as neural networks—are trained using inputs, outputs, and contextual variables (including categorical and continuous factors) to learn patterns associated with efficiency. Using the PISA 2022 dataset, results suggest that controlling for environmental variables affects efficiency levels and unit rankings, indicating that part of the observed inefficiency may be driven by environmental constraints rather than managerial performance.

Title: MINING, MILLS, AND EMISSIONS: DECOMPOSING EMISSION-REDUCTION PATHWAYS IN GLOBAL STEEL SUPPLY CHAINS

Authors: [Erik Enstad](#); Assistant Professor Giacomo Benini; Associate Professor Lars Jaffke

Affiliation: NHH Norwegian School of Economics

Decarbonizing steel production requires coordinated action across mining and steelmaking, yet marginal abatement costs for plant-level process improvements (Scope 1) versus upstream supplier switching (Scope 3) remain unmeasured. Steel mills, treated as DMUs, face two strategies: reducing emissions through improvements in environmental and technical efficiency, or sourcing iron ore and metallurgical coal from cleaner mines. This paper develops a mill-scoped two-stage network stochastic directional distance function to evaluate the cost-effectiveness of both pathways despite unobserved supplier–mill linkages. We estimate environmental and technical efficiency frontiers and CO₂ shadow prices for 93 iron ore mines, 151 metallurgical coal mines, and 143 steel mills using a five-year global panel. For each mill, feasible supplier networks are constructed subject to material balance, steelmaking route compatibility, geographic proximity, and transport costs. Supplier emissions are propagated through these networks to obtain mill-specific supply-chain footprints under alternative configurations. For each mill, we derive (i) marginal abatement costs from efficiency improvements (Scope 1) and (ii) emission reductions achievable through switching to cleaner suppliers (Scope 3). Sensitivity analysis identifies when mills should prioritize efficiency gains versus supplier switching under alternative carbon prices, informing decarbonization strategy and carbon border adjustment design.

10:30 - 12:00 | Mars 1 | Productivity 2

Chair: Giannis Karagiannis

Title: NONLINEAR PANEL DATA MODELS WITH ROBUST CORRELATED RANDOM EFFECTS WITH APPLICATION TO THE PUBLIC CAPITAL PRODUCTIVITY PUZZLE

Authors: [Prof. Dr. Daniel Henderson](#)¹; Emma Kate Henry¹; Prof. Dr. Andros Kourtellos²

Affiliation: ¹ The University of Alabama; ² University of Cyprus

While linear panel data models with correlated random effects maintain consistency even under misspecification of the individual effect, this robustness property fails in nonlinear settings. We address this limitation by replacing the traditional parametric specification of individual effects with a nonparametric function, preserving consistency of the structural parameters when the relationship between individual effects and covariates is unknown. We employ a profile least squares style approach, obtaining the finite-dimensional parameters through optimization of the profiled objective function. The estimator achieves parametric rates of convergence for the structural parameters while accommodating nonparametric estimation of the nuisance function. Simulations confirm the theoretical results, showing consistency while existing methods are biased and inconsistent when the individual effect specification is misspecified. We illustrate the practical relevance of our approach via a study of the public capital productivity puzzle whereby we show proper modeling of the production function and individual effects leads to positive and significant returns to public capital.

Title: AN INDUSTRY-LEVEL MEASURE OF QUALITY-ADJUSTED HUMAN CAPITAL IN THE EUROPEAN UNION

Authors: [Dr. Juan Duran](#)¹; Michelle Alicia Jordan²; Dr. Iulia Siedschlag¹

Affiliation: ¹ Economic and Social Research Institute (ESRI) / Trinity College Dublin; ² School of Research, Sciences Po

This paper examines the role of human capital in driving labour productivity growth across industries in the EU and the UK from 2010 to 2021. Building on Égert et al. (2022), we introduce a novel quality-adjusted human capital (QAHC) measure that combines both the quantity and quality of education, incorporating data from OECD's Programme for International Student Assessment (PISA) and Programme for the International Assessment of Adult Competencies (PIAAC) on test scores and mean years of schooling, alongside employment composition from the EU KLEMS & INTANProd database. We show that this measure yields reasonable output elasticities in a Stochastic Frontier model and that it has statistically significant link to labour productivity growth, particularly in goods-producing industries, unlike traditional proxies such as education attainment shares.

Title: THE WORKLOAD–PERFORMANCE RELATIONSHIP WHEN OVERSEEING ALGORITHMIC SYSTEMS

Authors: Dr. Changyu Men¹; Prof. Maud Van den Broeke²; [Prof. Marijn Verschelde](#)²; Dr. ir. Bart Roets³

Affiliation: ¹ University of Nottingham Ningbo China; ² IESEG School of Management; ³ Infrabel

Advances in technology are shifting decision-making tasks from humans to algorithmic systems, potentially reshaping the established workload–performance relationship. While prior research examines workload effects when individuals actively execute tasks, little is known about how workload affects performance when humans supervise algorithmic systems. We therefore study how workload should be conceptualized and how it influences performance in supervisory algorithm-driven environments, and whether this relationship varies across individuals with different overriding automation tendencies (OAT).

Using a purposefully constructed event-level dataset from railway digitized control rooms, where controllers oversee algorithm-based decisions, we find a monotonic negative relationship between workload intensity and operational performance. This contrasts with prior evidence from traditional task settings, where the relationship may follow an inverted U-shape. Moreover, the negative effect is weaker for controllers with higher OAT. We show that both the overall effect and its heterogeneity are mediated by changes in the likelihood of overriding algorithmic decisions. These findings provide implications for workload-aware task allocation in algorithm-supervisory settings.

Title: ANALYZING LABOR PRODUCTIVITY CHANGES IN THE GERMAN BREWING INDUSTRY

Authors: [Prof. Giannis Karagiannis PhD](#)¹; Dr. Magnus Kellerman²; Prof. Klaus Salhofer³

Affiliation: ¹ University of Macedonia; ² Bavarian State Research Centre for Agriculture; ³ Boku University

The sources of productivity changes can be analyzed in two directions: first, explanation of productivity changes at an aggregate level (i.e., industry, sector) by means of productivity changes at a lower level (i.e., firms) and what has been called reallocation effect (i.e., expansion, contraction, entry and exit of firms) and second, the decomposition of productivity changes into factors such as technical change, change in technical efficiency, scale effect, etc. The aim of this paper is to combine them into an integrated framework for providing a more insightful analysis of productivity changes. For the purposes of the present paper, we use the Griliches-Regev decomposition at the aggregate level, the Tornqvist productivity index at the firm level and a stochastic frontier model. Our empirical results concern the sources of labor productivity in a sample of 118 German breweries during the period 1996-2008 and indicate that the within effects, in particular technical change and the scale effect, clearly dominated the effects from industry restructuring.

Keywords: decomposition of aggregate productivity; drivers of productivity; labor productivity; German brewing industry

13:30 - 15:00 | Terra & Jupiter | Special plenary in honot of Knox Lovell

Chair: Robin E. Sickles

Title: ON THE ORIGINS OF AIGNER, LOVELL AND SCHMIDT, 1977 AND THE DEVELOPMENT OF STOCHASTIC FRONTIER ANALYSIS

Authors: [Peter Schmidt](#)

Title: A PRESENTATION OF KNOX LOVELL'S LAST PUBLICATION: MEASURING CLIMATE RISKS: A NEW MULTIDIMENSIONAL INDEX FOR GLOBAL VULNERABILITY AND RESILIENCE

Authors: [Valentin Zelenyuk](#)

Title: LATENT CLASS MODELS WITH PERSISTENCE IN REGIME CHANGES: A DISTRIBUTED LAG ANALYSIS

Authors: [Luis Orea Sanchez](#)

15:30 - 17:00 | Terra | Sustainability/Eco-efficiency 3

Chair: Moriah Bostian

Title: MEASUREMENT, DECOMPOSITION AND DETERMINANTS OF GREENHOUSE GAS EMISSION EFFICIENCY: AN APPLICATION TO AUSTRIAN DAIRY FARMS

Authors: [Dr. Andreas Eder](#)

Affiliation: BOKU University

I propose a measure of eco-efficiency with respect to greenhouse gas (GHG) emissions that is multiplicatively decomposed into a value-added generating efficiency (i.e., how efficient primary inputs are transformed into value added) and a GHG emission-generating efficiency (i.e., how efficient emission-generating inputs are transformed into GHG emissions). Both efficiencies are derived from a by-production approach that models the overall technology as an intersection of the value added-generating and the GHG emission-generating technology. The proposed eco-efficiency measure is compared to the frontier eco-efficiency measure (Kuosmanen & Kortelainen, 2005) commonly applied in the prevailing literature. Our approach is illustrated by an application to assessing the GHG emission efficiency of Austrian dairy farms. In a second-stage regression analysis I investigate the factors explaining differences in GHG emission efficiencies and its two components across farms.

Keywords: Environmental performance, Frontier-based eco-efficiency model, By-production technology, Data Envelopment Analysis

Title: FARM-LEVEL ENVIRONMENTALLY SUSTAINABLE PRODUCTIVITY AND PRECISION AGRICULTURE

Authors: Dr. Maria Vrachioli¹; [Dejana Golic](#)²; Tassos Haniotis PhD²; Tamas Krisztin PhD²

Affiliation: ¹ Technical University of Munich (TUM); ² International Institute for Applied Systems Analysis (IIASA)

Sustainable productivity growth is essential for aligning agricultural competitiveness with climate and environmental objectives. This paper measures environmentally adjusted productivity at farm level, focusing on whether precision agriculture enables simultaneous yield gains and greenhouse gas mitigation. We use a unique panel dataset from a Greek rice farm, located in Chalastra nearby Thessaloniki, consisting of 11 plots observed over period 2016–2023 with detailed information on input use, detailed tractor analytics, NDVI, soil characteristics, weather, rice yields, and fertilizer-induced N₂O emissions. We model production as a joint process generating a desirable output (rice) and an undesirable output (N₂O), and estimate environmentally adjusted total factor productivity using a directional distance function framework. Precision intensity is captured through spatial and temporal nitrogen management and NDVI-guided practices, while weather variability is explicitly incorporated. Results indicate that precision nitrogen management improves nitrogen use efficiency, increases environmentally adjusted productivity, and reduces emissions intensity, particularly under high-temperature conditions. The paper's main contribution lies in integrating undesirable outputs into farm-level productivity measurement using high-resolution precision data, providing policy-relevant evidence for climate-smart agricultural support.

Title: VALUING POLLUTION-GENERATING COMMODITIES: A SHADOW PRICING APPROACH.

Authors: Dr. Arnaud ABAD¹; [Prof. Walter BRIEC](#) PhD²; Dr. Paola RAVELOJAONA

Affiliation: ¹ INRAE NANCY; ² University of Perpignan

This paper develops a theoretical production model that provides a dual characterization of pollution-generating technologies. In particular, it derives dual representations of both the widely applied VRS-based Shephard weak disposable (WD) production model (Färe et al., 1989) and the by-production model (Murty et al., 2012). To the best of our knowledge, this paper is the first to establish a dual representation of the by-production model, based on a new duality result linking the directional distance function and a pseudo-profit function that incorporates environmental considerations. In doing so, the paper offers a theoretical foundation for valuing pollution-generating commodities using a shadow-pricing approach.

Title: SHADOW PRICING ECOSYSTEM SERVICES IN BOREAL FORESTS

Authors: [Prof. Moriah Bostian](#)¹; Shuyi Wang²; Prof. Tommy Lundgren²

Affiliation: ¹ Lewis & Clark College; ² Swedish University of Agricultural Sciences (SLU)

Boreal forests are multifunctional landscapes that simultaneously supply market goods, such as timber and bioenergy, and crucial non-market ecosystem services, including biodiversity and carbon sequestration. Managing these outputs inevitably involves trade-offs. To quantify them, we estimate shadow prices using a multiple-output directional distance function (DDF) that accounts for both desirable and undesirable outputs. We extend the standard model by endogenizing the directional vector and correcting for sampling variation via bootstrap methods. Applying this framework to a county-by-year panel of Swedish forests (2008–2014), we find that shadow prices vary across space and time but remain generally low. This suggests that enhancing biodiversity and carbon sequestration could be achieved with limited opportunity costs for timber production. Further, we explore substitution patterns through Morishima elasticities, offering guidance on least-cost strategies for improving environmental outcomes. Our results reveal underexploited potential for conservation policy to capitalize on the relatively low costs of ecosystem service provision in boreal forest systems.

