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Parallel Session "*Mathematical methods for sustainability challenges*" September 15th, 14:00 – 17:40 <u>https://meet.google.com/nwy-eoot-dsu</u>

**BOOK OF ABSTRACTS** 

# Retailer-consumers model in electricity market under demand response

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## Extended abstract<sup>1</sup>

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In order to meet emission reduction targets, power systems are evolving towards a generation mix that is more decentralized, less predictable and less flexible to operate due to the massive integration of renewable and distributed energy sources. To enable the large-scale integration of these renewables and to enhance the decarbonizing of electricity systems without endangering the security of supply, additional flexibility is needed to be provided in the form of demand-side management (DSM), and in particular, via demand response programs [1, 2, 3]. Demand response (DR) programs have gained much attention during the last three decades to optimize the decisions of the electricity market participants. It can potentially enhance system reliability and manage price volatility by modifying the amount or time of electricity consumption.

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Given the DR literature is maturing in many respects, there are still gaps in using the program to solve the structural problems with conflicting objectives of players under uncertainty. Particularly, there is a need for novel approaches which guide the design of DR programs that integrate RES into the power system wherein consumers' behavior towards the market is accounted for explicitly via utility functions under uncertainty [4, 5].

Our paper addresses this research gap by modeling and solving an energy retailer's problem whose objective is to maximize profit, and consumers' problem whose objective is to maximize their utility and reduce electricity bills, given the inherent uncertainties in the market. The problem is solved by two market frameworks, first by modeling retailer's market power through a bi-level program which can be solved as a nonlinear mathematical program with equilibrium constraints (MPEC), and second by considering an equilibrium model with perfect competition solved as a mixed-integer linear programming (MILP) problem. The required techniques to test and compare the performance of the models are undertaken with realistic data. The paper finds the following main results: (1) The retailer can maximize its expected profit with market power. (2) The consumers can minimize their procurement cost and disutility with the equilibrium model. (3) The proposed models are adaptable to any group of consumers with flexible demand and with different market configurations. (4) There is a significant cost-saving potential while adopting the DR program as the social welfare is optimal for both players. (5) Modeling the consumers' behavior explicitly with their utility function under a dynamic pricing environment reveals more information towards the integration of the much-needed renewable sources into the power system using smart technologies.

The proposed model can be further extended in different directions. (1) we can model generating companies and market operators' problems by applying a similar methodology employed in our paper. (2) We can include the RES generation schedule and main grid trading constraints by explicitly modeling consumers' problems with intelligent appliances so that they can trade their energy instead of being net consumers. (3) We can consider pollution in the objective function of DR optimization problem which could give better policy direction to the integration of technology, market, and innovation in the power system to achieve emission reduction targets.

#### Keywords

Demand response; Complementarity constraints; MILP; MPEC; Retailercustomer equilibrium.

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# Forecasting and investigating dependence between renewable and non-renewable energies via a Mixture copula-ARJI-GARCH model

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## Extended abstract<sup>1</sup>

Following Chan & Maheu (2002) [1] and Chang (2012) [2], we set up a Mixture-copula-based on the ARJI-GARCH model to investigate the timevarying and nonlinear dependence between renewable and non-renewable energies. The data of our analysis consists of daily closing prices of the Dax Global Alternative Energy Index and the MSCI World Energy Index for traditional commodities. The sample period spans from 01/01/2013to 06/02/2020, for a total of 1852 data points per series retrieved from Bloomberg. Like Chan & Maheu (2002) [1], we develop a GARCH model with the auto-regressive jump-intensity (ARJI) specification designed as an auto-regressive moving average form to capture many form of autocorrelation. The jump model coupled with a generalised autoregressive conditional heteroscedasticity (GARCH) specification of volatility is a very useful framework to provide reliable forecasts. With this model we can take into account

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the persistence in the conditional variance and the time variation in the conditional jump intensity which implies time variation in the volatility and also in the conditional skewness and kurtosis related to the mean and variance of jump size and jump intensity of the returns. Many energy markets are subjected to rapid and often unexpected changes that lead to jumps either upwards or downwards, due to natural disasters, geopolitical developments, strategic action and many others unexpected events. Consequently a considerable part of variance can be attributed to the extreme price movements leading to heavy-tailed distributions on the returns observed in the market under study. According to the Literature, the ARJI-GARCH model is a useful tool for dealing with extreme events and sudden price chances (see e.g. Lee et al., 2010 [3] among others). In the second step of our study, drawing attention to the co-movement structure over time in the extreme left and right tails respectively, we can capture the asymmetric dependence between renewable and non renewable indexes through a mixture of Clayton and Gumbel copulas (see Chang, 2012 [2]). These results were then used in hedging operations.

