Economics 2099 – Market Design (= HBS 4150)

Scott Duke Kominers

Logistics

Time. Tuesdays, 15:00–17:45+ϵ (beginning September 3, 2019).

Location. FIRST CLASS meets in Littauer 300. Regular meetings are in Aldrich 12.

Office Hours.

- In clusters – `https://2099-group.youcanbook.me/`.
- By appointment – `https://scottk.youcanbook.me/`.
- Over dinner – After class each week, there will be an *optional*, informal "design dinner" in Harvard Square. (Restaurants will be selected via social choice mechanism.)

Course Webpage.

- `http://www.scottkom.com/courses/Market-Design_2019-2020/`.

Teaching Assistant.

- Ravi Jagadeesan (ravi.jagadeesan@gmail.com).

Course E-mail Address.

- econ2099@gmail.com.

Overview

Description. This course explores the theory and practice of market design. Key topics include auctions, labor market matching, school choice programs, online markets, organ exchange systems, financial market design, and matching with contracts. The first half of the course will introduce market design and its technology; subsequent weeks will discuss recent papers alongside their classical antecedents.

Quasi-Prerequisites. Courses in microeconomics (Economics 1011a, 1080, and/or 2010a,b) and game theory (Economics 1052, 2052 and/or 2087hf) will provide useful context and technical background. Some understanding of algorithms, complexity, and/or combinatorics (e.g., Computer Science 121, 124, and/or 224, Math 152, and/or Applied Math 107) will at times be useful. Courses at the intersection of economics and computation (e.g., Computer Science 136, 234, and/or 236r) are highly complementary. However, I do not believe in formal prerequisites—these observations are made only for the purpose of guidance.

If you are interested in taking the course and are concerned about the difficulty of the material, please *see enrollment information below* and then get in touch early in (or before) the fall semester. I am inclined to reward individuals for taking risks and stretching themselves.

Nota Bene. This year, Mohammad Akbarpour and Shengwu Li are teaching a particularly complementary one-off(?) course on "Simplicity and Complexity in Economics" (Economics 2071).

Enrollment. GSAS, HBS, and MIT doctoral students may enroll directly. Students in other programs and schools require permission of the instructor, and will need to file a brief application (at `https://tinyurl.com/2099app19/`) detailing their backgrounds and reasons for wanting to enroll. Applications are due Saturday, September 7, at 23:00 EDT.

Harvard University, Fall 2019.

Requirements. Evaluation will be based upon (1) class discussion and participation, including a few pre- or post-class polls and/or reflections and (2) a written "proposal" sketching the content of a market design research or policy paper.

Proposals can be theoretical, empirical, or policy-oriented. The evaluation standard is slightly different for graduate students and undergraduates: Graduate students should aim to produce a proposal that if completed into a full paper would have a nonzero chance at publication in a top journal (or conference) in the appropriate field; undergraduates should/may aim just below that (a top field journal, or tier-1.5 conference). In any event, all proposals should contain as much of the content of the paper as I should reasonably expect you to be able to complete in a couple of months (or even better, slightly more than that!); this means not just a problem statement and survey of the related literature, but also a detailed description of the solution approach, as well as preliminary results. (More information on proposal structure will be provided later.) If your proposed project is empirical and the data is not available within the timeframe of the class, you should give a clear outline of how the data can be obtained, along with precise specification of the proposed empirical strategy. Group work/collaboration is strongly encouraged. *The more seriously and successfully you undertake the proposal exercise, the more actively I will help you execute the project described therein over the Spring term.*

A one-paragraph summary of your proposal topic idea will be due on September 29, 2019, and a 1-2 page sketch will be due on November 1, 2019. The final proposal will be due on December 9, 2019 (the last day of Reading Period).

How to Read this Syllabus. "Background" readings will be presented in class. Readings listed as "For Class Discussion" will be discussed intensively, and thus should be read in advance. (I will give specific advance reading guidance.) "Further Reading" references may be touched upon in class sessions, but are mostly provided as suggestions for students who wish to explore in more depth.

Topics

Introduction/Overview – September 3, 2019.

For Class Discussion.

