Market Design
ECON 40041 (Fall 2020)
Department of Economics • University of Notre Dame

Instructor: Maciej H. Kotowski
Email: <maciej.h.kotowski@nd.edu> [Please include "ECON 40041" in the subject line.]
Office Hours: Tuesday & Thursday 16.30–18.00 [via Zoom; scheduled online]
Class Meetings: Tuesday & Thursday 09.35–10.50 [O'Shaughnessy Hall 115]
Course Website: <https://sakai.nd.edu>

Overview

This course studies the theory and practice of market design, with particular focus on auctions, matching mechanisms, and platforms. Using the tools of microeconomics, game theory, and mechanism design, the course examines the operation of markets and the design of effective market rules. Key topics include spectrum and internet auctions, entry-level labor markets, school choice programs, and financial markets, among others.

Audience

This course is suitable for undergraduate students majoring in economics. Upper-year students in other quantitively-oriented disciplines, such as computer science or mathematics, or students from the business school may also find the course interesting. While the course emphasizes economic content rather than minute technical details, mathematical arguments are employed often. Students with little or no mathematical training will likely be better served by delaying the course until they develop the proper skills.

Prerequisites

The most important prerequisites for the course are a willingness for critical and creative thinking, imagination, and some grit.

Economics: The formal prerequisite for the course is successfully completing a course in intermediate microeconomics. Some familiarity with game theory is helpful but is not required. Students who do not satisfy the formal prerequisite but who otherwise have a strong quantitive background may enroll in the course with the instructor's permission.

Mathematics: Basic algebra and high-school level calculus appear throughout the course. Otherwise, the course is mathematically self-contained. Skills in logical thinking and a willingness to follow mathematical proofs are essential.

Requirements and Grading

The course requirements include the completion of several problem sets, a midterm exam, and a research paper. Your grades on these tasks will be weighted as follows:

Problem Sets	15 %		
Midterm Exam	35 %		
Research Paper	50 %	Proposal	5 %
		Draft	10 %
		Final Paper	35 %
Total	100 %		

Letter grades will be assigned based on your final weighted score.

Problem Sets

Problem sets are graded primarily for completion and only a "✓± / no credit" will be offered for feedback. You are responsible for consulting the suggested solutions on your own to verify your mastery of the material. Earning a ✓− or better gives you full credit for the problem set. Sloppy, half-hearted, late, or incomplete work is unlikely to receive credit. Your lowest problem set grade will be dropped when calculating your course grade.

Unless noted otherwise, you may work in small groups (two or three students) on the problem sets. However, you must hand in independently written-up solutions. If you collaborate, identify other group members on your write-up. There is no need to type up your solutions, but sloppy work will not receive credit. Problem set due dates are the following:

Problem Set	Date Due
1	August 19
2	August 25
3	September 3
4	September 17
5	October 1
6	October 27
7	November 10

Midterm Exam

There will be an in-class midterm exam on October 8, 2020.

The exam is closed-book. Non-programmable calculators are allowed. Other electronics are not allowed.

If you miss the midterm exam and your absence is excusable per university policy (e.g., a documented illness), a rescheduled midterm exam will be arranged on a case-by-case basis. Unexcused absences will receive a grade of zero for this part of the course. In exceptional cases of a prolonged health-related absence or an unexpected disruption to in-person instruction, a take-home exam may be offered instead.

Research Paper

You must write a research paper on a topic related to the course. The approximate length is 4–5,000 words. See the course handout "[1] Research Paper Instructions" for details.

- A paper proposal is due on September 8, 2020.
- A preliminary draft of at least 1,000 words is due on October 23, 2020.
- The final paper is due on November 12, 2020.

Readings

All required readings are freely accessible through the university's library resources.

There is no official or required textbook for the course. The textbook

- [Haeringer] *Market Design: Auctions and Matching* by Guillaume Haeringer (MIT Press, 2018)

provides valuable information on nearly all of the topics on the syllabus. Among all books for the course, this one checks the most boxes. Sometimes, this book is less advanced than the class material.

For many lectures, there are supplemental readings from other books. Sometimes, these books are more advanced than the class material.