#### Keywords

Jump process; Copula; Nonlinear dependence; Energy markets.

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# Optimal design of exchange networks with blind inputs and its application to Eco-industrial parks

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## Extended abstract<sup>1</sup>

Motivated by the design and optimization of the water exchange networks in Eco-Industrial Parks (EIP) [1], we investigate the abstract Blind-Input model for general exchange networks [2]. This abstract model is based on a Game Theory approach, formulating it as a Single-Leader-Multi-Follower (SLMF) game [3, 4]: at the upper level, there is an authority (leader) that aims to minimize the consumption of natural resources, while, at the lower level, agents (followers) try to minimize their operating costs. We introduce

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the notion of Blind-Input contract, which is an economic contract between the authority and the agents in order to ensure the participation of the latter ones in the exchange networks. More precisely, when participating in the exchange network, each agent accepts to have a blind input in the sense that she controls only her output fluxes, and the authority commits to guarantee a minimal relative improvement in comparison with the agent's stand-alone operation. The SLMF game is equivalently transformed into a single mixed- integer optimization problem. Thanks to this reformulation, examples of EIP of realistic size are then studied numerically.

#### Keywords

Optimization; Eco Industrial Park; Game theory; Single-Leader-Multi-Follower.

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# ICT as a determinant of inefficiency: An efficiency measurement in education of selected OECD countries

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## **Extended abstract**<sup>1</sup>

The role of information and communication technologies (ICT) in education is well established. There seems to be a consensus among scholars and practitioners that ICT has benefited efficiency and effectiveness of daily organization [1]. While effectiveness denotes the extent to which ICT can improve education outcomes, efficiency refers to the extent to which ICT can replace traditional instruction methods. Regarding the efficiency measurement of educational institutions, there is a large literature examining this issue. However, the role of ICT as a determinant of inefficiency is scarcely addressed. This paper aims to investigate the efficiency of selected 24 OECD countries in terms of education by including ICT as a determinant of inefficiency. Using the OECD PISA data of 2009 to 2018, we used the parametric approach namely, stochastic frontier analysis, to accomplish the objective of the study. Four random components of the stochastic frontier model, i.e., statistical noise, individual heterogeneity, persistent inefficiency, and timevarying inefficiency, were incorporated into the model [2], [3], [4]. This study represents the first attempt of an efficiency analysis in an international comparison by modelling the four-component heteroscedastic model, where the ICT plays as a determinant of the time-varying inefficiency. This study is expected to allow more purposeful policy recommendations as well as expand the literature regarding efficiency measurement in education.

## Keywords

Education; Efficiency; ICT; Panel data; Stochastic frontier analysis.

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# Semiparametric multinomial multilevel models for predicting higher education dropout

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## Extended abstract<sup>1</sup>

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In the era of the data collection, many applicative studies deal with categorical data, but the developments of regression models for multinomial responses are, in some cases, still limited. Categorical hierarchical data are an example in which the interaction between multilevel and multinomial models induces numerical and modelling difficulties [1]. In this study, we analyse Politecnico di Milano data with the aim of profiling students, standing on the final outcome of their concluded university career [2]. In particular, we distinguish between graduate, early dropout and late dropout students. This study's aim is to model and predict the probability of students to belong to

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these three categories, considering, in addition to their personal characteristics, their nested structure within 19 engineering degree programmes. To this end, we propose a semiparametric multinomial multilevel model [3, 4] in which we consider students (level 1) nesed within degree programs (level 2). We assume the random-effects coefficients to follow a discrete distribution with an a priori unknown number of support points, that represent subpopulations within which highest level units are clustered. We develop an EM algorithm to estimate the model parameters [5]. Since the random effects of different logits (i.e., realtive to each response category) arise from the same subject, we model the joint distribution of the random-effects coefficients across response categories. The advantage introduced by the proposed modelling is twofold: (i) the former is that, by assuming a discrete distribution at the highest level of the hierarchy, we avoid the integration issues that arise in the parametric approach and we develop a computationally easier alternative to the parametric one; (ii) the latter is that this method can be used as a clustering tool, since it identifies a latent structure of subpopulations at the highest level of the hierarchy.