David Gale and Lloyd S. Shapley. College admissions and the stability of marriage. *American Mathematical Monthly*, 69:9–15, 1962.

Background.

Ronald H. Coase. The problem of social cost. *Journal of Law and Economics*, 3:1–44, 1960.

Alvin E. Roth. The evolution of the labor market for medical interns and residents: A case study in game theory. *Journal of Political Economy*, 92:991–1016, 1984.

Alvin E. Roth. The economist as engineer: Game theory, experimentation, and computation as tools for design economics. *Econometrica*, 70:1341–1378, 2002.

Alvin E. Roth. Deferred acceptance algorithms: History, theory, practice, and open questions. *International Journal of Game Theory*, 36:537–569, 2008.

Scott Duke Kominers, Alexander Teytelboym, and Vincent P. Crawford. An invitation to market design. *Oxford Review of Economic Policy*, 33:541–571, 2017.

Further Reading.

Christopher Avery, Christine Jolls, Richard A. Posner, and Alvin E. Roth. The market for federal judicial law clerks. *University of Chicago Law Review*, 68:793–902, 2001.

L. E. Dubins and D. A. Freedman. Machiavelli and the Gale-Shapley algorithm. *American Mathematical Monthly*, 88:485–494, 1981.

John H. Kagel and Alvin E. Roth. The dynamics of reorganization in matching markets: A laboratory experiment motivated by a natural experiment. *Quarterly Journal of Economics*, 115:201–235, 2000.

Muriel Niederle and Alvin E. Roth. Unraveling reduces mobility in a labor market: Gastroenterology with and without a centralized match. *Journal of Political Economy*, 111:1342–1352, 2003.

Alvin E. Roth and Xiaolin Xing. Jumping the gun: Imperfections and institutions related to the timing of market transactions. *American Economic Review*, 84:992–1044, 1994.

Alvin E. Roth and Elliott Peranson. The redesign of the matching market for American physicians: Some engineering aspects of economic design. *American Economic Review*, 89:748–780, 1999.

The Market Designer's Toolbox – September 10, 2019.
For Class Discussion.

Parag A. Pathak and Tayfun Sönmez. Leveling the playing field: Sincere and sophisticated players in the Boston mechanism. *American Economic Review*, 98:1636–1652, 2008.

Background.

Parag A. Pathak and Tayfun Sönmez. School admissions reform in Chicago and England: Comparing mechanisms by their vulnerability to manipulation. *American Economic Review*, 103:80–106, 2013.

Nicole Immorlica and Mohammad Mahdian. Incentives in large random two-sided markets. *ACM Transactions on Economics and Computation*, 3:#14, 2015.

Fuhito Kojima and Parag A. Pathak. Incentives and stability in large two-sided matching markets. *American Economic Review*, 99:608–627, 2009.

Eduardo M. Azevedo and Jacob D. Leshno. A supply and demand framework for two-sided matching markets. *Journal of Political Economy*, 124:1235–1268, 2016.

Scott Duke Kominers. Respect for improvements and comparative statics in matching markets. Harvard University Working Paper, 2019.

Benjamin N. Roth and Ran I. Shorrer. Making it safe to use centralized markets: Dominant individual rationality and applications to market design. MIT Working Paper, 2017.

Avinatan Hassidim, Ran I. Shorrer, and Assaf Romm. "Strategic" players in a strategy-proof environment. Hebrew University Working Paper, 2015.

Georgy Artemov, Yeon-Koo Che, and Yinghua He. Strategic 'mistakes': Implications for market design research. 2017.

Shengwu Li. Obviously strategy-proof mechanisms. *American Economic Review*, 107: 3257–3287, 2018.

Further Reading.

Itai Ashlagi, Yash Kanoria, and Jacob D. Leshno. Unbalanced random matching markets: The stark effect of competition. *Journal of Political Economy*, 125:69–98, 2017.

Itai Ashlagi and Yannai A. Gonczarowski. Stable matching mechanisms are not obviously strategy-proof. *Journal of Economic Theory*, 177:405–425, 2018.

Avinatan Hassidim, Déborah Marciano, Assaf Romm, and Ran I. Shorrer. The mechanism is truthful, why aren't you? *American Economic Review Papers & Proceedings*, 107: 220–224, 2017a.