15:30 - 17:00 | Venus 1 | Agriculture 4

Chair: Dr. Salomé KAHINDO PhD

Title: ADOPTION OF CROP–LIVESTOCK INTEGRATION AND TECHNICAL EFFICIENCY IN SOYBEAN FARMING: EVIDENCE FROM SÃO PAULO, BRAZIL

Authors: [Larissa Aparecida Lopes de Souza](#)¹; Prof. Dr. Marcelo José Carrer¹; Dr. Marcela de Mello Brandão Vinholis²; Prof. Dr. Adauto Brasilino Rocha Jr.³; Larissa Gui Pagliuca¹; Rodrigo Damasceno¹

Affiliation: ¹ Federal University of São Carlos (UFSCar); ² Brazilian Agricultural Research Corporation (EMBRAPA); ³ University of California, Santa Cruz

The transition toward more efficient resource-use production systems is essential for the sustainability of Brazilian agriculture. Crop–Livestock Integration (CLI) system can meet this goal. This article evaluated the adoption and impacts of CLI systems on Technical Efficiency (TE) and Technology Gaps of soybean farms. It was employed a selectivity correction model for stochastic production frontiers (SPFs) combined with a meta-frontier production function. SPF variables include soybean output in ton; inputs as land, capital in machinery, labor, fertilizers and pesticides; precipitation and irrigation. Interviews with 152 farmers in São Paulo, Brazil, provided cross-sectional microdata from the 2023/24 season. A probit model showed that farmers' schooling, associativism, and location in Presidente Prudente positively affect CLI adoption, while farmers' experience has a negative effect. Estimates of SPFs and meta-frontier revealed significant differences in managerial and technology gaps. The average of TE scores of adopters (0.74) was higher than that of non-adopters (0.66). Although adopters achieved higher global efficiency, they were farther to the meta-frontier. The findings suggest that CLI system adoption can be relevant for a more efficient use of resources, due to the synergistic effects of soybean–pasture rotation, but it did not result in an increase in potential production level. Findings can support policies promoting efficient and sustainable agriculture.

Title: AGRICULTURAL PRODUCTIVITY AND CARBON DIOXIDE EMISSIONS IN BRAZIL: EVIDENCE FOR THE BORLAUG HYPOTHESIS

Authors: Ricardo Muniz Simões; [Prof. Humberto Francisco Silva Spolador](#) PhD

Affiliation: "Luiz de Queiroz" College of Agriculture - University of São Paulo

AGRICULTURAL PRODUCTIVITY AND CARBON DIOXIDE EMISSIONS IN BRAZIL: EVIDENCE FOR THE BORLAUG HYPOTHESIS

This study examines the relationship between agricultural productivity and carbon dioxide (CO₂) emissions in the Brazilian Cerrado biome, which since the 1990s has become one of the country's main agricultural frontiers. The analysis contributes to the broader theoretical debate between the Borlaug hypothesis and the Jevons paradox. A two-stage quantitative approach is employed. In the first stage, total factor productivity indices (TFPI) for agricultural activities are obtained by a stochastic frontier model for all municipalities in the Cerrado using panel data from 2006 and 2017. In the second stage, regression analysis is used to assess the association between TFPI and average net agricultural CO₂ emissions, employing fixed-effects and random-effects models. The results reveal a negative relationship between TFPI and CO₂ emissions, providing empirical support for the Borlaug hypothesis within the biome. Moreover, variables such as per capita GDP, population density, urban area, native vegetation, and the presence of soybean and sugarcane crops play a mediating role in the relationship between productivity and emissions. These findings suggest that gains in agricultural productivity can contribute to achieving clean development goals and mitigating climate change.

Keywords: Emissions, Cerrado, Total Factor Productivity, Brazil

Title: CONSISTENT AGGREGATION AND DECOMPOSITION OF PRODUCTIVITY CHANGE: APPLICATION TO ENERGY PRODUCTIVITIES IN NORWEGIAN FISHERIES

Authors: [Dr. Kenneth Løvold Rødseth PhD¹](#); Prof. Kristin Helen Roll²; Prof. Timo Kuosmanen³

Affiliation: ¹ Institute of Transport Economics (TØI); ² University of South-Eastern Norway; ³ University of Turku

Aggregation of firm performances to the industry level in a consistent and economically meaningful way is a key methodological challenge in productivity analysis. A prominent approach is the denominator rule – a necessary and sufficient condition for consistent aggregation of ratio-based performance measures. The current paper develops a corresponding approach for productivity and efficiency changes, by defining and proving a rule for consistent aggregation of firm-level performance measures involving compound ratios.

The new approach is utilized for empirical investigation of energy productivity changes of the Norwegian fishing fleet and its associated vessel groups, which differ substantially regarding vessel and gear types and regulatory frameworks. A key result is that the energy productivity changes of one of the vessel groups exert a substantial influence on industry energy productivity change, despite its negligible contributions both to industry output and value creation.

The main explanation is that the weights required for consistent aggregation regard the relative change in energy- and output-specific market shares. To investigate their individual contributions, we decompose industry-level energy productivity change into industry average productivity change, energy and output structural changes and the energy intensity gap. Thereby, the proposed methodology offers a richer decomposition of energy productivity change than most comparable studies.

Title: CAN PRICE INCENTIVES DRIVE LEGUME ADOPTION? A TECHNICAL AND ECONOMIC BEST PRACTICES STUDY FROM FRANCE

Authors: Prof. Jean-Philippe BOUSSEMART¹; Dr. Maé GUINET²; [Dr. Salomé KAHINDO PhD³](#); Dr. Nicolas MUNIER-JOLAIN²; Dr. Romain NANDILLON²; Prof. Raluca PARVULESCU³

Affiliation: ¹ Université de Lille, CNRS, UMR 9221 -LEM; ² UMR Agroécologie, INRAE, Dijon, France; ³ IESEG School of Management, Univ. Lille, CNRS, UMR 9221 -LEM

Despite their agronomic and environmental benefits, legume cultivation remains limited in European agriculture due to persistently low market prices and structural disincentives. This study proposes a method to reconcile quantity- and value-based production frontiers, offering a new perspective on this misalignment. Alignment is defined as the situation in which revenue-maximizing behavior leads to the same level of physical output—here measured as legume protein production—as a quantity-maximizing benchmark. Using non-parametric Free Disposal Hull (FDH) models, we show that under current prices, such alignment is not achieved, highlighting a disconnect between price incentives and the protein production potential of legumes. We then simulate output-specific legume price adjustments to identify the conditions required to restore align-

ment. The method is applied to 699 French cropping systems from the DEPHY network. Results indicate that moderate, individualized legume price increases—averaging 24%—are sufficient to align revenue-maximizing behavior with the physical production frontier, allowing nearly all systems to reach their legume protein potential while maintaining revenue maximization. This approach provides a decision-support tool for designing targeted pricing strategies to promote sustainable, legume-rich cropping systems in European agriculture.

15:30 - 17:00 | Mars 1 | Banking & Finance 2

Chair: Alfons Oude Lansink

Title: MICROFOUNDATIONS IN MEASUREMENT AND THEORY

Authors: [Junyi Zhu](#)

Affiliation: Deutsche Bundesbank

Macroeconomic research often conflates two aggregation logics: closed aggregation, which derives macro relations deductively from micro-level models, and open aggregation, which constructs macro variables through principle-based rules embedded in national accounts. This paper argues that the axiomatic approach to index number theory should be understood as a device for securing causal invariance at the macro level.

Closed aggregation presumes full observability of heterogeneous units and strong structural assumptions, conditions rarely met in practice. When these fail, bottom-up aggregation may produce unstable macro relationships and confounded policy interpretation.

Index-number principles such as proportionality, consistency, and chaining act as invariance constraints that stabilize macro variables under compositional and structural change. This mirrors thermodynamics: temperature was operationally defined and used for intervention long before its reduction to molecular kinetics.

Real value added, measured via double deflation, may diverge from micro-founded physical output, yet its invariant construction enables coherent analysis of macro interventions such as changes in money supply or interest rates. Stable measurement is thus a prerequisite for credible causal inference.

Keywords: Causal Invariance, Aggregation, Real Value Added, Index Number Theory

Title: ASYMMETRIC PASS-THROUGH OF THE CENTRAL BANK'S POLICY RATE TO BANKS' RETAIL RATES: EVIDENCE FROM PAKISTAN'S BANK-LEVEL DATA

Authors: [Prof. Alfred Haug PhD](#); Prof. Dorian Owen PhD; Syed Hussain

Affiliation: University of Otago

The efficacy of monetary policy largely depends on the size and speed of policy interest rate pass-through to bank retail interest rates. A recently developed two-step non-linear autoregressive distributed lag method is applied to estimate the extent of the central bank's policy rate pass-through to retail rates of commercial banks operating in Pakistan. As an emerging and developing economy with a dual banking system that includes both conventional and Islamic banks, Pakistan is a relevant case study for other similar economies. A potentially asymmetric long-run relationship is specified between the retail rate and the positive and negative cumulative partial sums of the monetary policy rate changes. The results reveal asymmetric adjustments in both lending and deposit rates in the long run. Lending rates respond more fully to policy rate hikes than to cuts, with approximately complete pass-through of increases in the policy rate to lending rates. For deposit rates, pass-through is only partial with banks reluctant to fully adjust deposit rates in either direction. Furthermore, findings point to heterogeneity in monetary policy transmission across the banking system. Bank-level analysis shows that the characteristics of banks, such as ownership, nature of a bank's operations and market power, affect the extent of their pass-through.

Keywords: Interest rate pass-through efficacy, monetary policy transmission, retail interest rates, asymmetry.

Title: BEYOND STATIC EFFICIENCY: A DYNAMIC DEA MODEL FOR SUSTAINABLE MUTUAL FUNDS

Authors: Prof. Dr. Alfons Oude Lansink¹; Dr. Magdalena Kapelko²; [Dr. Albane Tarnaud](#)³

Affiliation: ¹ Wageningen University & Research; ² Wroclaw University of Economics and Business; ³ IESEG

School of Management, Univ. Lille, CNRS, UMR 9221 -LEM

This paper employs a dynamic Data Envelopment Analysis (DEA) model to evaluate the performance of mutual funds while integrating Environmental, Social and Governance performance. Although DEA has been widely used to estimate efficient frontiers in portfolio applications, and recent studies have incorporated ESG performance into efficiency assessments, existing approaches remain predominantly static and overlook the dynamic nature of fund management and the role of adjustment costs. Our empirical analysis relies on an unbalanced panel of 188 to 464 mutual funds classified as Article 9 under the Sustainable Finance Disclosure Regulation (SFDR), i.e., funds that explicitly pursue sustainability as an investment objective. The sample covers the period from October 2023 to July 2025. We simultaneously consider two desirable outputs – the funds' average returns and ESG scores – and one undesirable output – the funds' volatilities of returns. Fund fees (expense ratio) and asset allocations serve as inputs, while changes in fund size capture the dynamic adjustment effects. The model distinguishes between technologies generating good and bad outputs and accounts explicitly for portfolio reallocation over time. Our results provide a more comprehensive assessment of mutual fund performance by incorporating sustainability and adjustment dynamics within a unified efficiency framework, offering improved insights for portfolio optimization and managerial decision-making.

Title: RISK-RETURN-ESG INEFFICIENCY OF EUROPEAN MUTUAL FUNDS: A BY-PRODUCTION APPROACH

Authors: [Prof. Alfons Oude Lansink](#)¹; Dr. Magdalena Kapelko; Dr. Albane Tarnaud

Affiliation: ¹ Wageningen University

Data Envelopment Analysis (DEA) has been widely used in the evaluation of the performance and (in)efficiency of mutual funds in terms of their risk and returns. However, only few papers have considered their sustainability performance. This paper contributes to this literature by proposing a by-production framework for the estimation of inefficiency of mutual funds in terms of their risk, returns and Environmental, Social and Governance (ESG) performance. The empirical analysis focuses on all mutual funds issued in Euros with their monthly observations for one year (March 2024 – February 2025). We construct two technologies, one for the production of good outputs of return and ESG, and the second one for the generation of bad output, i.e. the mutual funds' risk. The results show on average for all months slightly larger inefficiencies in the generation of bad output rather than in the generation of good outputs. Furthermore, this paper analyses the monthly variation in inefficiencies of good and bad outputs of mutual funds.

15:30 - 17:00 | Mars 2 | Justice 1

Chair: Stavros Kourtzidis

Title: THE JUSTICE PRODUCTION TECHNOLOGY

Authors: Prof. Giannis Karagiannis¹; Prof. Antonio Peyrache²; [Prof. Angelo Zago PhD](#)³; Prof. Osman Zaim⁴

Affiliation: ¹ University of Macedonia (Thessaloniki); ² Centre for Efficiency and Productivity Analysis (CEPA), The University of Queensland (St. Lucia); ³ University of Verona; ⁴ Kadir Has University

In this paper we discuss the production process of courts of justice with a special focus on characterizing the role that queues, i.e., long processing times, play within this system. The basic identity that governs case flow, which we call the case balance condition, also provides a link in enhancing our interpretation of courts of justice as queuing systems. Within this framework, we discuss standard performance measures used in the industry, notably the clearance rate (CR) and the disposition time (DT) and show how they are related through the case balance condition. We introduce a family of efficiency models that take explicitly into account this condition, plus some nested versions that either consider the caseload (pending plus incoming cases together) or none of them. Moreover, we introduce a version which allows for pending cases to be a congesting factor. These models are all nested versions of the general model, so it is relatively easy to empirically test which one better fits the data at hand. We illustrate their use with data on Turkish courts for 2015 and 2021 and we show that, at least in this setting, we reject the model without the caseload data in favor of the more general model that includes the cases information. More research is needed in order to make a better connection between the case balance condition and the efficiency measurement models based on DEA, which we leave for future endeavor.