- [Bichler] *Market Design: A Linear Programming Approach to Auctions and Matching* by Martin Bichler (Cambridge University Press, 2017).
- [Klemperer] *Auctions: Theory and Practice* by Paul Klemperer (Princeton University Press, 2004).
- [Krishna] *Auction Theory* by Vijay Krishna (Academic Press, 2002/2009).
- [Milgrom] *Putting Auction Theory to Work* by Paul Milgrom (Cambridge University Press, 2004).
- [Roth and Sotomayor] *Two-Sided Matching: A Study of Game-Theoretic Modeling and Analysis* by Alvin E. Roth and Marilda A. Oliveira Sotomayor (Cambridge University Press, 1990).

Among the above titles, Krishna (2009) is the most useful book for the auction theory portion of the course. Roth and Sotomayor (1990) is the most useful book for the matching theory portion of the course. Bichler (2017) is a good compromise—it covers both auction and matching theory. Bichler (2017) and Klemperer (2004) can be freely accessed online via the Notre Dame library website.

There are several popular books that qualify as course-related leisure reading. The following books are informative, readable, and less technical than the course material.

- [Roth] *Who Gets What—And Why: The New Economics of Matchmaking and Market Design* by Alvin E. Roth (Houghton Mifflin Harcourt, 2015).
- [Fisman and Sullivan] *The Inner Lives of Markets: How People Shape Them-And They Shape Us* by Ray Fisman and Tim Sullivan (PublicAffairs, 2016).
- [Evans and Schmalensee] *Matchmakers: The New Economics of Multisided Platforms* by David Evans and Richard Schmalensee (HBR Press, 2016).

Audio/Video Recordings

I kindly ask you not to make personal audio or video recordings of the lectures.

COVID-19 Accommodation and Response

The ongoing public health situation presents a challenge for university operation. *I am nevertheless committed to delivering the best possible learning experience.* Please help me in this endeavor and together we can have a rewarding class.

The following policies will apply this term:

- If you cannot attend a lecture in person due to health concerns (e.g., illness, quarantine order, etc.), please participate in class via Zoom video conference during its regularly-scheduled time. A link will be available on the course website.
- Except for the research paper and the midterm exam, all assignments are to be submitted online. This will require you to upload a `*.pdf` file with your answers.
- All office hour meetings will be conducted via Zoom video conference. A link will be available on the course website for automatic appointment scheduling.
- The university is mandating assigned seating in all courses. Please sit in the same spot for the duration of the term.

Advice

1. Understand and follow the University's Academic Honor Code.
2. Exam questions will resemble problem set questions. Seek out further practice problems—look beyond the assigned class material.
3. Read the assigned readings twice—before *and* after lecture.
4. If pressed for time, practice solving problems in lieu of memorizing a text's details.
5. Paraphrasing advice I've received from Richard Zeckhauser, when you are having trouble getting your thinking straight about a new problem,
   - go to the simplest case;
   - go to an extreme case;
   - try plugging-in simple numbers.

   Remember, appropriate simplification is the great art of economic modeling.
6. Please inform the instructor of typos and suspected mistakes in course materials.
7. Please ask questions in class. Illuminating digressions are exciting. However, I may defer your question to a later date or to office hours if it will get us too far off track.
8. Please make use of office hours. Even if you have no specific questions about the course material, please feel welcome to visit, chat, ask questions, or simply say hello.

Credits and Acknowledgements

In preparing this course I have drawn on the course materials, lectures, research papers, and presentations of many scholars and colleagues. I have also benefited from informal discussions with many of them. In addition to sources on the reading list, the following influenced this course's curriculum, material, and exposition.

- Course syllabi and/or online course materials from similar courses at other institutions, including those by Peter Cramton, Ettore Damiano, Guillaume Haeringer, Fuhito Kojima, Scott Kominers, Paul Milgrom, Daniel Quint, Al Roth, and others.
- My personal and class notes from the course "Auction Theory" taught by Takashi Kunimoto (McGill University, 2006) and from game theory and information economics courses taught by Ben Hermalin, Shachar Kariv, Botond Kőszegi, and Matthew Rabin (University of California, Berkeley, 2006–9).
- Presentation slides from the AEA Continuing Education Program on "Matching Market Design" (Abdulkadiroğlu, Agarwal, and Pathak, January 7–9, 2018).