#### Keywords

Semiparametric models; Multinomial regression; Multilevel models; Student dropout; Higher education.

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# Axiomatic of the multi-equation modeling of pollution-generating technologies and nonparametric estimation

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## Extended abstract<sup>1</sup>

For several decades, two main approaches have dominated the way undesirable outputs are included in production technology. The first approach treats pollution as an additional input and, the second imposes the weak disposability assumption of undesirable outputs. Recently, several studies have pointed out the issues associated with both approaches, notably in terms of implied trade-offs. Among the alternatives, the multi-equation framework or 'by-production' as coined by [1] provides an innovative way of treating undesirable outputs. The by-production approach splits the overall technology into sub-processes, usually two. One is for producing desirable outputs, and the second is for the generation of undesirable outputs. Theoretically, the model provides all the appropriate trade-offs. However, in the DEA framework, representation revolves around appropriately assessing the different output efficiency scores. [1] have suggested that good and bad output efficiencies be measured independently given their respective sub-technology. [2] underlined some issues with independently considered technologies. Using some principles in network analysis, [3] and [4] suggested augmenting

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the DEA model by some dependence constraints that link both technologies. The continuing discussion on properly representing the by-production model in DEA stems directly from the multi-intensity variables describing each a specific sub-technology. A solution to get around this complexity is to estimate a reduced form model that summarizes all the trade-offs implied in the by-production. Based on these trade-offs and their sign, a reduced form DEA model for the by-production can be estimated. This article follows this avenue and is built upon [5], who used a reduced by-production technology for shadow pricing corporate social responsibility. Our contribution lies in providing more discussion on the reduced form and the implications of the different trade-offs. Finally, the reduced form is compared to the existing multi-intensity variables DEA using Monte Carlo simulations.

#### Keywords

undesirable outputs; multi-equation; reduced form; DEA; Monte-Carlo..

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# It's all about hierarchies: An Analytic Hierarchy Process for the EU Waste Hierarchy

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#### Extended abstract<sup>1</sup>

In this paper a new composite indicator is devised by integrating the Goal Programming Synthetic Indicator methodology [1] with the Analytic Hierarchy Process [2, 3]. The proposed approach is used to evaluate to which extent European countries fulfill the European Union (EU) requirements in terms of waste management. Taking into account the EU Waste Hierarchy, a dashboard of indicators is identified together with a set of targets that European countries are supposed to meet [4]. By means of the Analytic Hierarchy Process two different scenarios are proposed. The first one rewards the countries with good performance in the higher level of the Waste Hierarchy, while the second one penalizes countries whose infringements are in the lower part of the Waste Hierarchy. While the existing contributions exclude the highest level of the hierarchy and take into account just waste treatment actions, our analysis considers also waste prevention, thus offering a systemic

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circular perspective [5]. The analysis is performed using Eurostat data on 28 European countries from 2013 to 2018. For each year, countries are assessed in terms of their ability to keep the right waste management track delineated by the Waste Hierarchy principles. Countries' ranking over time is first obtained and then interpreted in light of countries policies and achievements, deriving policy suggestions to improve waste management strategy able to reach the expected results.

#### Keywords

Analytic Hierarchy Process; Goal Programming Synthetic Indicator; Ranking; EU Waste Hierarchy; EU waste targets

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# Sustainability and tourist flow networks: a mean field bi-level optimization approach

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## Extended abstract <sup>1</sup>

The widespread acknowledgement of tourism as a strategic pillar for economic growth and development has boosted competitiveness among tourist destinations. This concept has been greatly emphasized during the current COVID-19 pandemic crisis. Nevertheless, the massive presence of tourists imposes the challenge of adopting sustainable tourism practices to balance economic prosperity opportunities with potential threats to the environment and local communities.