Title: A HYBRID COST EFFICIENCY MODEL UNDER FIXED AND NON-FIXED PRICES: A CASE STUDY ON THE POLISH JUSTICE COURTS

Authors: Prof. Magdalena Kapelko¹; [Dr. Dimitrios Sotiros](#)²; Dr. Sebastian Tomczak²

Affiliation: ¹ Wroclaw University of Economics and Business; ² Wroclaw University of Science and Technology

Justice courts, beyond handling legal matters, should pursue the efficient allocation of public resources. Therefore, their economic efficiency should be regularly assessed. However, studies evaluating the performance of justice courts rarely focus on the economic dimension of efficiency at the micro level. To fill this gap, the contribution of this study is twofold. Firstly, from the methodological point of view, we propose a new non-parametric framework for measuring cost efficiency that is capable of handling exogenously fixed and non-fixed prices and identifying cost–demand relationships. Secondly, from the empirical perspective, we show the applicability of this new framework to Polish district courts over the period 2017–2021. The results reveal that only 10% of the courts are cost efficient. Interestingly, on average, the model suggests an increase in the number of all employees and in non-fixed salaries, as well as a reduction in the volume of capital. The results also suggest that the reallocation of resources can lead to significantly fewer pending cases.

Title: ADOPTION OF TECHNOLOGY AND ITS CONSEQUENCES FOR PERFORMANCE - SWEDISH DISTRICT COURTS

Authors: [Prof. Jonas Månsson PhD](#)¹; Prof Christopher O'Donnell²; Senior Lectur Anupama Unnikrishnan¹

Affiliation: ¹ Blekinge Institute of Technology; ² University of Queensland

In 2017, the Swedish National Audit Office reviewed the performance of the Sweden's district courts. One result of the audit was that capacity utilisation varied substantially between courts. The auditors recommended a more flexible staff allocation so that idle capacity could support other courts with larger backlogs. The recommendation was dismissed, citing Sweden's neighbourhood principle; the idea that public services, including the courts, should be equally accessible regardless of where citizens live. The pandemic in 2020 changed this landscape. Covid-19 restrictions reduced face-to-face hearings, but each court retained discretion in how to adapt. Video-conference hearings (VCH) offered a way to comply with the restrictions. During Covid some courts adopted VCH extensively (high adopters), while others continued to rely on traditional in-person hearings (low adopters). Drawing on unique data, including precise records of videoconference usage, we find that courts with low adoption experienced significantly weaker productivity growth than high adopters. We also observe that productivity gains diminished after restrictions were lifted in 2022, in parallel with declining use of video hearings. Our conclusion is that innovation does not always need to move the frontier. Sometimes, as in the case of Swedish district courts, productivity improves when institutions are compelled to make better use of existing technologies.

Keywords: Productivity, Swedish district courts, Technology adoption, Covid-19 restrictions

Title: ON MODELING PENDING CASES IN COURT EFFICIENCY ANALYSIS

Authors: Prof. Giannis Karagiannis PhD¹; [Prof. Stavros Kourtzidis](#)²; Dr. Panagiotis Ravanos³

Affiliation: ¹ University of Macedonia; ² University of Dundee; ³ European Commission DG JRC

Pending cases have a dual role in modeling courts' technology: as an input, pending cases at the beginning of the year constitute along with incoming cases the number of caseloads to be resolved during the year and as a undesirable output, pending cases at the end of the year reflect the cases that have not been proceeded. To appropriately account for the dual role of pending cases we rely on what we refer to as the Case Balance Condition, which is a simplified form of the Material Balance Condition when all the material flow coefficients are equal to one. We estimate the efficiency of the first-instance courts in Greece by using a directional output distance function and assuming either weak disposability or weak G-disposability. We show that compatibility with the Case Balance Condition restricts the choice of the direction vector along which to gauge efficiency to just one, i.e., the unit vector, and this should be true for under both weak disposability and weak G-disposability; otherwise all courts are found efficient. We also show that, in the case of weak disposability and under variable returns to scale, the abatement factor is equal to one and thus, the uniform and the non-uniform abatement factors formulations are equivalent, and that the slacks of all but the judge and judicial staff variables are equal to zero.

Keywords: Pending cases; case balance condition; weak disposability; directional output distance function;

Greek first-instance courts

Friday, June 19, 2026

09:00 - 10:30 | Terra & Jupiter | Life-time Achievement Award to Erwin Diewert

Chair: Valentin Zelenyuk**Title:** CAPTURING THE ECONOMIC VALUE OF HOUSEHOLD SOLAR ELECTRICITY IN NATIONAL ACCOUNTS**Authors:** [Paul Schreyer](#)**Affiliation:** Organisation for Economic Co-operation and Development (OECD)

The installation of solar panels on private homes is a rapidly expanding component of the environmental transition. National statistical agencies have begun integrating this form of household production into national accounts and GDP. We develop an explicit model of household electricity production to determine the appropriate valuation of own-produced electricity and to assess its implications for measured prices and quantities of household final consumption expenditure, as well as for real income. Our results support the current statistical practice for valuing and recording household-generated electricity within expenditure measures. At the same time, the model highlights the importance of accompanying the measures in the National Accounts with indications of more broadly defined welfare gains from avoided grid purchases.

Title: PRICE INDEXES: BUILDING ON ERWIN DIEWERT'S CONTRIBUTIONS**Authors:** [Robert Hill](#)

I consider how the works of Erwin Diewert have influenced my own research on price indexes. The topics covered range from superlative price indexes, spatial chaining of price indexes, real estate price indexes/owner-occupied housing to price indexes for scanner data.

Title: INTEGRATING CAPITAL THEORY INTO DEPRECIATION ESTIMATION: A BUILDER'S MODEL APPROACH TO ASSET MEASUREMENT**Authors:** [Prof. Dr. Chihiro Shimizu PhD](#)**Affiliation:** Hitotsubashi University

Accurate capital input measurement is essential for productivity analysis but remains complicated by the problem of allocating the purchase price of long-lived assets over time. Capital theory shows that asset prices, user costs, and depreciation profiles are jointly determined through no-arbitrage conditions and stock-flow accounting identities. In practice, however, depreciation is typically imposed exogenously—often as a geometric schedule—without separating physical deterioration, retirement, obsolescence, and asset-specific price changes. This paper develops a market-based framework for estimating structure depreciation rates that is consistent with capital theory and capital services measurement. The approach addresses a fundamental identification problem in property markets: assets are traded as bundles of land and structures. To isolate the structure component, we implement the Builder's Model, which anchors structure values using replacement-cost logic based on construction cost indices and building characteristics, while identifying land values as residuals from observed property prices. Using valuation and transaction data combined with construction cost information, the model estimates flexible age-price profiles and distinguishes depreciation from revaluation, providing a theoretically coherent foundation for capital measurement and productivity research.

11:30 - 13:00 | Terra | DEA Methods 4

Chair: Alexander Öttl**Title:** A SPATIAL SCAN STATISTIC FOR SECOND STAGE ANALYSIS OF BRAZILIAN DISTRIBUTOR SYSTEM OPERATORS

Authors: Tatielle Menolli Longhini; [PhD Marcelo Azevedo Costa](#); Bruno de Almeida Vilela

Affiliation: Universidade Federal de Minas Gerais, Brazil

This study analyzes the impact of environmental heterogeneity on the regulatory assessment of electricity distribution companies' efficiency in Brazil. An integrated approach is presented that combines Data Envelopment Analysis (DEA), as adopted by the Brazilian regulator, with spatial scan statistics (SaTScan) and econometric adjustments using Ordinary Least Squares (OLS) applied to second-stage efficiency scores. In the first stage, cost efficiency scores of Brazilian electricity distribution companies are estimated using a DEA model aligned with the current regulatory methodology. In the second stage, environmental variables considered by the regulator are analyzed through spatial scan statistics for continuous data, combined with OLS regressions, allowing the endogenous identification of spatial clusters associated with statistically distinct efficiency patterns. The results indicate the existence of a cluster concentrated in the Northern region of the country, associated with specific environmental and operational characteristics. Regressions estimated inside and outside the cluster reveal that the marginal effects of environmental variables exhibit similar behavior across regions, while the observed differences are primarily concentrated in the level of efficiency scores. The integration of spatial dependence into the econometric adjustment in the second stage contributes to a more consistent and comparable assessment of distributors' performance across units.

Title: ASSESSING THE INDIVIDUAL CONTRIBUTIONS OF INPUTS AND OUTPUTS TO ENVIRONMENTALLY SUSTAINABLE PRODUCTIVITY CHANGE

Authors: [Dr. Paola Ravelojaona](#)

Affiliation: Université de Lorraine, CEREFIGE, France

This paper introduces a new formulation of productivity measurement, namely an exponential Hicks-Moorsteen productivity index. This formulation captures the specific contributions of individual inputs and outputs to productivity change. The practical aspect of the proposed approach is demonstrated using a convex neutral production model accounting for both economic and emission-causing components. An empirical illustration is provided, analyzing productivity variations across 27 countries over the period 1987-1990 and using the non-parametric data envelopment analysis approach.

Keywords: Data Envelopment Analysis, Exponential Distance Function, Total Factor Productivity

Title: CHECKING THE CONVERGENCE OF BOOTSTRAP DEA AND IMPUTATION-PROPELLED DEA

Authors: [ARDHANA M PRABHASH](#); Dr. Vipin Valiyattoor PhD

Affiliation: Indian Institute of Science education and Research Bhopal, India

This study explores the sensitivity of non-parametric efficiency scores to sample variation, particularly in performance analysis. In the literature, the application of Data Envelopment Analysis (DEA) is highly constrained by the nature and suitability of the dataset that feeds into the efficiency model. When the dataset is small, the DEA framework has fewer benchmarking observations to construct an efficient frontier, thereby magnifying the impact of each individual data point. In such cases, even small variations in a single observation can alter the efficiency frontier or change the relative rankings of the decision-making units (DMUs). Since DEA models are easily affected by data, bootstrap DEA (BDEA) algorithms have emerged as a tool to overcome DEA's shortcomings. The existing literature on bias correction has yet to tap the potential of modern Artificial Intelligence and Machine Learning techniques. This study is the first in the literature to examine the convergence of data-driven hybrid DEA, the Imputation-Propelled DEA (IPDEA) model with BDEA, to overcome the finite-sample bias inherent in the DEA framework. We empirically validate the theoretical hypothesis, the IPDEA can converge to Bootstrap DEA by applying the proposed framework to improve performance evaluation and data-driven goal setting in the Indian Manufacturing sector. Our findings show that the Imputation-Propelled DEA converges towards the true frontier and/or Bootstrap DEA in most industries.

Title: VISUALIZING AND ANALYZING TRADE-OFFS IN DATA ENVELOPMENT ANALYSIS USING GRAPH THEORY

Authors: [Alexander Öttl](#)¹; Prof. Mette Asmild

Affiliation: ¹ University of Copenhagen

Trade-offs, or weight restrictions, allow adjustments to the production possibility set in Data Envelopment Analysis (DEA). Such adjustments can have a strong impact on discriminatory power and therefore require careful justification. To improve the understanding and analysis of trade-offs, we propose a graphical representation in the form of weighted directed graphs. This representation facilitates clearer communication of the underlying implications of trade-offs to stakeholders. Moreover, tools from graph theory can be applied for further analysis, such as detecting inconsistent trade-offs or weight restrictions that allow infinite or free production, using the Bellman–Ford algorithm. Overall, this paper aims to link DEA with graph theory to strengthen the justification and analysis of imposed trade-offs and weight restrictions.

11:30 - 13:00 | Jupiter | Productivity 3

Chair: Thomas Triebs

Title: REVISITING TOTAL FACTOR PRODUCTIVITY IN CHINA: A DUAL-FRONTIER MEASUREMENT OF CATCH-UP AND RELATIVE COMPETITION EFFECTS

Authors: [Prof. Dr. Zhiyang Shen PhD](#); Prof. Dr. Michael Vardanyan

Affiliation: IESEG School of Management

While China's economic growth model has been extensively studied, less attention has been given to the distributional and competitive structures underlying productivity growth. This paper revisits China's total factor productivity (TFP) from a productivity-based perspective by introducing a nonparametric dual-frontier framework. Using directional distance functions, we construct both best-practice and worst-practice frontiers to evaluate each decision-making unit's composite gap between potential efficiency improvement and relative competitive position. Based on this framework, we further derive a measure of relative competition effects, interpreted as an "involution-type" efficiency outcome arising from intensified peer competition without corresponding frontier advancement. Empirical analysis based on provincial panel data from China yields three main findings. First, China's TFP growth largely follows a non-Pareto improvement path, with resources and policy support disproportionately concentrated in a small number of regions, particularly economic special zones. Second, sustained technological progress in these leading regions has been the key force driving outward shifts of the national production frontier and overall productivity growth. Third, non-special-zone provinces primarily approach the frontier through catch-up and relative competition effects, narrowing efficiency gaps despite limited contributions to frontier expansion.

