University of Cologne

Department of Economics – Chair in Economics and Energy Economics

Quantitative Methods in Energy Economics

Winter Term 2021/22 – Online Course

Dr. Frank Obermüller

Schedule

	Date	Time	Content	Topic
1	15. Oct	14:00 - 15:30	Introduction / Lecture	EPA
2	15. Oct	16:00 - 17:30	Lecture	EPA
3	29. Oct	14:00 - 15:30	Lecture	EPA
4	29. Oct	16:00 - 17:30	Lecture	EPA
5	05. Nov	14:00 - 15:30	Lecture	Optimization
6	05. Nov	16:00 - 17:30	Lecture	Optimization
7	12. Nov	14:00 - 15:30	Lecture	Optimization
8	12. Nov	16:00 - 17:30	Lecture	Optimization
9	26. Nov	14:00 - 15:30	Office Hours/ Slot for Individual Questions (*Optional)*	
10	17. Dec	14:00 - 15:30		
11	14. Jan	9:00 - 17:00	Student Presentations	Mandatory! EPA / Optimization.
12	23. Jan	23:59h	Strict Deadline for Written Paper Submission	Mandatory!

Participation at the presentation date (14.01.2022) is mandatory.

Deadline for the paper submission is: 23.01.2022, 23:59h.

Note that there is no lecture on 22. Oct. 2021.

Once you have registered for the examination, the registration is binding and students who do not hand in a seminar paper or who do not present their paper will receive a failing grade. Thus, please make sure that you are able to attend the presentation days, before registering for the course.

Objective of this course

The objective of this course is to understand, implement and apply quantitative methods in energy economics. These methods allow fundamental insights for investment decisions e.g. of generation units (renewables, thermals) as well as operational decisions.

The course covers the fields of:

1. **Empirical Productivity Analysis (EPA):**
   Benchmarking analyses which are used e.g. to determine the efficiency and thus the rate-of-return of the natural monopoly. The field of application covers transmission system operators or public transportation.
2. **Electricity Market Optimization:**
   Applying dispatch models which allow to simulate the electricity system with its generating units to fulfill demand

The course aims on enabling the students to perform own analyses in the energy economic sector with these methods.

Course Summary

Course Requirements	The course is designed for Master students or PhD students with a slight background in energy economics. Each student is required to submit and present a research proposal. The student can choose between the two covered topics, e.g. "empirical productivity analysis" or "energy market optimization". The research proposal should not extent 5000 words (approx. 10 pages) which states the purpose, an outline of the applied methodology and data, and a results section with results discussion. Each presentation should be approx. 15 mins with 5 mins discussion.
Language	English
Software	Students are required to use a suitable software for implementation and application of the quantitative methods. 1. Productivity analysis: I recommend using "R" as free statistical programming language, with existing packages for e.g. SFA and DEA. Other software as Stata or Python are suitable as well. (Link to "R": https://cran.r-project.org/bin/windows/) 2. Energy Market Optimization: It is recommended to install the free test Version of GAMS: https://www.gams.com/download/ The free version with restricted number of variables and constraints is sufficient for the small test examples within the course. Other programming languages (matlab, python, etc.) with respective optimization packages are suitable as well. The examples from the course are in GAMS. Template code is provided in GAMS. Most probable, the course will receive a free-of-charge, temporal-limited course license for GAMS which extends the GAMS' free test version capabilities.

Course structure	The course is split into two parts. The first part (first half of the sessions) is dedicated to the first topic of productivity analysis. The second part (second half of the sessions) is dedicated to the second topic of energy market optimization. Each part consists of four lectures in which theory and practical implementation will be studied. After both parts, the students are requested to select one of the two topics for writing a research proposal. The research proposal will be presented at the student's presentation date (presentation and discussion of the paper).
Mode of Examination	combined examination The final grade consists of: • 60% Seminar Paper • 30% Presentation of seminar paper • 10% Oral Discussion
Credits	6 ECTS
Application	Master students: please register on KLIPS. After you receive a seat in the course, make sure to register for the examination (Lehrveranstaltungsprüfung *"Quantitative Methods in Economics")* before December 29th, 23:59. PhD Students, please register for the course by sending an email to Maria Kotzias.
Lecturer	Dr. Frank Obermüller Mail: f.obermueller@hotmail.com
Organisation	Maria Kotzias Mail: maria.kotzias@uni-koeln.de

Content

Part 1 – Empirical productivity analysis

Introduction:

Empirical productivity analysis is a suitable analysis and benchmarking method to assess productivity of business units. One main application is for natural monopolies. Since natural monopolies do not fierce direct competition, productivity analysis is one option to assess their productivity. The distribution system operators in the energy system (electricity as well as gas) are a typical example for natural monopolies. The German regulator "Bundesnetzagentur" needs to assess the productivity of the distribution system operators in order to determine the allowed rate of return. Thus, the Bundesnetzagentur performs a productivity analysis and applies state-of-the-art benchmarking methods like Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). For each system operator, such as RheinEnergie or Stadtwerke München, it is highly relevant to achieve high results on the benchmarking to increase their rate-of-return. A deep understanding of the drivers and methods in the benchmarking are therefore sufficient. This will be covered by the first part of the course.