I have also benefited from many conversations with Chris Avery, Ivan Balbuzanov, Sangram Kadam, Alex Teytelboym, and Richard Zeckhauser about this course's subject matter.

Course Calendar and Reading List

The calendar may be adjusted depending on our progress. You are expected to read essential and required readings. Classic and supplemental readings are recommended, but optional.

Key

- •• *essential reading* — something you must read, period.
- • *required reading* — the lecture presumes you have read this.
- ○○ *classic reading* — an important classic paper; read if you have time.
- ○ *supplemental reading* — consult for more information.

[**1**] **August 11** / Introduction.

- •• Gale, David, and Lloyd S. Shapley. 1962. College Admissions and the Stability of Marriage. *American Mathematical Monthly* 69(1):9–15.
- • Varian, Hal R. 1989. What Use is Economic Theory? Mimeo. `<http://people.ischool.berkeley.edu/~hal/Papers/theory.pdf>`
- ○ Bichler, Chapter 1.
- ○ Eisenmann Thomas R., and Scott Duke Kominers. 2018. Making Markets. Harvard Business School Technical Note 818-096.
- ○ Haeringer, Chapter 1.
- ○ Roth, Alvin E. 2002. The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics. *Econometrica* 70(4):1341–1378.
- ○ Roth, Alvin E. 2008. What have we learned from market design? *Economic Journal* 118:285–310.

[**2**] **August 13** / Technical Essentials 1: Probability and Game Theory.

- ○ Bichler, Chapter 2.
- ○ Haeringer, Appendix A.
- ○ Krishna, Appendices A–C, F.
- ○ Peters, Hans. 2015. *Game Theory: A Multi-Leveled Approach* (Berlin: Springer). `<https://doi.org/10.1007/978-3-662-46950-7>`

[3] August 18 / Technical Essentials 2: Probability and Game Theory (con't).

[4] August 20 / Auctions 1: First-price, second-price, English, and Dutch Auctions.

- ○○ Vickrey, William. 1961. Counterspeculation, Auctions, and Competitive Sealed Tenders. *Journal of Finance* 16(1):8–37.
- ○ Bichler, Chapter 4.1–4.3.
- ○ Haeringer, Chapter 2.
- ○ Klemperer, Chapter 1.
- ○ Krishna, Chapter 2.

[5] August 25 / Auctions 2: Revenue Equivalence.

- ○ Bichler, Chapter 4.4.
- ○ Haeringer, Chapter 2.
- ○ Krishna, Chapter 3.
- ○ Klemperer, Chapter 1 (Appendix 1.A).
- ○ Milgrom, Chapter 4.

[6] August 27 / Auctions 3: Optimal Auctions & Mechanism Design.

- • Bulow, Jeremy, and John Roberts. 1989. The Simple Economics of Optimal Auctions. *Journal of Political Economy* 97(5):1060–1090
- ○○ Myerson, Roger B. 1981. Optimal Auction Design. *Mathematics of Operations Research* 6(1):58–73.
- ○○ Riley, John G., and William F. Samuelson. 1981. Optimal Auctions. *American Economic Review* 71(3):381–392.
- ○ Bichler, Chapter 4.7.
- ○ Klemperer, Chapter 1 (Appendix 1.B); Part C.
- ○ Kotowski, Maciej H. 2018. On Asymmetric Reserve Prices. *Theoretical Economics* 13(1):205–238.
- ○ Krishna, Chapter 5.
- ○ Milgrom, Chapter 4.

[7] September 1 / Auctions 4: Optimal Auctions & Mechanism Design (con't).

[8] **September 3** / Auctions 5: Common and Interdependent Values.

- ○○ Milgrom, Paul R., and Robert J. Weber. 1982. A Theory of Auctions and Competitive Bidding. *Econometrica* 50(5):1089–1122.
- ○ Krishna, Chapters 6 and 7.
- ○ Milgrom, Chapter 5.