Title: REDUCING EXTREME TRADE-OFFS IN REGULATORY BENCHMARKING THROUGH FRONTIER REFINEMENT

Authors: [Sara Kamali](#)¹; Prof. Mohsen Afsharian²; Prof. Heinz Ahn¹

Affiliation: ¹ Technische Universität Braunschweig; ² Leibniz FH, University of Applied Sciences

Frontier benchmarking is central to incentive regulation and widely used by regulators to set efficiency targets and shape firms' cost-reduction incentives. However, it can generate excessive flexibility in input–output trade-offs and create incentives to appear efficient via extreme profiles. Using the Brazilian water and sewage sector as motivation, we study exogenous weight restrictions as a regulatory response to these challenges. We show that such restrictions can shift the efficient frontier in a broad (not just local) way, changing efficiency scores and potentially reducing transparency and comparability over time. We propose an alternative, regulator-friendly method that avoids extreme trade-offs implied by unrestricted weights. The proposed method detects and removes weak or isolated facets (hyperplanes) and then evaluates firms against the remaining well-supported efficient facets, leading to a simpler and more stable frontier. This approach preserves the status of truly efficient firms on well-supported facets, reduces sensitivity to extreme observations, and is harder to manipulate because the remaining facets are supported by multiple firms.

Title: A THEORY OF TECHNOLOGY-BASED PRODUCTIVITY INDEX

Authors: [Prof. Sung Ko Li PhD](#)¹; Dr. Long Zhao PhD²

Affiliation: ¹ Hong Kong Shue Yan University and Hong Kong Baptist University; ² Hunan University

There are several unsolved problems with the measurement of productivity. For example, to compute

the value of a productivity index for any arbitrary production technology, many researchers assume constant returns to scale in their empirical technology. If this is true, why can a wrong assumption capture the characteristics of a “true” technology. To provide answers, we point out that the value of productivity depends on the production technology. This paper establishes a theoretical framework for technology-based productivity index. First, we show that, under a set of fundamental axioms, a unique ranking system of productivity exists, and it is a total preordering. Second, an iso-productivity surface is found, which can be treated as a measurement standard of productivity. Third, there exists a productivity level for each input-output vector. Such levels are consistent with the ranking system of productivity. Fourth, a productivity index can be constructed, and such index can measure productivity changes correctly. Applying our new theory to analyze some current productivity indexes in literature, we show that the input-oriented and output-oriented Malmquist productivity indexes assuming constant returns to scale are able to capture correct productivity changes. Finally, we provide arguments to support that, when the production technology changes over time, the geometric mean formula is preferred to other choices in literature.

Title: FIRM SUBSIDIES AND FACTOR USE

Authors: [Thomas Triebs](#)¹; Mingyang Li; Kai Sun

Affiliation: ¹ Loughborough University

Subsidies for industry are a widely used policy tool. Policy makers hope that subsidies increase employment, improve competitiveness, or foster innovation. But despite these clear policy objectives, firms’ behavioral responses to subsidies are not well understood. For instance, the literature on the empirical effect of subsidy on productivity is as large as it is ambiguous. Besides issues of empirical modelling, the variety of potential mechanisms makes it difficult to draw clear conclusions. In this paper we try to produce some robust conclusions by focussing on a single, theoretically founded, mechanism. How does subsidy affect firms’ input decisions? We model subsidy as an effective input price reduction in a shadow cost minimization framework. Note that the subsidy should not be modelled as an input as it cannot substitute for other input. Subsidy is a payment that affects prices. Assuming that firms have no bargaining power for inputs, subsidies reduce shadow prices, but not market prices. A prediction of this model is that if the subsidy reduces an input’s shadow price the firms will use more of it and its marginal product will decrease. Also, the firm becomes price inefficient in the sense that shadow and market prices diverge. We apply this model to Chinese manufacturing data.

Keywords: Productivity, Subsidies, Shadow Prices, China

11:30 - 13:00 | Venus 1 | Justice 2

Chair: Maria Silva

Title: EFFICIENCY ANALYSIS OF FIRST INSTANCE COURTS IN NORTH MACEDONIA A POLICY PERSPECTIVE

Authors: [Dr. Katerina Shapkova Kocevska](#) PhD

Affiliation: Ss Cyril and Methodius University in Skopje

One of the central strategic priorities for the Republic of North Macedonia in the upcoming years, as outlined in the Development Sector Strategy for the Judiciary, is to enhance judicial efficiency and reorganize the court network. Achieving these objectives requires reform efforts grounded in evidence based policy decisions. In this context, our study seeks to provide an objective assessment of the efficiency of 27 first instance courts in the country, which constitute a core pillar of the judicial system. In our work we employ Data Envelopment Analysis (DEA). The analysis uses data on court resources, including the number of judges and administrative staff, as well as data on pending, incoming, and resolved civil and criminal cases for the years 2023, 2024, and 2025. The results from this work will be used to detect the differences in efficiency among first – instance courts, to identify the most efficient courts, and to contribute to the ongoing judicial reform efforts by providing empirical evidence that can support improvements in overall judicial efficiency.

Key words: efficiency analysis, data envelopment analysis, first – instance courts, North Macedonia

Title: LOWERING THE BAR TO FILL THE BENCH: THE QUALITY-QUANTITY TRADE-OFF IN JUDICIAL

LABOR MARKETS**Authors:** [Deborah Kaut](#)¹; Armela Maxhelaku**Affiliation:** ¹ Maastricht University

When public institutions compete for scarce high-skill workers, does hiring “better” talent raise productivity, or can it backfire? We study German courts facing a tightening pipeline of fully qualified jurists and exploit quasi-exogenous swings in the supply of top performers driven by cohort-level variation in the Second State Exam. Linking these shocks to court production data (2002–2020), we measure productivity using an output-oriented Malmquist index that decomposes change into catch-up to best practice and shifts in the best-practice frontier. Counterintuitively, adding one additional top-tier entrant reduces productivity in mainstream courts by about 0.19%. The decline reflects a deterioration in relative efficiency while the frontier does not move, implying that elite talent creates local frictions rather than sector-wide performance gains. The negative response is concentrated among mainstream and already high-performing courts; low-performing courts show no robust effects. Yet decision quality improves: appeal reversal rates fall by up to 4%. Variation in judicial pay and public–private wage gaps does not moderate these effects, consistent with sorting driven more by intrinsic than extrinsic incentives. Overall, the results reveal a quality–quantity trade-off: under rigid processes and misaligned objectives, scarce stars can lower throughput even as they raise accuracy.

Title: DECONSTRUCTING THE CLEARANCE RATE AS A MEASURE OF COURT PERFORMANCE**Authors:** [Prof. Pablo Arocena](#)¹; Prof. Daniel Santín²**Affiliation:** ¹ Universidad Pública de Navarra; ² Universidad Complutense de Madrid

In many countries, growing concern has emerged over court congestion and its impact on the quality and timeliness of justice delivered to citizens. On the one hand, policy debates focus on the efficient organization and functioning of courts; on the other, there are frequent calls for additional resources to address increasing workloads driven by higher litigation rates and greater case complexity.

One commonly used measure of court performance is the clearance rate, defined as the ratio between the total number of cases resolved by a court in a given year and the number of cases filed in that same year. The European Commission for the Efficiency of Justice (CEPEJ) uses clearance rates at the country level as a key indicator of judicial performance. In this paper, we propose a novel decomposition of the clearance rate at the court level into four components: case-resolving efficiency, scale efficiency, case-mix efficiency, and demand-processing capacity.

We implement this decomposition using a Data Envelopment Analysis (DEA) applied to Spanish first-instance and instruction courts between 2015 and 2024, which exercise jurisdiction over both civil and criminal matters. The results reveal substantial differences in diagnostic patterns across courts and regions, highlighting the importance of tailored policy measures to effectively address court congestion.

Keywords: Judicial Courts, Clearance rate, Efficiency, DEA.

Title: COMPARING COMMERCIAL COURTS IN IBERIAN PENINSULA**Authors:** [Prof. Maria Silva](#)¹; Prof. Pablo Arocena²; Dr. Diogo Dias³**Affiliation:** ¹ Católica Porto business School; ² Universidad de Navarra (Spain); ³ Ca

This paper analyses the performance of Portuguese and Spanish commercial courts, focusing on key methodological challenges that arise in cross-country judicial efficiency comparisons. Employing DEA frontier methods we first examine the choice of inputs and outputs used to evaluate court performance, discussing alternative specifications and their implications for efficiency measurement. Particular attention is given to the selection of input measures and the need to include some measure of caseload, and to the measurement units of case related variables: contrasting simple case counts with weighted measures based on estimated time requirements, we highlight how methodological choices can substantially influence performance rankings and policy conclusions.

Third, and most importantly, we address the issue of comparability across jurisdictions. Cross-country court comparisons are uncommon due to institutional, procedural, and statistical differences that complicate the mapping of equivalent case types. We propose a harmonization strategy to construct comparable categories of commercial cases between Portugal and Spain, allowing for a more consistent benchmarking framework.

The paper contributes to the literature on judicial performance evaluation by providing methodological guidance for international benchmarking and offering new empirical evidence on commercial courts in two Southern European legal systems.

11:30 - 13:00 | Mars 1 | Education 2

Chair: Gabriela Sicilia

Title: TO WHAT EXTENT CAN TUITION DISCOUNTING BE APPLIED IN LOW-TUITION REGIMES? A STOCHASTIC COST FRONTIER STUDY OF HIGHER EDUCATION INSTITUTIONS IN TAIWAN

Authors: [Prof. Tsu-Tan Fu PhD¹](#); Associate Professor Wei-Hsin Kong PhD²; Prof. Wen-Jen Tsay PhD¹

Affiliation: ¹ Soochow University (Taiwan); ² National I-Lan University

Tuition discounting is a widely adopted strategy among higher education institution to support enrollment and revenue management goals. Nevertheless, under low-tuition regimes, institutions face a trade-off between offering discounts to boost enrollment and maintaining sufficient revenue to ensure educational quality. The central policy question, therefore, is: to what extent can tuition be reduced without compromising teaching and research quality? This study develops a conceptual framework and empirical model linking cost savings and tuition discounting. By employing a quality-embedded stochastic frontier average cost model, we estimate the potential cost savings arising from both efficiency improvement and scale adjustment. These savings indicating the financial room that universities can use for implementing tuition discounting without deteriorating quality. Using data from 126 Taiwanese universities over the academic years 2020–2023, we find that total potential cost savings amount to 13% of educational cost, equivalent to approximately 40% of tuition paid by students. Since efficiency improvement accounts for about 70% of total cost savings, while scale adjustment contributes the remaining 30%. This suggests that in the short run, universities should prioritize improving operational efficiency as the primary means of generating savings for tuition discounting. In the longer term, structural reforms that optimize institutional scale can further enhance sustainability.

Title: MEASURING SOCIAL BENEFIT-COST EFFICIENCY IN EUROPEAN SPORTS INDUSTRY USING DYNAMIC DEA

Authors: [Pin-Hsuan Sung](#); Prof. Dr. Chin-Yi Fang PhD

Affiliation: National Taiwan Normal University

This study integrates Benefit-Cost Analysis (BCA) with Data Envelopment Analysis (DEA) to develop a dynamic Social Benefit-Cost Efficiency framework for assessing how sport-related investments convert into social welfare. Using data from 30 European countries over a three-year period during the immediate post-pandemic period, general government expenditure (COFOG) on recreation and sport, average weekly working hours in the sports industry, and sport-related employment are treated as inputs, while self-perceived health and overall life satisfaction serve as outputs, with national land area specified as a carryover variable. An output-oriented Dynamic DEA model estimates efficiency and annual changes. The results reveal substantial variation in resource conversion efficiency across countries, with an average score of 0.822. Slack analysis indicate that lower-efficiency countries have seen increasing gaps in overall life satisfaction from the first to the third year, suggesting more countries require improvement in this dimension. For self-perceived health, less efficient countries consistently display positive slack values over the same period, indicating that this output requires enhancement of approximately 1.1%–1.6%. The study provides a cross-country comparison tool and extends DEA applications in social welfare efficiency assessment. By integrating BCA with DEA, it offers a practical approach to evaluating multi-dimensional, non-monetized social outcomes.

Title: CONSTRUCTION OF EUROPEAN EDUCATION POLICY: OUTLINING WAYSTATIONS BASED ON REGIONAL CAPACITY

Authors: [Dr. Dovile Stumbriene PhD¹](#); Prof. Jose Luis Ruiz PhD²; Prof. Inmaculada Sirvent PhD²

Affiliation: ¹ Vytautas Magnus University; ² Universidad Miguel Hernandez

The construction of European education policy is a result of compromise and consensus between multiple institutions and policy actors. Since 2020, education policy and the European education space have been re-

visited and tweaked once again through the construction of the new framework, the European Education Area (EEA). Representing EU-level goals in the EEA strategic framework for each indicator, the European Commission outlines a way for all EU countries towards the European vision. This paper focuses on the performance evaluation of the European education space at the subnational level, accounting for regional disparities. We discuss how to set targets as part of a supranational planning strategy to improve performance in education based on common indicators. This paper proposes a benchmarking approach using Data Envelopment Analysis to set attainable targets that direct improvements towards the common European vision. Peer selection preferences based on regional capacity are integrated to define each region's achievable targets. The proposed approach was applied to 148 regions at the NUTS 2 level, covering 25 European countries. Given that success in achieving the European vision depends on each country's efforts, we suggest outlining "waystations" for each region based on its capacity, rather than a common way for all EU countries. Setting targets aligned with regions' capacity to drive performance improvement towards a common vision is the focal point of this paper.