There are many definitions for sustainability, but the most effective one is "the capacity to endure" [1]: from an economic perspective this leads to find an equilibrium between short and long-term objectives so that to maximize

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short-term revenues along with long-term growth strategies.

Within the tourism industry a straight definition is provided by the WTO for which sustainable tourism is "tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities"[2]. In this study we apply the tools of the mean field game theory [3] to support a local authorities to deal with the challenging problem of finding the total visitors' experiential satisfaction while attaining the maximum sustainability benefits. To this end, inspired by the study in [4], we introduce a theoretical model that describes the visitors flows in a network which depicts an area of tourist attractions.

We also propose and formalize a bi-level optimal control model which addresses the often conflicting objectives of defining a sustainable-oriented policy by the local authorities while visitor aim at maximizing their satisfaction [5]. Specifically, the model upper level addresses the problem of selecting an optimal sustainable oriented control strategy, while its lower level describes the visitor flows in the assumption that the visitor satisfaction can be expressed in terms of the minimization of an appropriate cost function.

#### Keywords

Sustainability; Tourism Sustainable Management; Bi-level Optimization; Network Flow Optimal Control; Mean Field Game.

Session: Mathematical methods for sustainability challenges (Organizers: G. D'Inverno, R. Riccardi)

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# Groundwater exploitation and illegal behaviors in a differential game

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#### Extended abstract<sup>1</sup>

When a groundwater basin is exploited by a large number of farmers, acting independently, each farm has little incentive to practice conserving it and this can lead to over-extraction of the resource. In countries where groundwater has long been consid- ered an open access good, the definition of new rules to govern access to groundwater and its use is increasingly perceived as necessary. This requires the design of innovative institutional frameworks, involving the redistribution of responsibilities between public authority and user communities and greater use of economic tools that provide incentives for legal and sustainable pumping. This paper constructs, with a differential game approach, both theoretically and empirically, a framework for describing the characteristics of cost-effective groundwater management plans, describing how individual decisions on the use of water in a legal and illegal way to be part of the farmers impact on the water resource and how sanc-

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tions and monitoring activities can mitigate not appropriate behaviors and improve the conservation of the resource.

#### **Keywords**

Groundwater extraction; Water agency; Differential game.

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#### Name of parallel Session:

Mathematical Methods for Sustainability Challenges. Organizers:

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# ESG Investing: A Chance to Reduce Systemic Risk

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## Extended abstract<sup>1</sup>

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This paper studies whether (E)nvironmental, (S)ocial and (G)overnance compliance of assets held in portfolio by equity mutual funds mitigates the negative effects of financial distress which propagates from a fund to another. Three main aspects motivate our research. ESG investing (1) reduces stakeholder risk, (2) relies on longer investment horizons, and (3) exploits a market segment which is not mainstream. We provide an answer to this research question by taking quarterly observations during the period March

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Session: Mathematical methods for sustainability challenges. Organizers: Giovanna D'Inverno, Rossana Riccardi

2016 to June 2018 of the open-ended equity mutual funds that are ESG ranked by Morningstar. In such a network, funds are interconnected only indirectly through the holdings they have in common. Contagion is then indirectly mediated by the overlap between portfolios, and it is due to firesales spillover. To model indirect contagion, we follow [1] who rely on a linear market-impact model [2]. For all cross-sections in our time span, we measure the relative total loss of market value for funds in the top 20% and bottom 20% of the ESG score distribution when all funds in the network liquidate a fraction of their portfolios. We test the alternative hypothesis that the relative total loss experienced by the High ESG ranked funds is different from the relative total loss for the Low ESG ranked funds against the null hypothesis that this difference is zero. We accept the alternative in six out of 10 cross-sections, and when the difference is statistically significant, the loss is always lower for the High ESG ranked funds. Different robustness checks are also performed. Our results show that contagion is less effective among funds achieving high ESG performance in periods with lower asset volatility. In periods of higher asset volatility, we did not observe a clear dominance of the High ESG ranked funds over the other class of funds. **Keywords** 

ESG investing; Systemic Risk; Market Impact; Network; Indirect Contagion.

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