Course agenda:

- Motivation and current Distribution System Operator (DSO) Regulation in Germany
- DEA: Basic Concepts, Additional topics, Case Studies
- SFA: Basic Concepts, Additional topics, Case Studies

Potential References (no must-read in advance):

- Bogetoft P. and Otto L. (2011), Benchmarking with DEA, SFA, and R, Springer.
- Coelli T., Prasada Rao D.S., O'Donnell C.J., and Battese G.E. (2005), An Introduction to Efficiency and Productivity Analysis 2nd Edition, Springer.
- Coelli T., Estache A., Perelman S., and Trujillo L. (2003), A Primer on Efficiency Measurement for Utilities and Transport Regulators, The World Bank.
- https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/GeneralInformationOnEnergyRegulation/GeneralInformationEnergyReg_node.html
- Agrell, Bogetoft, et al. (2008), Ergebnisdokumentation: Bestimmung der Effizienzwerte Verteilnetzbetreiber Strom, Sumicsid and EE2.
- Agrell, Bogetoft, et al. (2014), Effizienzvergleich für Verteilnetzbetreiber Strom 2013, Swiss Economics & Sumicsid (im Auftrag der BNetzA).

Part 2 – Energy market optimization

Introduction:

The energy market faces increased complexity due to recent changes, e.g. by renewable energies, batteries, industry participation and market integration. Energy system models can help to understand effects and development of the energy market. Those insights are relevant for decisions like power plant investments, grid reinforcements or portfolio extensions. In case a market participant wants to invest in a new wind energy park, hourly electricity prices as well as generation profiles are relevant for the profitability. The system operator needs to estimate whether the grid infrastructure can manage additional generation at this location. And the market regulator needs a good estimate on the long-run system adequacy (i.e. system stability) in case the wind generation pushes secured thermal generation out of the market. The course provides basic theory of the energy system as well as the method of electricity market optimization with GAMS to the students. Additionally, the course covers briefly current topics of energy market optimization such as the physical consideration of the grid via load-flow modeling, high numbers of scenarios as well as the linkage of electricity market models with energy systems (gas, heating, hydrogen, fuels). These extensions are relevant for current governmental studies like Netzentwicklungsplan, Ten-Year Net Development Plan and the Mid-Term Adequacy Forecast.

Course agenda:

- Motivation: Coal-phase out in Germany
- Basics in Optimization and GAMS
- Set up and application of an Electricity market model
- Case Study (Power Plant investment)
- State-of-the-art concepts of electricity system optimization (nodal pricing, load-flow/ptdf, high scenario numbers, energy system modeling)

Potential References (no must-read in advance):

- Rosenthal, Richard E.: GAMS - A User's Guide, 2010. Chapter 2.1
- Several working paper from EWI PhDs and others
- Netzentwicklungsplan (https://www.netzentwicklungsplan.de/de), TYNDP (https://tyndp.entsoe.eu/tyndp2018/), MAF (https://www.entsoe.eu/outlooks/midterm/)
- Kirschen, D. S., & Strbac, G. (2018). *Fundamentals of power system economics*. John Wiley & Sons.

- Morales, J. M., Conejo, A. J., Madsen, H., Pinson, P., & Zugno, M. (2013). Integrating renewables in electricity markets: operational problems (Vol. 205). Springer Science & Business Media.
- Edoli, E., Fiorenzani, S., & Vargiolu, T. (2016). *Optimization methods for gas and power markets: theory and cases*. Springer. *[Note: From my perspective, very advanced reading but with practical relevance for companies, projectors, and decision-makers. Covers uncertainties and the value of flexibility options.]*
- Ing, D. W., Weigt, H., von Hirschhausen, C., Thum, M., & für Energiewirtschaft, D. S. (2009). Modeling competition and investment in liberalized electricity markets.
- Soroudi, A. (2017). Power system optimization modeling in GAMS (Vol. 78). Switzerland: Springer. *[Note that this text book provides some nice topics and examples as well as GAMS code. But it is very important that the Economic Dispatch, ch.2, should have no second order term for fuel costs from my point of view (i.e. $a_i = 0$, p.65ff, eq. 3.1 and subsequent). It is for me very unreasonable to have quadratically increasing fuel costs. My view is that costs of electricity production are in general convex or assumed to be linear. Meaning: The more to produce, the more efficient I can run my generator. This is in line with part-load losses which a generating unit faces if generation is below 100%.]*