Title: BEYOND PERFORMANCE: PRODUCTIVITY AND EQUITY DYNAMICS ACROSS OECD EDUCATION SYSTEMS

Authors: [Prof. Dr. Gabriela Sicilia PhD¹](#); Giovanna D'Inverno; Rosa Simancas; Cristina Polo

Affiliation: ¹ Universitat Autònoma de Barcelona

This paper examines the evolution of productivity and equity in OECD education systems over the last decade and the institutional factors shaping these dynamics. The empirical strategy builds on four pillars. First, we measure productivity gaps using a conditional Global Malmquist index, enabling cross-country comparisons over time and decomposing productivity change into efficiency (catch-up) and technological shifts while identifying benchmark systems. Second, to assess equity trends, we combine a robust conditional Benefit-of-the-Doubt (BoD) model with Global Malmquist indices to construct a multidimensional equity composite indicator. By incorporating conditional models, we account for cross-country socioeconomic heterogeneity and obtain more comparable evaluations of productivity and equity dynamics. Third, we jointly analyse productivity and equity trajectories to examine whether efficiency gains involve trade-offs or complementarities with equity over time, distinguishing between frontier systems that improve in both dimensions and catch-up systems with greater scope for progress. Finally, we relate these dynamics to institutional arrangements and policy features — including private sector participation, early tracking, ability grouping and grade retention — providing new comparative evidence on the policies associated with more productive and equitable education systems.

11:30 - 13:00 | Mars 2 | Sustainability/Eco-efficiency 4

Chair: Arne Henningsen

Title: STATISTICAL INFERENCE FOR WORLD GREEN EFFICIENCY AND PRODUCTIVITY DYNAMICS: THEORY AND APPLICATION

Authors: Prof. Valentin Zelenyuk¹; [Professor Shirong Zhao PhD²](#)

Affiliation: ¹ University of Queensland; ² Dongbei University of Finance and Economics

This study examines efficiency and productivity dynamics across 40 countries (16 OECD and 24 Non-OECD) from 2005 to 2019, incorporating CO2 emissions as an undesirable output a critical yet often overlooked dimension in prior research. To do so, we develop new statistical inference framework that accounts for undesirable outputs and enables constructing confidence intervals and tests for changes in efficiency and productivity across groups. The results reveal significant biases in raw efficiency estimates, underscoring the necessity of bias correction for valid inferences. Among other results, in our empirical part, we find that OECD countries consistently outperformed Non-OECD nations in efficiency, though the global financial crisis adversely affected efficiency and productivity across all groups. These findings underscore the importance of incorporating environmental externalities and applying rigorous statistical methods in cross-country performance analysis.

Keywords: Efficiency, Data Envelopment Analysis, Directional Distance Functions, Aggregation, Statistical

Title: ENVIRONMENTAL TOTAL FACTOR PRODUCTIVITY AND THE COST-EFFECTIVENESS OF GHG

EMISSION REDUCTION

Authors: [Yang Liu](#); Dr. Maria Vrachioli; Prof. Dr. Johannes Sauer

Affiliation: Technical University of Munich

China's diversified agricultural policies have effectively improved both the yield and environmental performance of the crop sector. Quantifying productivity trends and their drivers is key to formulating strategies for high-quality and low-carbon crop development. This study uses input-output panel data of crop products to examine changes in the environmental total factor productivity (ETFP) of the crop sector and its major sub-sectors across 30 Chinese provinces from 2001 to 2020. The results show that the ETFP of the crop sector exhibited a wavelike growth pattern, mainly driven by technological progress. In addition, reducing greenhouse gas (GHG) emissions can significantly improve the ETFP and shows considerable potential. Over the entire study period, the crop sector could mitigate up to 35.5% of GHG emissions to reach the frontier target value. The average marginal abatement cost is 4106 yuan/tonne CO_{2e}. Spatially, the GHG emission mitigation potential and cost-effectiveness in the western and central regions are higher than those in the eastern region. Therefore, inter-regional cooperation can leverage regional differences to optimise total reduction costs and establish a carbon market, which would positively impact both the crop economy and the environment.

Environmental total factor productivity, Productivity decomposition, GHG shadow price, Crop sector

Title: CIRCULARITY FOR ENHANCING AGRICULTURAL PRODUCTIVITY IN AUSTRIA & BAVARIA

Authors: [Müller Flores](#), L.; Vrachioli, M.²; Frick, F.²; Sauer, J.²; Hambrusch, J.; Tribl, C.; Zeilinger, J.

Affiliation: ²Technical University of Munich (TUM)

Reaching the goal of safeguarding food security while reducing input use and environmental harm in agriculture needs that we ensure a certain level of agricultural productivity. The CAP-AB project focuses on the measurement of traditional and environmentally adjusted productivity within Austrian and Bavarian agriculture. The project considers the principle of circularity by incorporating this concept into productivity measurement, applying an environmentally adjusted total Factor Productivity (envTFP) framework, which extends traditional productivity metrics by incorporating environmental indicators such as greenhouse gas emissions and resource use efficiency. The project is structured into three work packages (1) assessing farm-level economic and environmental performance along different degrees of circularity, (2) evaluating the impact of Common Agricultural Policy (CAP) investment funds on circular practices and productivity using causal inference methods, and (3) enhancing the framework for a broader EU applicability. CAP-AB contributes to the EU's climate and competitiveness goals by offering a robust methodology for evaluating both economic and environmental aspects of a farm performance, and the effectiveness of CAP measures in promoting circular, resource-efficient, and climate-friendly agriculture.

Title: SUSTAINABLE PRODUCTIVITY & SUSTAINABLE PROFITABILITY

Authors: [Dr. Arne Henningsen](#)¹; Frederic Ang²; Moriah Bostian³; Hervé Dakpo⁴; Maria Vrachioli⁵

Affiliation: ¹ University of Copenhagen; ² University of Reading; ³ Lewis & Clark College; ⁴ Université Paris-Saclay, INRAE, AgroParisTech, PSAE; ⁵ Technical University of Munich

Our previous work suggests measuring Sustainable Productivity as the ratio between a quantity index of all societal benefits of the production (i.e., market outputs, positive externalities) and a quantity index of all societal costs of the production (i.e., traditional inputs, negative externalities), where societal valuations of all benefits and costs are used as weights in these quantity indices. We use constant weights across all considered time periods and producers in order to focus on changes and differences in quantities and to obtain a Sustainable Productivity Index that is in line with index number theory.

When using observation-specific societal valuations instead of constant societal valuations as weights in the quantity indices, we basically perform a social cost-benefit analysis. We consider the resulting ratio as a Sustainable Profitability Index that indicates the ratio between the societal value of all societal benefits and the societal value of all societal costs.

If social valuations change over time or differ between producers, Sustainable Profitability differs from Sustainable Productivity, where Sustainable Profitability can be decomposed into Sustainable Productivity (focusing on differences in quantities) and a kind of Terms-of-Trade component (focusing on differences in

societal valuations).

We apply this framework to a country-level panel data set, taking into account greenhouse gas emissions as a negative externality.

14:00 - 15:30 | Terra | Organized session 4: Efficiency in system design

Chair: Konstantinos Triantis

Title: EFFICIENCY DRIVEN DESIGN OF SOCIO-TECHNICAL ENGINEERED SYSTEMS: AN OVERVIEW

Authors: [Konstantinos Triantis](#); Joseph Godfrey; Yas Mashayekhy; Saman Mohsenirad; Leon Sobrie; Maria Tomai

Affiliation: System Performance Laboratory (www.spl.ise.vt.edu), Grado Department of Industrial and Systems Engineering, Virginia Tech, Academic Building 1, Alexandria VA, USA

As engineered systems shape many processes in a wide variety of contexts, there is a prevalent need to evaluate their efficiency performance in ways that account for both technical performance and human behavior. However, efforts to improve efficiency in engineered systems often fall short of fulfilling this need because they treat human behavior as a fixed or secondary factor, rather than recognizing it as an integral part of how these systems function and perform. In response to this challenge, this paper integrates the concepts of efficiency analysis with those of engineered systems viewed as socio-technical systems. As such, it brings together ideas and frameworks from the domains of safety science, socio-technical systems, decision theory, systems engineering, efficiency analysis, and data science. The basic premise of this chapter is that the efficiency measurement paradigm could inform the design of engineered systems that have fundamental socio-technical system characteristics. In order to initiate the integration of the ideas and frameworks from the various disciplines cited above, we rely on systems thinking representations. Through methodological innovations and case studies, the paper illustrates how efficiency performance metrics can be embedded into the design and operational phases of engineered systems. Diverse application domains covered in this chapter include transportation, healthcare, and evacuation modeling, demonstrating how efficiency analysis can inform system architecture, resource allocation, and policy design. Furthermore, we discuss the challenges of efficiency performance measurement in dynamic systems under uncertainty, underscoring the importance of context-sensitive evaluation methods that account for environmental heterogeneity. Overall, the paper offers theoretical conceptualizations and analytical approaches for engineers and researchers to improve the efficiency management of complex engineered systems.

Title: UNDERSTANDING COMPLEX TRANSPORTATION SYSTEMS: RAILWAY DELAYS AND POLICY INTERVENTIONS FOR IMPROVED PERFORMANCE

Authors: [Yas Mashayekhy](#); Konstantinos Triantis

Affiliation: System Performance Laboratory (www.spl.ise.vt.edu), Grado Department of Industrial and Systems Engineering, Virginia Tech, Academic Building 1, Alexandria VA, USA

This research aims to understand complex transportation systems—particularly railway networks—and to identify, analyze, and propose policies that can mitigate train delays to enhance economic efficiency while maintaining balance among other key operational performance objectives, such as safety and workload. The overall framework integrates efficiency evaluation, qualitative and quantitative system dynamics, and policy design and analysis. All analyses use open, publicly available data, and supplemented by interviews. Specific datasets are shared specifically with SPL-Virginia Tech as part of a Non-Disclosure Agreement (NDA) with INFRABEL the Belgian National Railway Company.

Title: A PROBLEM TYPE TAXONOMY USING DONABEDIAN'S STRUCTURE-PROCESS-OUTCOME MODEL

Authors: Joseph Godfrey; Leon Sobrie; [Maria Tomai](#); Konstantinos Triantis

Affiliation: System Performance Laboratory (www.spl.ise.vt.edu), Grado Department of Industrial and Systems Engineering, Virginia Tech, Academic Building 1, Alexandria VA, USA

Not all organizational problems are puzzles with fixed structures and clear processes that give rise to computable outcomes. Contemporary problems in organizations often emerge from dynamic interactions among

evolving structures, procedures, and outcomes. Building on Donabedian’s Structure-Process-Outcome (SPO) model, we propose a taxonomy that conceptualizes problems as “incomplete systems”. This taxonomy identifies six distinct problem archetypes: puzzle-solving, discovery, planning, design, invention, and innovation, each offering a unique approach to problem-solving. We illustrate the utility of this framework through a case study of Belgian railway Traffic Control Centers (TCCs), where human operators and autonomous technologies collaboratively manage a safety-critical environment, that focuses on: safety, economic efficiency and workload. Interviews grounded in Transactive Memory Systems (TMS) theory show how the taxonomy facilitates the diagnosis of shared responsibility challenges, using the six archetypes as interpretive lenses. This work offers researchers and practitioners a practical approach for navigating problem-solving in dynamic organizational settings.

Title: TRUST-BASED INPUT REGIMES AND CLIMATE RESILIENCE EFFICIENCY: A CROSS-COUNTRY META-FRONTIER DEA STUDY WITH ROBUST SIMULATION-BASED AUGMENTATION

Authors: [Juan Carlos Franco](#); Konstantinos Triantis

Affiliation: System Performance Laboratory (www.spl.ise.vt.edu), Grado Department of Industrial and Systems Engineering, Virginia Tech, Academic Building 1, Alexandria VA, USA.

Climate resilience is not the same for different countries, and cross-country analysis does not take into account the bounds of social context for feasible climate resilience. The research aims to find out if social capital in the form of trust influences the efficient conversion of social capital into climate resilience for different countries. Instead of taking trust as an independent variable for analysis, the study consider three different dimensions of trust as exogenous inputs for the production function: institutional trust, interpersonal trust, and particularized trust. The research method involves trust-based k-means clustering and output-oriented data envelopment analysis with variable returns to scale and meta-frontier benchmarking for 84 countries based on data from the World Values Survey/European Values Survey and the ND-GAIN Country Index. The combination of these datasets helps to estimate the efficiency of different countries. The problem of small sample sizes for each cluster is addressed by the ROBPCA-KDE Monte Carlo method for better discrimination of the frontiers. The results of the research highlight significant variability in the efficient conversion of social capital into climate resilience for different countries. The research also finds that interpersonal and particularized trust are positively correlated with climate resilience efficiency and proximity to the global meta-frontier for different countries. The implications of the research are that climate resilience is different for different countries due to production possibility constraints based on trust and the efficiency of each regime of trust.