[9] **September 8** / Auctions 6: Auctions for Multiple Goods.

- ○ Bichler, Chapter 5.
- ○ Krishna, Chapters 12 and 13.
- ○ Milgrom, Chapter 7.

[10] **September 10** / Auctions 7: The Vickrey–Clarke–Groves (VCG) Mechanism.

- ○ Ausubel, Lawrence M., and Paul Milgrom. 2005. The Lovely but Lonely Vickrey Auction. In *Combinatorial Auctions*. Edited by Peter Cramton, Yoav Shoham, and Richard Steinberg. Cambridge, MA: MIT Press.
- ○ Haeringer, Chapter 4.
- ○ Krishna, Chapter 16.
- ○ Lucking-Reiley, David. 2000. Vickrey Auctions in Practice: From Nineteenth-Century Philately to Twenty-First-Century E-Commerce. *Journal of Economic Perspectives* 14(3):183–192.
- ○ Milgrom, Chapters 2 and 8.

[11] **September 15** / Auctions 8: Position Auctions and Internet Advertisements.

- • Varian, Hal R. 2009. Online Ad Auctions. *American Economic Review: Papers & Proceedings* 99(2):430–434.
- ○ Cowen, Tyler. "Hal Varian on Taking the Academic Approach to Business." *Conversations with Tyler*. Audio File [56:32]. June 19, 2019. `<https://bit.ly/3gH9ITU>`
- ○ Edelman, Benjamin, Michael Ostrovsky, and Michael Schwarz. 2007. Internet Advertising and the Generalized Second-Price Auction: Selling Billions of Dollars Worth of Keywords. *American Economic Review* 97(1):242–259.
- ○ Varian, Hal R. 2007. Position Auctions. *International Journal of Industrial Organization* 25(6):1163–1178.

- ○ Haeringer, Chapter 5.
- ○ Krishna, Chapter 17.

[**12**] **September 17** / Matching Markets 1: The "Marriage Market" Model.

- •• Gale, David, and Lloyd S. Shapley. 1962. College Admissions and the Stability of Marriage. *American Mathematical Monthly* 69(1):9–15.
- ○○ Roth and Sotomayor, Chapters 2 and 3.
- ○ Bichler, Chapter 11.2.
- ○ Haeringer, Chapter 5.

[**13**] **September 22** / Matching Markets 2: The "Marriage Market" Model (con't).

[**14**] **September 24** / Matching Markets 3: The "Marriage Market" Model (con't).

[**15**] **September 29** / Matching Markets 4: The "College Admissions" Model.

- ○○ Roth and Sotomayor, Chapter 5.
- ○ Roth, Alvin E. 1985. The College Admissions Problem is Not Equivalent to the Marriage Problem. *Journal of Economic Theory* 36(2):277-288.

[**16**] **October 1** / Matching Markets 5: The "College Admissions" Model (con't).

[**17**] **October 6** / Application: The National Resident Matching Program.

- • National Residential Matching Program. "How the NRMP Matching Algorithm Works." *YouTube.* Video File [4:51]. October 17, 2017. `<https://youtu.be/kvgfgGmemdA>`
- • Roth, Alvin E., and Elliott Peranson. 1999. The Redesign of the Matching Market for American Physicians: Some Engineering Aspects of Economic Design. *American Economic Review* 89(4):748–780.
- ○ Haeringer, Chapter 10.
- ○ Roth, Alvin E. 1984. The Evolution of the Labor Market for Medical Interns and Residents: A Case Study in Game Theory. *Journal of Political Economy* 92(6):991–1016.
- ○ Roth, Alvin E. 1986. On the Allocation of Residents to Rural Hospitals: A General Property of Two-Sided Matching Markets. *Econometrica* 54(2):425–427.

[18] **October 8** / Midterm Exam.

[19] **October 13** / Matching Markets 6: The Kelso-Crawford (1982) Model.

- ○○ Kelso, Alexander S., and Vincent P. Crawford. 1982. Job Matching, Coalition Formation, and Gross Substitutes. *Econometrica* 50(6):1483–1504.
- ○○ Roth and Sotomayor, Chapter 6.