Ran I. Shorrer. Simultaneous search: Beyond independent successes. Pennsylvania State University Working Paper, 2019.

School Choice – September 17, 2019. (Featuring Kentaro Tomoeda.)
For Class Discussion.

Yan Chen and Onur Kesten. Chinese college admissions and school choice reforms: Theory and experiments. Tepper School of Business Working Paper, 2014.

Background.

Michel Balinski and Tayfun Sönmez. A tale of two mechanisms: Student placement. *Journal of Economic Theory*, 84:73–94, 1999.

Atila Abdulkadiroğlu and Tayfun Sönmez. School choice: A mechanism design approach. *American Economic Review*, 93:729–747, 2003.

Atila Abdulkadiroğlu, Nikhil Agarwal, and Parag A. Pathak. The welfare effects of coordinated assignment: Evidence from the New York City high school match. *American Economic Review*, 107, 2017.

Atila Abdulkadiroğlu, Parag A. Pathak, and Alvin E. Roth. Strategyproofness versus efficiency in matching with indifferences: Redesigning the NYC high school match. *American Economic Review*, 99:1954–1978, 2009.

Onur Kesten. School choice with consent. *Quarterly Journal of Economics*, 125:1297–1348, 2010.

Fuhito Kojima. School choice: Impossibilities for affirmative action. *Games and Economic Behavior*, 75:685–693, 2012.

Isa Emin Hafalir, M. Bumin Yenmez, and Muhammed Ali Yildirim. Effective affirmative action in school choice. *Theoretical Economics*, 8:325–363, 2013.

Further Reading.

Atila Abdulkadiroğlu, Parag A. Pathak, and Alvin E. Roth. The New York City high school match. *American Economic Review*, 95:364–367, 2005a.

Atila Abdulkadiroğlu, Parag A. Pathak, Alvin E. Roth, and Tayfun Sönmez. The Boston public school match. *American Economic Review*, 95:368–371, 2005b.

Caterina Calsamiglia and Maia Güell. The illusion of school choice: Empirical evidence from Barcelona. CEPR Discussion Paper No. DP10011, 2014.

Battal Doğan and M. Bumin Yenmez. Unified enrollment in school choice: How to improve student assignment in Chicago. Boston College Working Paper, 2017.

Umut Dur, Scott Duke Kominers, Parag A. Pathak, and Tayfun Sönmez. Reserve design: Unintended consequences and the demise of Boston's walk zones. *Journal of Political Economy*, 126:2457–2479, 2018.

Umut Dur, Parag A. Pathak, and Tayfun Sönmez. Explicit vs. statistical preferential treatment in affirmative action: Theory and evidence from Chicago's exam schools. 2016.

Federico Echenique and M. Bumin Yenmez. How to control controlled school choice. *American Economic Review*, 105:2679–2694, 2015.

Roland G. Fryer, Jr. and Glenn C. Loury. Valuing diversity. *Journal of Political Economy*, 121:747–774, 2013.

John William Hatfield, Fuhito Kojima, and Yusuke Narita. Improving schools through school choice: A market design approach. *Journal of Economic Theory*, 166:186–211, 2016.

Onur Kesten and M. Utku Ünver. A theory of school-choice lotteries. *Theoretical Economics*, 10:543–595, 2015.

Parag A. Pathak. The mechanism design approach to student assignment. *Annual Review of Economics*, 3:513–536, 2011.

Parag A. Pathak. What really matters in designing school choice mechanisms. In Bo Honoré, Ariel Pakes, Monika Piazzesi, and Larry Samuelson, editors, *Advances in Economics and Econometrics, 11th World Congress of the Econometric Society*, pages 176–214. 2017.

Parag A. Pathak and Peng Shi. How well do structural demand models work? Counterfactual predictions in school choice. *Journal of Econometrics*, forthcoming.

Peng Shi. Guiding school-choice reform through novel applications of operations research. *Interfaces*, 45:117–132, 2015.

Organ Allocation – September 24, 2019. (Featuring Mohammad Akbarpour.)

For Class Discussion.