14:00 - 15:30 | Jupiter | Agriculture 5

Chair: Vivian Wei Huang

Title: AGRICULTURAL SERVICES AND RESOURCE ALLOCATION EFFICIENCY: EVIDENCE FROM CHINA

Authors: [Prof. Ruizhi PANG PhD](#); Prof. Xuejie BAI

Affiliation: Nankai University

Resource misallocation is widely recognized as a major source of productivity loss in developing-country agriculture, particularly in economies dominated by smallholder production. This paper investigates whether the expansion of agricultural service can improve resource allocation efficiency and productivity. We develop a framework in which agricultural services—such as mechanization outsourcing and specialized cultivation services—function as a market-based mechanism that mitigates scale constraints, reduces capital indivisibility, and facilitates cross-farm factor reallocation.

Using farm-level panel data from rural China, we estimate total factor productivity (TFP) and decompose efficiency into technical and allocative components. We further quantify factor misallocation following a distortion-based approach and compute productivity losses associated with dispersion in marginal revenue products. Our empirical analysis shows that access to agricultural services significantly increases farm-level productivity and reduces the dispersion of marginal products across farms, indicating improved resource allocation efficiency. These effects are particularly pronounced among small-scale and credit-constrained households.

Title: EFFICIENCY AND PEER-TARGET ANALYSIS IN EUROPEAN BEEKEEPING: LEARNING FROM EACH OTHER**Authors:** [Prof. Dr. Ludwig Lauwers PhD](#); Marie Van Espen; Prof. Dr. Wim Verbeke PhD**Affiliation:** Ghent University (UGent)

Since European beekeeping is highly diverse, suggesting generic pathways to improve productivity is not straightforward and even impossible. This paper aims at deriving improvements paths from the outcomes of frontier analysis techniques, despite the tension between the homogeneity assumption of these techniques and the observed heterogeneity in beekeeping. A peer-target analysis is done on the outcomes of both data envelopment analysis (DEA) and full disposable hull (FDH) analysis, and this both for a meta frontier and technology-specific frontiers. A prior classification of beekeepers in hobbyists, semi-professionals and professionals is used. The research not only yields traditional efficiency scores, but also a measure of technology gap for each category of beekeepers. Technology gap is the lowest for semi-professionals and rather high in the two other categories. This indicates that many beekeepers reflect themselves to targets as linear combinations of peers from other categories. Smart combining of outcomes from different frontier techniques allows for detecting eligible contact farms as a mirror for followers' improvement and for grouping the followers in more homogeneous clusters. Although the rather formal and desk-top nature of the analysis outcomes, and despite the enormous variability in beekeeping, efficiency analysis proves to yield building-block insights for beekeeper's improvement advisory and policy.

Title: PRODUCTIVITY GROWTH ADJUSTED FOR ANIMAL HEALTH IN SWEDISH DAIRY FARMS**Authors:** [Dr. Frederic Ang](#)¹; Dr. Enoch Owusu-Sekyere²; Dr. Karin Alvåsen²; Prof. Helena Hansson²**Affiliation:** ¹ University of Reading; ² Swedish University of Agricultural Sciences (SLU)

Productivity analyses in the livestock sector often overlook the critical role of animal health in the production process, which potentially leads to biased performance assessments. The current study addresses this gap by explicitly incorporating animal health as both an input and an output in productivity measurement. Within a distance function framework, we develop an animal health-adjusted Malmquist productivity index that decomposes productivity change into technical change, technical efficiency change, and scale efficiency change. Using data envelopment analysis and panel data from Swedish dairy farms covering the period 2009-2016, we estimate an average annual productivity growth of 2.5%, primarily driven by technological progress of 1.8% per year. The results show notable differences between conventional and health-adjusted productivity estimates, which underscore the importance of integrating animal health into productivity analysis in the livestock sector.

Title: ARE ENVIRONMENTAL EFFICIENCIES OF SWEDISH AGRICULTURE MORE TRANSIENT OR MORE PERSISTENT? HETEROGENEITY AND DETERMINANTS**Authors:** [Dr. Vivian Wei Huang PhD](#)**Affiliation:** Swedish University of Agricultural Sciences (SLU)

This study estimates the environmental efficiency of Swedish agriculture from 2009 to 2023 using the Generalized True Random Effects (GTRE) approach with data from the Swedish Farm Accountant Data Network (FADN). A four components directional output-distance function is employed to account for farm-size heterogeneity, transient and persistent technical efficiency, and random errors, with greenhouse gas (GHG) emissions from crop and dairy farms considered as undesirable outputs. Results indicate an average total environmental inefficiency of 51.7%, suggesting significant potential for improvement. Transient environmental efficiency (0.63) is found to be smaller than persistent environmental efficiency (0.79). Additionally, age and the expenditure share of warming costs within total energy costs are associated with both types of inefficiency, while economic size, electricity expenditure share, family labor share, and location significantly influence transient efficiency. Subsidies exhibit mixed correlations with environmental efficiency. These findings suggest that targeted policies promoting energy-efficient technologies, farm-size optimization, and refined subsidy structures could enhance long-term environmental performance in Swedish agriculture.

14:00 - 15:30 | Venus 1 | SFA methods 3**Chair:** Alecos Papadopoulos

Title: BAYESIAN ESTIMATION OF PANEL STOCHASTIC FRONTIER MODELS WITH SPATIALLY AND TIME-VARYING INEFFICIENCY**Authors:** [Rouven E. Haschka](#)

This paper considers a panel stochastic production frontier with firm-specific effects model that allows technical inefficiency to vary spatially and over time. Specifically, we assume that inefficiency follows an AR(1) process. That is, the current year's inefficiency for a firm depends on its past inefficiency plus a transient inefficiency incurred in the current year. Inter-firm variations in the transient inefficiency are explained by unobserved spatial effects. This location-specific unobserved spatial heterogeneity is modeled by means of a Gaussian Markov random field. Inference becomes feasible through Markov chain Monte Carlo simulation techniques. We provide Monte Carlo simulation results to examine and compare the finite-sample performances of the Bayesian approach.

Title: INDIRECT INFERENCE IN PANEL STOCHASTIC FRONTIER MODEL WITH ENDOGENOUS SWITCHING AND ENDOGENOUS INPUTS**Authors:** [Dr. Hung-pin Lai PhD](#)**Affiliation:** National Chung Cheng University

This paper introduces a panel stochastic frontier model that accounts for sample selectivity, unobserved heterogeneity, and endogenous regressors. Building on Greene (2010) and Lai (2015), the framework extends the four-component stochastic frontier model by incorporating endogenous switching and sample selection, while allowing regressors to correlate with both transient and persistent inefficiency. To address the computational challenges of high-dimensional integration, we adopt the indirect inference (II) method of Gourieroux et al. (1993), which circumvents direct likelihood evaluation. Monte Carlo simulations demonstrate that the proposed estimator performs well in finite samples, yielding accurate and efficient results. The model offers a practical tool for empirical researchers dealing with selection bias, endogeneity, and heterogeneity in panel data stochastic frontier analysis.

Keywords: indirect inference approach, panel data, sample selection, stochastic frontier, persistent and transient technical inefficiency

Title: SEMIPARAMETRIC PANEL DATA MODELS WITH INTERACTIVE FIXED EFFECTS**Authors:** Emma Kate Henry; [Dr. Daniel Henderson PhD](#)**Affiliation:** The University of Alabama

This paper develops methods for estimation and inference in semiparametric panel data models with both correlated random effects and interactive fixed effects. Building on the Mundlak specification to control for unobserved heterogeneity in both the cross-sectional and time dimensions, our estimation procedure identifies the nonparametric function, finite-dimensional parameters associated with observed time-invariant and cross-section-invariant regressors, and unobserved interactive effects. We develop a two-stage estimation approach: the first stage jointly estimates the parametric components and interactive effects, while the second stage recovers the nonparametric function using Robinson-style estimation. We establish the asymptotic properties of our proposed estimators under large N asymptotics with fixed T . Monte Carlo simulations support the asymptotic developments. We illustrate the practical utility of our approach via an empirical application examining the relationship between firm innovation and market competition.

Title: UNDER-REPORTING IN MACROECONOMIC OUTPUT AND INPUT DATA SERIES: A TWO-TIER STOCHASTIC FRONTIER APPROACH**Authors:** [Dr. Alecos Papadopoulos PhD](#)**Affiliation:** Athens University of Economics and Business

There are various reasons for which we expect that business revenue, as well as capital and labor employed, are under-reported, including tax evasion motives but also accounting rules. This leads to a two-tier stochastic frontier (2TSF) formulation of the production function, where the opposing latent forces represent the under-reporting of output and of inputs respectively. We explore whether these tendencies at the microlevel are present also at the aggregate. Using National Accounts data as collected by the Penn World

Table v.11.0, we estimate the degree of under-reporting in the output and in the input (capital and labor) macroeconomic data series, separately for each year for the period 1950-2023, for all countries with available data in each year.

Keywords: Under-reporting; macroeconomic data series; two-tier stochastic frontier model.

14:00 - 15:30 | Mars 1 | Country analysis 2

Chair: Isabel Narbon-Perpina

Title: QUALITY PERFORMANCE OF WATER UTILITIES SERVICES IN SUB-SAHARAN AFRICA. A NON-PARAMETRIC ANALYSIS OF DRC

Authors: [Jeannine Mwaku PhD](#); Prof. Dr. Barnabé Walheer

Affiliation: University of Liège, Liège, Belgium

Today in the Democratic Republic of Congo, statistics show a huge gap between the amount of water produced and the amount distributed. In fact, approximately 40% of the water produced never reaches consumers. This highlights the problem of water loss in a country where access to drinking water is already extremely limited.

These water losses, as revealed by the data, represent a source of inefficiency that impacts both consumers and the REGIDESO, “Régie de distribution d’eau”, a public sector company in charge of water distribution in urban areas in DRC. However, reducing these water losses could generate resources that could be reinvested to increase investment and improve service quality.

In this paper, we employ the Data Envelopment Analysis (DEA) approach to construct quality performance indicators to reduce water losses produced by REGIDESO. Our analysis utilizes disaggregated panel data from 99 REGIDESO operating centers over a nine-year period (2016–2024). This proves particularly valuable because recent studies suggest that analyzing the performance of African countries is of limited use due to the reliance on heterogeneous aggregated data.

Our results show inefficiencies and ineffectiveness at REGIDESO’s operating centers and also indicate that water losses could be reduced without requiring new investments.

Keywords: DEA, quality performance, water losses, DRC.

Title: INVESTMENT PERFORMANCE OF INDIAN FINANCIAL ASSETS UNDER MEAN-STANDARD DEVIATION VS. MEAN-SEMIDEVIATION MODEL: APPLICATION OF STOCHASTIC FRONTIER ANALYSIS

Authors: [Prof. Dr. Anup Kumar Bhandari PhD](#)

Affiliation: Indian Institute of Technology Madras

We compare investment performance of Indian equities and equity-portfolios under two different frameworks; mean – standard deviation (SD) and mean – semideviation (Semi). The data of top 500 companies listed on the Bombay Stock Exchange (BSE) are collected over the periods January 2000 to December 2024 to form portfolios. Standard deviation as a measure of total risk provides equal weight to both the upside and downside variation, unlike semideviation that consider the downside variation only. We use stochastic frontier analysis (SFA) because it allows to fit frontier under the assumption that the risk and returns are unknown. Also, it has advantage over data envelopment analysis as it makes possible to fit the frontier using noisy data. It has found in the mature Indian financial market, the financial assets performed better under the mean – semideviation frontier.

Our findings suggest that the usage of mean–semideviation frontier is limited in measuring investment performance. Furthermore, the complete collapse of the semideviation frontier in the first chart visually reinforces the known limitation that SFA models are highly vulnerable to small sample sizes (Lamb & Tee, 2024).

Title: CORPORATE TAX UNDER-REPORTING IN DEVELOPING COUNTRIES: EVIDENCE FROM ETHIOPIA

Authors: [Dr. FIKRU KEFYALEW ALEMAYEHU Associate Professor](#)¹; Prof. Subal Kumbhakar²; Dr. Soressa Jarra³

Affiliation: ¹ University of Inland Norway; ² Binghamton University; ³ Kotebe University

This paper proposes a novel Structured Latent Stochastic Frontier Model (SLSFM) that jointly estimates income and tax reporting in the presence of endogenous underreporting, based on administrative panel data from the Ethiopian Ministry of Revenue on tax filings for the period from 2005 to 2023. The framework nests standard half-normal, truncated-normal, and exponential-gamma specifications for the one-sided component, and estimates the dependence structure without considering external instruments, combining elements of copula-based and control-function approaches. The SLSFM reduces attenuation bias and yields interpretable behavioral parameters that link income generation and reporting decisions. The framework provides micro-structural foundations for analyzing compliance heterogeneity, particularly in low-enforcement environments.