[20] **October 15** / Allocation and Trading Procedures 1: Trading Cycles.

- ○○ Shapley, Lloyd S., and Herbert Scarf. 1974. On Cores and Indivisibility. *Journal of Mathematical Economics* 1(1):23–37.
- ○ Abdulkadiroğlu, Atila, and Tayfun Sönmez. 1999. House Allocation with Existing Tenants. *Journal of Economic Theory* 88(2):233–260.
- ○ Balbuzanov, Ivan, and Maciej H. Kotowski. 2019. Endowments, Exclusion, and Exchange. *Econometrica* 87(5):1663–1692.
- ○ Haeringer, Chapter 11.

[21] **October 20** / Allocation and Trading Procedures 2: Trading Cycles (con't).

[22] **October 22** / Application: Transplant Organs.

- National Academy of Science. "The Matchmaker: An Economist Tackles Kidney Exchange." *YouTube.* Video File [5:51]. November 30, 2016. <https://youtu.be/TJio37FoOBQ>
- Roth, Alvin E., Tayfun Sönmez and M. Utku Ünver. 2004. Kidney Exchange. *Quarterly Journal of Economics* 119(2):457–488.
- ○ Haeringer, Chapters 16.

[23] **October 27** / Application: School Choice Mechanisms.

- Abdulkadiroğlu, Atila, and Tayfun Sönmez. 2003. School Choice: A Mechanism Design Approach. *American Economic Review* 93(3):729–747.
- ○ Haeringer, Chapters 13 and 14.

[24] October 29 / Application: Radio Spectrum and the FCC Incentive Auction.

- McMillan, John. 1994. Selling Spectrum Rights. *Journal of Economic Perspectives* 8(3):145–162.

○○ Coase, R. H. 1959. The Federal Communications Commission. *Journal of Law and Economics* 2:1–40.

○ Haeringer, Chapter 6.

○ Klemperer, Part D.

○ Milgrom, Paul, and Ilya Segal. 2020. Clock Auctions and Radio Spectrum Reallocation." *Journal of Political Economy* 128(1):1–31.

○ Milgrom, Paul. 2017. *Discovering Prices: Auction Design in Markets with Complex Constraints.* New York: Columbia University Press.

[25] November 3 / Application: Feeding America.

- Prendergast, Canice. 2017. How Food Banks Use Markets to Feed the Poor. *Journal of Economic Perspectives* 31(4):145–162.

○○ Hylland, Aanund, and Richard Zeckhauser. 1979. The Efficient Allocation of Individuals to Positions. *Journal of Political Economy* 87(2):293–314.

○ Prendergast, Canice. 2017. The Allocation of Food to Food Banks. Mimeo.

○ Haeringer, Chapter 1.

[26] November 5 / Application: Electricity Markets.

- Cramton, Peter. 2017. Electricity Market Design. *Oxford Review of Economic Policy* 33(4):589–612.

○ Wilson, Robert. 2002. Architecture of Power Markets. *Econometrica* 70(4):1299–1340.

[27] **November 10** / Application: Financial Markets.

- Budish, Eric, Peter Cramton, and John Shim. 2014. Implementation Details for Frequent Batch Auctions: Slowing Down Markets to the Blink of an Eye. *American Economic Review: Papers & Proceedings* 104(5):418–424.
  - Budish, Eric, Peter Cramton, and John Shim. 2015. The High-Frequency Trading Arms Race: Frequent Batch Auctions as a Market Design Response. *Quarterly Journal of Economics* 130(4):1547–1621.
  - Haeringer, Chapter 7.

[28] **November 12** / Application: Two-Sided Markets and Course Wrap-Up.

- Rysman, Marc. 2009. The Economics of Two-Sided Markets. *Journal of Economic Perspectives* 23(3):125–143.
  - Einav, Liran, Chiara Farronato and Jonathan Levin. 2016. Peer-to-Peer Markets. *Annual Review of Economics* 8:615–35.
  - Rochet, Jean-Charles, and Jean Tirole. 2006. Two-Sided Markets: A Progress Report. *RAND* Journal of Economics 37(3):645–667.