Michael A. Rees, Ty B. Dunn, Christian S. Kuhr, Christopher L. Marsh, Jeffrey Rogers, Susan E. Rees, Alejandra Cicero, Laurie J. Reece, Alvin E. Roth, Obi Ekwenna, et al. Kidney exchange to overcome financial barriers to kidney transplantation. *American Journal of Transplantation*, 17:782–790, 2017.

A. C. Wiseman and J. S. Gill. Financial incompatibility and paired kidney exchange: Walking a tightrope or blazing a trail? *American Journal of Transplantation*, 17:597–598, 2017.

Background.

Stephen Leider and Alvin E. Roth. Kidneys for sale: Who disapproves, and why? *American Journal of Transplantation*, 10:1221–1227, 2010.

Alvin E. Roth, Tayfun Sönmez, and M. Utku Ünver. Kidney exchange. *Quarterly Journal of Economics*, 119:457–488, 2004.

Alvin E. Roth, Tayfun Sönmez, and M. Utku Ünver. Efficient kidney exchange: Coincidence of wants in markets with compatibility-based preferences. *American Economic Review*, 97:828–851, 2007.

Itai Ashlagi and Alvin E. Roth. New challenges in multihospital kidney exchange. *American Economic Review*, 102:354–359, 2012.

Mohammad Akbarpour, Shengwu Li, and Shayan Oveis Gharan. Thickness and information in dynamic matching markets. *Journal of Political Economy*, forthcoming.

Nikhil Agarwal, Itai Ashlagi, Eduardo Azevedo, Clayton R. Featherstone, and Ömer Karaduman. Market failure in kidney exchange. *American Economic Review*, forthcoming.

Gary S. Becker, Julio J. Elias, and Karen Ye. The shortage of kidneys for transplant: Altrusim, exchanges, opt in versus opt out, and the market for kidneys. Becker Friedman Institute Working Paper, 2013.

Further Reading.

Nikhil Agarwal, Itai Ashlagi, Eduardo Azevedo, Clayton Featherstone, and Ömer Karaduman. What matters for the productivity of kidney exchange? *AEA Papers & Proceedings*, 108:334–340, 2018a.

Nikhil Agarwal, Itai Ashlagi, Michael Rees, Paulo Somaini, and Daniel Waldinger. An empirical framework for sequential assignment: The allocation of deceased donor kidneys. MIT Working Paper, 2018b.

Nikhil Agarwal, Itai Ashlagi, Paulo Somaini, and Daniel Waldinger. Dynamic incentives in wait list mechanisms. *AEA Papers & Proceedings*, 108:341–347, 2018c.

Sandro Ambuehl. An offer you can't refuse? Incentives change what we believe. Rotman School of Management Working Paper, 2016.

Atila Abdulkadiroğlu and Tayfun Sönmez. House allocation with existing tenants. *Journal of Economic Theory*, 88:233–260, 1999.

Itai Ashlagi and Alvin E. Roth. Free riding and participation in large scale, multi-hospital kidney exchange. *Theoretical Economics*, 9:817–863, 2014.

Itai Ashlagi, David Gamarnik, Michael Rees, and Alvin E. Roth. The need for (long) chains in kidney exchange. NBER Working Paper No. 18202, 2012.

Haluk Ergin, Tayfun Sönmez, and M Utku Ünver. Dual-donor organ exchange. *Econometrica*, forthcoming.

Judd B. Kessler and Alvin E. Roth. Don't take 'no' for an answer: An experiment with actual organ donor registrations. NBER Working Paper No. 20378, 2014.

Jacob Leshno. Dynamic matching in overloaded systems. Harvard University Working Paper, 2015.

Alvin E. Roth. Repugnance as a constraint on markets. *Journal of Economic Perspectives*, 21:37–58, 2007b.

Alvin E. Roth, Tayfun Sönmez, and M. Utku Ünver. A kidney exchange clearinghouse in New England. *American Economic Review*, 95:376–380, 2005.

Robert Slonim, Carmen Wang, and Ellen Garbarino. The market for blood. *Journal of Economic Perspectives*, 28:177–96, 2014.

Tayfun Sönmez and M. Utku Ünver. Market design for kidney exchange. In Nir Vulkan, Alvin E. Roth, and Zvika Neeman, editors, *The Handbook of Market Design*, pages 93–137. Oxford University Press, 2013.