Title: MODELLING THE FISCAL–SERVICE–SATISFACTION CHAIN: A PANEL NETWORK DEA STUDY OF SPANISH MUNICIPALITIES

Authors: Prof. María Teresa Balaguer-Coll PhD¹; [Prof. Isabel Narbón-Perpiñá PhD²](#); Prof. Diego Prior PhD²; Prof. Emili Tortosa-Ausina PhD¹

Affiliation: ¹ Universitat Jaume I; ² Universitat Autònoma de Barcelona

This study develops a three stage Network DEA model within a Panel Data DEA framework to evaluate the efficiency of 492 Spanish municipalities from 2015 to 2023 across the full public sector value chain. The first stage measures budgetary management efficiency by assessing how different revenue sources (tax, transfers, patrimonial income, and financial operations) are transformed into operational and capital expenditures under alternative hard and soft budget constraint scenarios. The second stage evaluates the ability of municipalities to convert mobilized financial resources into public services, including urban infrastructure, basic services, and social services. The third stage measures citizen satisfaction by linking service outputs to governance quality, civic engagement, safety, cultural participation, environmental behaviour, and socio-economic outcomes. We compute global efficiency and stage specific efficiencies and propose a decomposition identifying how adjusted local inefficiencies shape overall performance. By modelling the full sequence from fiscal capacity to citizen outcomes in a longitudinal setting, this framework addresses a key gap in existing literature, which typically focuses only on service provision. Expected results will show how effectively financial resources are transformed into services and, ultimately, into citizen satisfaction.

14:00 - 15:30 | Mars 2 | Sustainability/Eco-efficiency 5

Chair: Pablo Povedano Fernández

Title: PERFORMANCE EVALUATION OF BUS LINES USING THE BENEFIT-OF-THE-DOUBT APPROACH

Authors: Gabriel Eduardo Cursino da Silva; [Prof. Lucio Silva¹](#); Luann Bruno Vidal de Andrade; Thyago Nepomuceno

Affiliation: ¹ Universidade Federal de Pernambuco

Public transportation plays an essential role in urban mobility, making the evaluation of its performance indispensable. However, some authors point out challenges due to the particularities of the sector. In this context, the Benefit-of-the-Doubt (BoD) emerges as a promising approach by aggregating multiple indicators into a single composite measure, considering the varying importance of each. This study applies the BoD to evaluate the performance of 41 bus lines in a Brazilian municipality between 2024-2025, using bimonthly data. To ensure greater homogeneity, the bus lines were grouped into five clusters according to route length. The BoD with a metafrontier was applied within each cluster, enabling the joint evaluation of bus lines across different months under a common frontier. Six outputs were considered, five desirable and one undesirable. The results indicate that bus lines in Cluster 2 (7 km to 11 km) exhibited the lowest average performance (0.51) compared to the other clusters, whereas those in Cluster 4 (15 km to 22 km) achieved the highest (0.76). Overall, eight bus lines reached maximum performance within their respective clusters in at least one of the analyzed months. Supervised multivariate regression machine learning models were employed to forecast the outputs for the subsequent month. The models were evaluated using the root mean squared error, and the best-performing model was incorporated into the BoD to generate performance scores and define targets.

Title: THE INFLUENCE OF ENVIRONMENTALLY FRIENDLY VEHICLES ON AIR POLLUTION**Authors:** [Maria Jose Perez-Villadoniga](#); Ana Rodriguez-Alvarez; David Roibas; Darío Blanco Fernández**Affiliation:** University of Oviedo

Air pollution negatively affects the environment, human health and imposes substantial economic costs through productivity losses. The transport sector accounts for nearly one quarter of the EU's GHG emissions, with road transport responsible for approximately three quarters of these emissions. To reduce traffic-related air pollution, several actions have been taken in the EU to replace the most polluting vehicles by non-polluting ones, such as fiscal incentives.

To assess the impact of vehicle substitution on air pollution in Spain, we propose the use of a hyperbolic distance function, in which vehicles and fuel serve as inputs to produce traffic (vehicle-km) alongside non-desirable outputs (air pollutants). We assess the impact of environmentally friendly vehicles (based on the Spanish "environmental labels") on reducing pollution. We include meteorological variables and industrial GDP to control for their influence on pollution. Since factors such as weather conditions or vehicle type may affect desirable and undesirable outputs differently, we use the model in Perez-Mendez et al. (2019) to take this into account.

We use a panel dataset, where the Communities are the cross-sectional units. The period of analysis starts in 2016, when the "environmental labels" were introduced, and extends to include the most recent data available.

Key words: environmental pollution, traffic, distance function

Title: PRODUCTIVE EFFICIENCY OF METRO DC: 2020-2025—A SPATIAL ANALYSIS APPROACH**Authors:** [Robert Mosheim PhD](#); Carl Pasurka

This project attempts to evaluate the Metro subway system using productivity analysis measures like technical, allocative and scale efficiency as well as environmental efficiency using data from Metro's recent "Open Data" policy as well as EPA data on air quality.

Washington Metropolitan Area Transit Authority (WMATA) has recently improved operations through operational enhancements, technology upgrades and extended service. I am formulating a model with two outputs (one desirable and one undesirable), three inputs, labor, capital and energy, as well as several exogenous variables like train punctuality and mechanical failures. Data consists of observations for the 98 stations of the metro system over 6 years. This data is merged with data on local air pollution to quantify the statement that the primary environmental benefit DC Metro Rail (for example) is massive reduction in regional CO₂, NO₂ and CO emissions by providing an alternative to single-occupancy vehicles.

This study applies spatial econometric techniques. I test for the appropriateness of applying spatial techniques, construct a weight matrix for the entire Metro rail system and proceed to derive direct, indirect and induced effects. Environmental factors are considered when deriving the size of the environmental factors. The study estimates WMATA's environmental benefit to the entire region.

Title: FROM BLIND FUNDING TO SMART ALLOCATION: OPTIMISING ECO-EFFICIENCY IN URBAN TRANSPORT SERVICES**Authors:** Víctor Giménez¹; Gemma Pérez López²; [Pablo Povedano Fernández](#)²; Diego Prior¹; José Luis Zafra Gómez²**Affiliation:** ¹ Universidad Autónoma de Barcelona; ² University of Granada

This study evaluates the eco-efficiency of urban transport services from two complementary perspectives: the local operator and the funding Ministry. It distinguishes between operational outputs, which measure mobility provision, and environmental outputs, which focus on mitigating negative externalities like CO₂ emissions. Using a Data Envelopment Analysis (DEA) approach with variable returns to scale, the research applies a dual-model framework. Model 1 assesses managerial efficiency, determining the maximum environmental output achievable given current resources. Model 2 optimizes the environmental subsidy allocation to maximize sustainability without increasing costs or reducing current service levels.

By comparing both models, municipalities are classified as having "Managerial" or "Financial" limitations. Findings reveal significant heterogeneity in sector performance. The majority of municipalities exhibit a Managerial Limitation, often receiving excessive subsidies that do not translate into proportional improvements

in service quality or sustainability. Conversely, the Financial Limitation group suffers from structural underfunding, where current subsidy caps restrict their latent environmental potential. Results suggest the subsidy system requires a strategic, performance-based redistribution to align fiscal incentives with decarbonization goals, rather than a global increase in public spending.

16:00 - 17:10 | Terra | Manufacturing 2

Chair: Robin Sickles

Title: DO RECENT PUBLIC R&D FUNDING INCREASE SPANISH FIRMS' R&D? AN EMPIRICAL EVALUATION USING MACHINE-LEARNING TECHNIQUES

Authors: [Dr. Dario Blanco Fernandez PhD¹](#); Prof. Desiderio Romero Jordán PhD²; Prof. Inmaculada C. Álvarez PhD³; Prof. Luis Orea¹

Affiliation: ¹ University of Oviedo; ² Universidad Rey Juan Carlos; ³ Universidad Autónoma de Madrid

This study aims to assess the impact of public R&D funding on the R&D spending of Spanish manufacturing firms, using data from the ESEE survey for 2012–2023, coinciding with the Next Generation EU package. Prior research has extensively examined the effects of public funding on business R&D, increasingly relying on policy evaluation tools such as regression discontinuity designs and difference in differences. Our contribution is twofold. First, we focus on the most recent public R&D funding received by Spanish firms, which likely differs in nature from earlier programs. Second, we contribute methodologically to this field by implementing a machine learning enhanced synthetic control framework, which is more suitable than traditional quasi experimental approaches, as it allows us to capture complex relationships among variables in the so-called treatment equation. We then estimate treatment effects at the firm, year, and aggregate levels. This method mitigates misspecification biases often found in this literature. Our data supports the proposed methodology, as we find remarkable nonlinearities in our treatment equation. Overall, our empirical exercise shows how these new funds have been channeled, as our findings indicate that public R&D funding significantly increases external R&D expenditure but does not affect internal R&D investment. This suggests that subsidies primarily finance additional outsourced research rather than expanding firms' internal R&D capabilities.

Title: BRIDGING THE TECHNOLOGY GAP: ABSORPTION, ADOPTION AND TFP GROWTH OF INDIAN MANUFACTURING FIRMS

Authors: [Anuvinda Anuvinda](#); Dr. Vipin Valiyattoor PhD

Affiliation: Indian Institute of Science Education and Research Bhopal

Developing nations often rely on trade channels and foreign direct investment to boost their productivity growth and efficiency. However, evidence indicates that spillover effects from these channels might not improve the performance of firms if they do not have the capacity to absorb and adopt these technologies to meet their local requirements. The weaker firms might then be forced to exit the market due to the heightened competition. This study examines the impact of technology absorption and adoption on the total factor productivity of Indian manufacturing firms and analyzes the factors that influence their absorption capacity. Firms are classified as adopters of technology using cutting-edge tools based on Large Language Models, implemented on the technology notes (unstructured) of the firms. We find that the technology absorptions happen mainly through two channels -Internal R&D and imported /licensed technologies, which account for nearly 70-80% of the reported technology absorption strategies. Sector-wise analysis reveals a heterogeneous effect of the government of India's 2014 mandate across industries. Technology absorption efforts were found to have a negative influence on the technical efficiency change component (TEC) and reflecting a dynamic trade-off between absorption and efficiency. No significant effect was observed on the Technological Change (TC) component, which may be due to the gestation period required to realise technology-driven gain.

Title: THE ROLE OF SPATIAL DYNAMICS IN LABOR PRODUCTIVITY: A REGIONAL MULTIFACTOR PARTITIONING ANALYSIS OF MEXICO'S MANUFACTURING SECTOR: 1993-2018

Authors: Prof. Jesús Antonio López Cabrera PhD¹; Prof. Miguel Alejandro Flores Segovia PhD¹; [Prof. Robin Sickles PhD²](#)

Affiliation: ¹ Tecnológico de Monterrey; ² Rice University

Over the past 30 years, Mexico's economic liberalization has reshaped regional economic activities, resulting in a closely interconnected regional economy with strong global value chains (GVCs), particularly in the manufacturing sector, significantly impacting regional and industrial productivity dynamics. Our paper focuses on the distribution of economic activity across both space and time, also referred to as spatial dynamics. The economic activity we study is regional labor productivity within the Mexican manufacturing sector from 1993 to 2018, and our interest is in how it differs across various manufacturing segments characterized by distinct innovation processes, thereby influencing regional trajectories. We use two complementary methods. One is modified Multifactor Partitioning (MFP) and the other is formal spatial econometric modeling to identify potential spatial dynamics ignored in classical labor productivity decompositions. We find disparities in manufacturing labor productivity growth across regions and taxonomy groups, significant regional and interaction effects in the northern and central northern regions for specialized suppliers, and weaker effects in the southern and central regions for scale-intensive industries. These insights are valuable for policymakers seeking to address labor productivity disparities and promote more balanced economic development.

16:00 - 17:10 | Jupiter | Sustainability/Eco-efficiency 6

Chair: Iulia Siedschlag

Title: A CIRCULAR SLACKS-BASED METAFRONTIER PSEUDO-MALMQUIST INDEX FOR GROUP PERFORMANCE COMPARISON: APPLICATION TO GLOBAL PETROLEUM FIRMS

Authors: [Dr. Kwaku Ohene-Asare PhD¹](#); Emily Asaa Addison²; Dr. Eric D. Ofofu-Hene PhD³

Affiliation: ¹ University of Ghana Business School; ² Presbyterian University, Abetifi, Ghana; ³ Leeds Beckett Business School

Comparing performance across heterogeneous groups of decision-making units remains methodologically challenging when technologies differ and undesirable outputs are present. Conventional pseudo-Malmquist indices often face cross-group infeasibility, rely on radial measures, and blur the distinction between efficiency dispersion and structural technology gaps.

This paper develops a circular slacks-based metafrontier pseudo-Malmquist index (SMPM) that guarantees feasibility, satisfies transitivity, and incorporates non-proportional inefficiencies and undesirable outputs within a unified framework. The proposed index also enables a four-part decomposition into pure and scale efficiency spreads and pure and scale-related technology gaps. Interpretation rules are clarified under both constant and variable returns to scale. A Monte-Carlo study demonstrates that SMPM dominates the classical pseudo-Malmquist index and the circular pseudo-Malmquist index in terms of feasibility, ranking accuracy, and stability.

An empirical application to 58 global petroleum firms in 2024 shows that ownership differences are primarily efficiency-driven, whereas multinational advantages arise mainly from scale-related technology gaps. The framework provides a robust and operationally meaningful basis for benchmarking heterogeneous firms in sustainability-sensitive industries.

Title: DO PUBLIC-PRIVATE PARTNERSHIPS IMPROVE ENVIRONMENTAL PRODUCTIVITY? EVIDENCE FROM JAPAN'S SEWAGE TREATMENT SECTOR

Authors: [Prof. Takayoshi Nakaoka PhD](#)

Affiliation: Doshisha University

The purpose of a public-private partnership is to utilize the resources of private businesses in public services. In countries experiencing economic contraction, where the population size is expected to decrease over time, public services face challenges in resizing and improving efficiency. Implementing PPPs presents a viable and attractive strategy for policymakers. However, in response to residents' concerns that cost-cutting may compromise the quality and reliability of services, excessive wastewater treatment could occur, leading to deteriorated environmental performance. In this study, using 20 years of panel data of Japanese sewage treatment services and the Comprehensive Outsourcing Contract, which is a typical management contract of PPP in Japan, we investigate the impact of PPPs on environmental productivity by applying Data Envelopment Analysis. To address the endogeneity for implementing PPPs, we make a matched sample consisting of the treatment group that has signed the PPP contracts and the control group that has not yet signed them. Then, we apply the Camanho and Dyson-type Luenberger indicator introduced by Aparicio et al. (2021) to compare

productivity change between the treatment and control groups. Our results show that environmental productivity improves significantly during the initial contract period. However, after contract renewal, this positive effect disappears and productivity instead tends to decline, suggesting the possibility of a lock-in effect.

Title: TECHNOLOGY SPILLOVERS FROM FOREIGN DIRECT INVESTMENT ON THE GREEN INNOVATION PERFORMANCE OF LOCAL FIRMS

Authors: [Prof. Dr. Iulia Siedschlag PhD](#); Dr. Juan Duran PhD

Affiliation: Economic and Social Research Institute

This paper investigates whether and the extent to which foreign direct investment (FDI) generates technology spillovers on the green innovations (innovations with environmental benefits) of indigenous firms. While a large number of studies have examined productivity spillovers from FDI, the role of technology spillovers from FDI on the green innovation performance of domestic firms has been less explored. Using firm-level data from the Innovation in Irish Enterprises Survey over the period 2006-2022 combined with data from the World Input-Output database (WIOD), we examine both horizontal (intra-industry and intra-region) and vertical (supply chain) green innovation spillovers from foreign affiliates. Taken together, the results of this research indicate that technology spillovers from foreign affiliates could enhance the green innovation performance of indigenous firms. Further research results indicate that local firms engaged in R&D activities benefit from spillovers.

Keywords: Foreign direct investment, technology spillovers, green innovations

16:00 - 17:10 | Venus 1 | Justice 3

Chair: Jaap Bos

Title: NOT ALL CASES ARE CREATED EQUAL (OR WHY WEIGHT RESTRICTIONS ARE ESSENTIAL IN COURT EFFICIENCY STUDIES)

Authors: [Professor Mette Asmild PhD](#)¹; Alexander Öttl PhD¹; Prof. Jonas Månsson²

Affiliation: ¹ University of Copenhagen; ² Blekinge Institute of Technology

Court efficiency analyses, most of which employ Data Envelopment Analysis (DEA), are becoming increasingly prevalent in the literature, possibly influenced by the EU COST Action “Efficient Justice for All: Improving Court Efficiency through EU Benchmarking (EfficientJustice)”. A common feature of many DEA based studies is the use of counts of solved cases within different case types as separate outputs. However, this practice implicitly treats all case types as requiring comparable levels of resources, despite substantial and well documented variation in their complexity and workload implications.

In this paper we first argue why it is not appropriate to do DEA-based court efficiency studies with different case types as outputs without either first complexity weighting the cases somehow or alternatively including weight restrictions. We next discuss different possible criteria that may be used to choose the flexibility of the weight restrictions relative to a set of fixed weights.

Title: IT’S A COMPLEX CASE: BENCHMARKING COURTS OF JUSTICE

Authors: [Prof. Jaap Bos](#)¹; Prof. Mette Asmild²; Deborah Kaut¹

Affiliation: ¹ Maastricht University; ² University of Copenhagen

Complexity poses a fundamental challenge to measuring performance in public institutions, where outputs differ not only in quantity but in the inherent difficulty of the tasks performed. This problem is critical in the judicial sector, where conventional analyses often treat all cases (possibly within some overall case types) as comparable, thereby conflating managerial performance with variation in docket composition. We develop a complexity-adjusted benchmarking framework that decomposes case difficulty into expected and unexpected components. Drawing on data from Denmark’s 24 district courts (2016-2019), we show that expected complexity accounts for a significant amount of inefficiency in the system when measured against a single production frontier. When complexity adjustments are introduced sequentially, expected complexity also leads to pronounced changes in courts’ relative efficiency rankings. Unexpected complexity, by contrast,

reflecting idiosyncratic extremely complex cases, accounts for little of the overall variation in efficiency in both specifications. Yet when zooming in on the efficiency distributions within models, it is observed that especially smaller courts struggle with unexpected complexity. Accounting for both mechanisms reduces the risk of misguided reforms and yields a more accurate basis for evaluating and funding judicial performance.

16:00 - 17:10 | Mars 1 | Education 3

Chair: Gaetano Francesco Coppeta

Title: A BI-OBJECTIVE OPTIMIZATION APPROACH FOR STRATEGIC BENCHMARKING IN INTERVAL SCALE DEA WITH AN APPLICATION TO THE NATIONAL STUDENT SURVEY (NSS) IN THE UK

Authors: [Dr. Akram Dehnokhalaji](#)¹; Dr Nasim Nasrabadi²; Prof. Banu Lokman³

Affiliation: ¹ Aston Business School; ² University of Birjand; ³ University of Portsmouth

In this paper, we investigate the strategic benchmarking problem and develop a step-wise target-setting approach for guiding inefficient decision-making units (DMUs) towards Pareto optimal efficiency. We first formulate a target-setting DEA model to identify an intermediate benchmark that strictly improves the interval scale efficiency score. Building on this model, we develop a bi-objective optimization problem to generate a sequence of intermediate and final targets and achieve full efficiency with a prespecified number of iterations. The proposed method enables the decision makers to incorporate managerial priorities by specifying preferred directions for improvement. This will increase the practicality and flexibility of the benchmarking process. We also propose several mechanisms to improve computational efficiency of our proposed model. Although the methodology is developed for interval-scale DEA models, it is applicable to ratio-scale data as well. Numerical examples and an application to the efficiency analysis of UK universities using National Student Survey (NSS) data illustrate the performance of the proposed framework. We show that the method is computationally efficient and produces implementable improvement paths, providing an effective tool for strategic performance improvement.

Keywords: Interval scale data, Step-wise target setting, Bi-objective optimization.

Title: PERFORMANCE ASSESSMENT OF EUROPEAN EDUCATION SYSTEMS AT THE REGIONAL LEVEL: DECOMPOSING TEMPORAL TRENDS USING A ROBUST CONDITIONAL MALMQUIST INDEX

Authors: [Fernando Osório](#)¹; Prof. Ana Camanho PhD¹; Prof. Flávia Barbosa PhD²; Prof. Giovanna D'Inverno PhD³

Affiliation: ¹ INESC TEC, Faculdade de Engenharia, Universidade do Porto; ² INESC TEC, Faculdade de Economia, Universidade do Porto; ³ University of Pisa

This paper proposes a robust conditional approach based on a range directional 'Benefit-of-the-Doubt' (BoD) model to monitor the evolution of performance from 2020 to 2023 in the education and training systems of 200 European regions, including 180 at NUTS2 level. The methodological framework first establishes an 'ideal' performance point, representing the most ambitious level between empirically observed best practices and aspirational benchmarks identified by experts or policymakers. Subsequently, we propose a decomposition of the Malmquist Productivity Index under a BoD setting that isolates temporal and contextual effects while monitoring performance trends. The results revealed that Europe is progressing at uneven speeds, with notable disparities both within and across countries. While numerous regions exhibited marked improvements driven by significant gains at the best-practice frontier, others experienced notable performance declines, primarily due to efficiency setbacks.

Title: ECONOMIES OF SCALE AND SCOPE IN EUROPEAN HIGHER EDUCATION: THE ROLE OF SUBJECT MIX

Authors: [Dr. Gaetano Francesco Coppeta](#); Tommaso Agasisti; Prof. Luigi Brighi

Affiliation: Politecnico Di Milano , Italy

This paper examines economies of scale and scope in European higher education, focusing on how subject orientation shapes production technologies. Using panel data from the European Tertiary Education Register (ETER) combined with bibliometric information, we analyze 509 public universities over 2011–2019.

University technology is modeled through an input distance function within a stochastic frontier framework, estimated using a Generalized True Random Effects specification. Exploiting duality, we derive measures of economies of scale and scope directly from the estimated technology. We account for heterogeneity by distinguishing three technologies: generalist universities (STEM, Humanities and Health), medical-oriented institutions, and non-medical universities specialized in STEM and Humanities. Results reveal substantial heterogeneity in efficiency and scale - scope properties across technological groups. Economies of scale and scope depend systematically on subject mix, with medical education significantly affecting input requirements and output complementarities. The findings highlight the importance of technological heterogeneity in interpreting performance differences across European higher education systems.

16:00 - 17:10 | Mars 2 | Gender & Social Efficiency

Chair: Isotilia Costa Melo

Title: GENDER EFFECTS ON MICROFINANCE SOCIAL EFFICIENCY: A ROBUST APPROACH INCORPORATING UNDESIRABLE OUTPUTS

Authors: Prof. Dr. Cinzia Daraio; Prof. Dr. Francois Seck Fall; Prof. Leopold Simar; [Prof. Dr. Anne vanhems](#)¹

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This study investigates the impact of gender diversity at both the strategic and operational levels on the social efficiency of microfinance institutions (MFIs). Specifically, we assess how the presence of women on boards and among loan officers influences MFIs' ability to deliver social outcomes, particularly in serving female borrowers, considering the portion of the loan portfolio that is delinquent or overdue as an undesirable output. Using a novel robust nonparametric frontier estimation method developed by Daraio & Simar 2024, we estimate both efficiency scores and their derivatives, allowing for a more nuanced evaluation of marginal effects and returns to scale. Our analysis draws on a cross-sectional dataset of 346 MFIs worldwide, incorporating directional distance functions and conditional efficiency frontiers based on external gender-related variables. The findings reveal that while the direct effect of gender composition on inputs and outputs is limited, there is a significant joint and non-linear impact of female board and loan officer representation on mitigating the negative effects of portfolio delinquency. These results underscore the importance of integrated gender diversity across strategic and field levels in enhancing the social performance of MFIs and provide actionable insights for policymakers aiming to promote inclusive financial practices.

Title: GENDER, ICT ADOPTION AND TECHNICAL EFFICIENCY: A SELECTION-CORRECTED STOCHASTIC FRONTIER ANALYSIS OF INDIA'S UNINCORPORATED MANUFACTURING SECTOR

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Microenterprises form the backbone of economic development and employment generation in India, yet they often struggle with low productivity and limited scalability. Understanding the role of digital technologies in overcoming these challenges is therefore crucial. This study examines the impact of information and communication technology (ICT) adoption on the technical efficiency of micro manufacturing units, with a particular focus on gender differences, using firm-level cross-sectional data on unincorporated enterprises in India. The stochastic frontier framework is applied while accounting for production heterogeneity and correcting for potential selection bias associated with ICT adoption in order to obtain unbiased estimates of technical efficiency among unincorporated manufacturing units. We also account for heteroscedasticity in the inefficiency term. The findings show that ICT adoption enhances efficiency, with female-owned units exhibiting systematically higher inefficiency compared to male-owned units. At the same time, internet adoption yields relatively greater efficiency gains for women entrepreneurs, though their overall performance still lags that of male-owned units. These findings reflect the dual role of ICT, acting both as a driver of productivity through efficiency gains and as a potential leveller, while highlighting the importance of targeted interventions to overcome the structural barriers that continue to constrain the informal sector.

Title: INVERTED SBM-VRS BENCHMARKING OF WORKFORCE RELATIONS STABILITY UNDER MODERN SLAVERY RISK PRESSURES

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Modern slavery risk is amplified by socio-technical pressures that destabilize workplace governance, yet firms and sectors lack a benchmarking tool to diagnose where risk concentrates. We apply Multivariate Analysis and Slacks-Based Measure (SBM) Data Envelopment Analysis (DEA) model under Variable Returns to Scale (VRS) with an inverted efficiency logic to rank 1,990 firms from European Union, i.e. Decision-Making Units (DMUs), by risk. A firm is on the inverted frontier when it exhibits high institutional and innovation risk regarding global industry context with low outcome regarding Workforce Stability & Social Climate. Using our dataset, we model the Global Industry Context as inputs, i.e. Institutional Risk Context (IRC) and Innovation Risk Profile (IRP), and protective outcome as output: Workforce Stability & Social Climate (WSSC). Under the inverted SBM-VRS, firms closer to the inverted frontier are those for which stronger IRC/IRP pressures are associated with weaker WSSC, while firms farther from the frontier sustain higher WSSC despite adverse contexts. The resulting scores reveal heterogeneity and identifiable clusters of high-risk profile under combined institutional and innovation pressures. The results of the model provide slacks and inverted efficiencies to be considered on the analysis to move away from the inverted frontier. The approach supports prioritization of risk profiles in modern slavery due diligence for Supply Chain Management.