Neil Thakral. The public-housing allocation problem: Theory and evidence from Pittsburgh. Harvard University Working Paper, 2017.

M. Utku Ünver. Dynamic kidney exchange. *Review of Economic Studies*, 77:372–414, 2010.

Food Supply, Scrip, and Pseudo-Markets – October 1, 2019.

For Class Discussion.

Canice Prendergast. The allocation of food to food banks. Booth School of Business Working Paper, 2017a.

Canice Prendergast. How food banks use markets to feed the poor. *Journal of Economic Perspectives*, 31:145–62, 2017b.

Scott Duke Kominers and Alan Lam. Feeding America (A) and (B). Harvard Business School Case 818-130, Supplement 818-131, and Teaching Note 918-082, 2018.

Background.

Joan Sweeney and Richard James Sweeney. Monetary theory and the great Capitol Hill Baby Sitting Co-op crisis: Comment. *Journal of Money, Credit and Banking*, 9:86–89, 1977.

Ian A. Kash, Eric J. Friedman, and Joseph Y. Halpern. Optimizing scrip systems: crashes, altruists, hoarders, sybils and collusion. *Distributed Computing*, 25:335–357, 2012.

Ian A. Kash, Eric J. Friedman, and Joseph Y. Halpern. An equilibrium analysis of scrip systems. *ACM Transactions on Economics and Computation*, 3:#13, 2015.

Tayfun Sönmez and M. Utku Ünver. Course bidding at business schools. *International Economic Review*, 51:99–123, 2010.

Eric Budish. The combinatorial assignment problem: Approximate competitive equilibrium from equal incomes. *Journal of Political Economy*, 119:1061–1103, 2011.

Eric Budish and Estelle Cantillon. The multi-unit assignment problem: Theory and evidence from course allocation at Harvard. *American Economic Review*, 102:2237–2271, 2012.

Further Reading.

Mohammad Akbarpour and Afshin Nikzad. Approximate random allocation mechanisms. Stanford University Working Paper, 2017.

Anna Bogomolnaia and Hervé Moulin. A new solution to the random assignment problem. *Journal of Economic theory*, 100:295–328, 2001.

Eric Budish, Yeon-Koo Che, Fuhito Kojima, and Paul Milgrom. Designing random allocation mechanisms: Theory and applications. *American Economic Review*, 103:585–623, 2013.

Eric Budish and Judd B. Kessler. Bringing real market participants' real preferences into the lab: An experiment that changed the course allocation mechanism at Wharton. NBER Working Paper No. 22448, 2016.

Yinghua He, Antonio Miralles, Marek Pycia, and Jianye Yan. A pseudo-market approach to allocation with priorities. *American Economic Journal: Microeconomics*, 10:272–314, 2018.

Aanund Hylland and Richard Zeckhauser. The efficient allocation of individuals to positions. *Journal of Political Economy*, 87:293–314, 1979.

Andreu Mas-Colell. Indivisible commodities and general equilibrium theory. *Journal of Economic Theory*, 16:443–456, 1977.

Auctions and Generalized Matching – October 8, 2019. (Featuring Ravi Jagadeesan.)

For Class Discussion.

John William Hatfield and Paul Milgrom. Matching with contracts. *American Economic Review*, 95:913–935, 2005.

Background.

Alexander S. Kelso, Jr. and Vincent P. Crawford. Job matching, coalition formation, and gross substitutes. *Econometrica*, 50:1483–1504, 1982.

Frank Gul and Ennio Stacchetti. Walrasian equilibrium with gross substitutes. *Journal of Economic Theory*, 87:95–124, 1999.

Federico Echenique. Contracts vs. salaries in matching. *American Economic Review*, 102: 594–601, 2012.

Ravi Jagadeesan, Scott Duke Kominers, and Ross Rheingans-Yoo. Strategy-proofness of worker-optimal matching with continuously transferable utility. *Games and Economic Behavior*, 108:287–294, 2018.

Dirk Bergemann and Juuso Välimäki. Information acquisition and efficient mechanism design. *Econometrica*, 70:1007–1033, 2002.

John William Hatfield, Fuhito Kojima, and Scott Duke Kominers. Strategy-proofness, investment efficiency, and marginal returns: An equivalence. Becker Friedman Institute Working Paper, 2017.

Paul Klemperer. The product-mix auction: A new auction design for differentiated goods. *Journal of the European Economic Association*, 8:526–536, 2010.

Further Reading.

Hiroyuki Adachi. On a characterization of stable matchings. *Economics Letters*, 68:43–49, 2000.

Orhan Aygün and Tayfun Sönmez. Matching with contracts: Comment. *American Economic Review*, 103:2050–2051, 2013.

Elizabeth Baldwin and Paul Klemperer. Understanding preferences: "demand types," and the existence of equilibrium with indivisibilities. *Econometrica*, 87:867–932, 2019.

Benjamin Edelman, Michael Ostrovsky, and Michael Schwarz. Internet advertising and the generalized second-price auction: Selling billions of dollars worth of keywords. *American Economic Review*, 97:242–259, 2007.

Tamás Fleiner. A fixed-point approach to stable matchings and some applications. *Mathematics of Operations Research*, 28:103–126, 2003.

Frank Gul and Ennio Stacchetti. The English auction with differentiated commodities. *Journal of Economic Theory*, 92:66–95, 2000.

Yuichiro Kamada and Fuhito Kojima. Efficient matching under distributional constraints: Theory and applications. *American Economic Review*, 105:67–99, 2015.

R. Preston McAfee and John McMillan. Auctions and bidding. *Journal of Economic Literature*, 25:699–738, 1987.

Paul R. Milgrom and Ilya Segal. Deferred-acceptance auctions and radio spectrum reallocation. *Journal of Political Economy*, forthcoming.

Finance, Cryptocurrency, and Blockchain – October 15, 2019. (Featuring Ross Rheingans-Yoo.)
Readings to be announced.

Substitutes and Trading Networks – October 22, 2019.
For Class Discussion.

Tayfun Sönmez and Tobias B. Switzer. Matching with (branch-of-choice) contracts at United States Military Academy. *Econometrica*, 81:451–488, 2013.

Tayfun Sönmez. Bidding for army career specialties: Improving the ROTC branching mechanism. *Journal of Political Economy*, 121:186–219, 2013.

Background.

John William Hatfield and Fuhito Kojima. Substitutes and stability for matching with contracts. *Journal of Economic Theory*, 145:1704–1723, 2010.

Ravi Jagadeesan. Cadet-branch matching in a Kelso-Crawford economy. *American Economic Journal: Microeconomics*, 11:191–224, 2019.

Scott Duke Kominers and Tayfun Sönmez. Matching with slot-specific priorities: Theory. *Theoretical Economics*, 11:683–710, 2016.

John William Hatfield and Scott Duke Kominers. Hidden substitutes. Harvard University Working Paper, 2019.

Avinatan Hassidim, Assaf Romm, and Ran I. Shorrer. Redesigning the Israeli psychology master's match. *American Economic Review Papers & Proceedings*, 107:205–209, 2017b.

Avinatan Hassidim, Assaf Romm, and Ran I. Shorrer. Need vs. merit: The large core of college admissions markets. 2018. Pennsylvania State University Working Paper.

John William Hatfield and Scott Duke Kominers. Contract design and stability in many-to-many matching. *Games and Economic Behavior*, 101:78–97, 2017.

Michael Ostrovsky. Stability in supply chain networks. *American Economic Review*, 98: 897–923, 2008.

John William Hatfield and Scott Duke Kominers. Matching in networks with bilateral contracts. *American Economic Journal: Microeconomics*, 4:176–208, 2012.

John William Hatfield, Scott Duke Kominers, Alexandru Nichifor, Michael Ostrovsky, and Alexander Westkamp. Stability and competitive equilibrium in trading networks. *Journal of Political Economy*, 121:966–1005, 2013.

Tamás Fleiner, Zsuzsanna Jankó, Akihisa Tamura, and Alexander Teytelboym. Trading networks with bilateral contracts. Oxford University Working Paper, 2018.

Tamás Fleiner, Ravi Jagadeesan, Zsuzsanna Jankó, and Alexander Teytelboym. Trading networks with frictions. *Econometrica*, forthcoming.

Further Reading.

Eduardo M. Azevedo and John William Hatfield. Existence of stable matchings in large markets with complementarities. University of Texas at Austin Working Paper, 2018.

Eduardo M. Azevedo, E. Glen Weyl, and Alexander White. Walrasian equilibrium in large, quasilinear markets. *Theoretical Economics*, 8:281–290, 2013.

Yeon-Koo Che, Jinwoo Kim, and Fuhito Kojima. Stable matching in large economies. *Econometrica*, 87:65–110, 2019.

Ravi Jagadeesan. Complementary inputs and the existence of stable outcomes in large trading networks. Harvard University Working Paper, 2018.

John William Hatfield, Scott Duke Kominers, Alexandru Nichifor, Michael Ostrovsky, and Alexander Westkamp. Full substitutability. *Theoretical Economics*, forthcoming.

John William Hatfield, Scott Duke Kominers, Alexandru Nichifor, Michael Ostrovsky, and Alexander Westkamp. Chain stability in trading networks. Stanford University Working Paper, 2018a.

John William Hatfield, Scott Duke Kominers, and Alexander Westkamp. Stability, strategy-proofness, and cumulative offer mechanisms. Harvard University Working Paper, 2018b.

Jonathan Ma and Scott Duke Kominers. Bundling incentives in (many-to-many) matching with contracts. Harvard University Working Paper, 2018.

Ning Sun and Zaifu Yang. Equilibria and indivisibilities: Gross substitutes and complements. *Econometrica*, 74:1385–1402, 2006.

Ning Sun and Zaifu Yang. A double-track adjustment process for discrete markets with substitutes and complements. *Econometrica*, 77:933–952, 2009.

M. Bumin Yenmez. A college admissions clearinghouse. *Journal of Economic Theory*, 176: 859–885, 2018.

Collusion in Markets – October 29, 2019.
Readings to be announced.

Markets for Intellectual Property – November 5, 2019.
For Class Discussion.

Lauren Cohen, Umit G. Gurun, and Scott Duke Kominers. Patent trolls: Evidence from targeted firms. *Management Science*, forthcoming.

Scott Duke Kominers. One thing you don't need is stronger patents. *Bloomberg View*, July 6, 2017.

Background.

Andrei Hagiu and David B. Yoffie. The new patent intermediaries: Platforms, defensive aggregators, and super-aggregators. *Journal of Economic Perspectives*, 27:45–65, 2013.

Joshua S. Gans and Scott Stern. Designing markets for ideas. In Nir Vulkan, Alvin E. Roth, and Zvika Neeman, editors, *The Handbook of Market Design*, pages 222–248. Oxford University Press, 2013.

Robin Feldman and Mark A. Lemley. Do patent licensing demands mean innovation? *Iowa Law Review*, 101:137–189, 2015.

Eric Budish, Benjamin N. Roin, and Heidi L. Williams. Do firms underinvest in long-term research? Evidence from cancer clinical trials. *American Economic Review*, 105: 2044–2085, 2015.

Michele Boldrin and David K. Levine. The case against patents. *Journal of Economic Perspectives*, 27:3–22, 2013.

Colleen Chien. Why it's time to open up our patent system. *The Washington Post*, June 30, 2015.

Michael Kremer. Patent buyouts: A mechanism for encouraging innovation. *Quarterly Journal of Economics*, 113:1137–1167, 1998.

Lauren Cohen, John M. Golden, Umit G. Gurun, and Scott Duke Kominers. 'Troll' check? A proposal for administrative review of patent litigation. *Boston University Law Review*, 97:1775–1841, 2017.

Further Reading.

James E. Bessen, Michael J. Meurer, and Jennifer Ford. The private and social costs of patent trolls. *Regulation*, 34:26–35, 2011.

Lauren H. Cohen and Umit G. Gurun. Buying the verdict. NBER Working Paper No. 24542, 2018.

Lauren H. Cohen, Umit G. Gurun, Scott Duke Kominers, and George Hou. Patent trolling. Harvard Business School Background Note 218-085, 2018.

Christopher A. Cotropia, Jay P. Kesan, and David L. Schwartz. Unpacking patent assertion entities (PAEs). *Minnesota Law Review*, 99:649–703, 2014.

Gaétan De Rassenfosse, Adam B. Jaffe, and Elizabeth Webster. Low-quality patents in the eye of the beholder: Evidence from multiple examiners. NBER Working Paper No. 22244, 2016.

Timo Fischer and Jan Leidinger. Testing patent value indicators on directly observed patent value – an empirical analysis of Ocean Tomo patent auctions. *Research Policy*, 43:519–529, 2014.

Alberto Galasso and Mark Schankerman. Patent thickets, courts, and the market for innovation. *RAND Journal of Economics*, 41:472–503, 2010.

Josh Lerner and Jean Tirole. The economics of technology sharing: Open source and beyond. *Journal of Economic Perspectives*, 19:99–120, 2005.

Josh Lerner and Jean Tirole. Standard essential patents. *Journal of Political Economy*, 123:547–586, 2015.

Catherine E. Tucker. Patent trolls and technology diffusion: The case of medical imaging. 2014. MIT Working Paper.

Heidi L. Williams. Intellectual property rights and innovation: Evidence from the human genome. *Journal of Political Economy*, 121:1–27, 2013.

Heidi L. Williams. How do patents affect research investments? *Annual Review of Economics*, 9:441–469, 2017.

Inequality – November 12, 2019.
Readings to be announced.

Refugees, Immigration, and Economic Development – November 19, 2019.
(Featuring Reshma Hussam.)

For Class Discussion.

Reshmann Hussam, Natalia Rigol, and Benjamin Roth. Targeting high ability entrepreneurs using community information: Mechanism design in the field. Harvard Business School Working Paper, 2018.

Background.

Will Jones and Alexander Teytelboym. The Local Refugee Match: Aligning refugees' preferences with the capacities and priorities of localities. *Journal of Refugee Studies*, 31: 152–178, 2017a.

Olof Åslund and Dan-Olof Rooth. Do when and where matter? Initial labour market conditions and immigrant earnings. *Economic Journal*, 117:422–448, 2007.

David Delacrétaz, Scott Duke Kominers, and Alexander Teytelboym. Refugee resettlement. Oxford University Working Paper, 2019.

Kirk Bansak, Jeremy Ferwerda, Jens Hainmueller, Andrea Dillon, Dominik Hangartner, Duncan Lawrence, and Jeremy Weinstein. Improving refugee integration through data-driven algorithmic assignment. *Science*, 359:325–329, 2018.

Andrew Trapp, Alexander Teytelboym, Alessandro Martinello, Tommy Andersson, and Narges Ahani. Placement optimization in refugee resettlement. Oxford University Working Paper, 2018.

Benjamin N. Roth. Market design under weak institutions. In Scott Duke Kominers and Alexader Teytelboym, editors, *Fair by Design: Economic Design Responses to Inequality*. Oxford University Press, forthcoming.

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Interesting Properties of the Course Number(s).

- The course number is a "safe prime" – that is, 2099 is prime and $(2099-1)/2 = 1049$ is also prime.
- The binary representation of the course number (100000110011) is also the decimal representation of a prime.
- The course number is the smallest prime that is the sum of 29 consecutive primes ($2099 = 13 + 17 + \cdots + 139$).
- The course number is in the four-step Fibonacci sequence starting with 0, 1, 1, and 1.
- The course number is the least number having exactly 37 representations in the form $ab + ac + bc$ with $0 < a < b < c$.
- Assuming no changes in our calendar system, the year 2099 will have exactly three "Fridays the Thirteenth."
- The HBS cross-listing number is the first "5-powerful number" – that is, 4150 is the smallest number that is the sum of the fifth powers of its digits ($4150 = 1024 + 1 + 3125 + 0 = 4^5 + 1^5 + 5^5 + 0^5$).
- The HBS cross-listing number is the smallest integer k such that $\frac{50!+k}{50}$ is prime.
- The HBS cross-listing number is a Rothian number.
- The HBS cross-listing number satisfies a Spironacci-style recurrence.

$\mathbb{QED}$