

Overview of Research

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I am a microeconomic theorist studying market design. My research contributes to four areas of this field: matching, allocation without transfers, auctions, and the foundations of market design. The papers on **matching** formulated some of the first approaches to the study of complementarities, peer effects, and externalities, as well as a unifying approach to standard and far-sighted stability concepts. The papers on **allocation without transfers** constructed and analyzed incentive-compatible and efficient mechanisms, and they showed that in large markets ordinal school choice mechanisms become allocationally equivalent while the efficiency advantage of cardinal mechanisms remains pronounced. The papers on **auctions** developed the theory of pay-as-bid auctions, the main auction format for the sale of divisible goods such as treasuries or electricity. One of the papers on the **foundations of market design** established that risk-averse agents can trade efficiently. This unexpected result contrasts with the fundamental Myerson and Satterthwaite's theorem on the impossibility of efficient trade between quasi-linear agents. Another paper showed how commitment emerges and the celebrated Coase conjecture fails when one accounts for buyers' ability to leave the negotiating table.

1. Matching

Matching describes any contracting between agents on two sides of a market, e.g. who marries whom, who works for whom, and who buys from whom and at what prices. My main contribution in this area is formulating some of the first positive approaches to the study of complementarities, peer effects, and externalities, important phenomena that were assumed away in classical matching models.

My paper “**Stability and Preference Alignment in Matching and Coalition Formation**” (*Econometrica* 2012) introduces and analyzes matching and coalition formation environments in which agents' preferences over coalitions are fully determined by a commonly-known state of nature. Allowing for complementarities and peer effects, and assuming that there is a substantial variability of preferences across states of nature, the paper shows that there exists a core stable coalition structure in every state of nature if and only if agents' preferences are aligned in every state. This implies that there is a stable coalition structure if agents' preferences are generated by Nash bargaining over coalitional outputs. A further result proves that such a Nash sharing rule is representative: all stability-inducing rules for sharing outputs can be represented by agents' bargaining power profiles.

Building on this framework, the paper establishes that complementarities and peer effects overturn the received comparative statics of many-to-one matching. For instance, the paper shows how adding a complementary agent to one side of the market might increase the payoffs of other agents on the same side and decrease the payoffs of agents on the other side in the unique stable matching.

The paper also applies its framework to other questions. One application shows that agents match assortatively with respect to their productivity and their bargaining powers. This application is one of the first analyses of multidimensional assortative matching and it opens up a way to resolve Chiappori and Reny's critique of the empirical literature on risk sharing that presumes that agents match in a positive assortative way with respect to risk aversion: whereas such positive assortative matching cannot be rationalized in standard transferable utility models, it emerges in my framework when agents' bargaining powers are determined by their risk aversion. Furthermore, assuming that productivities are drawn randomly from a log-concave distribution, the paper shows that, in expectation, agents with more equal bargaining powers form larger coalitions: more equal societies cooperate more.

“Matching with Externalities,” joint with Bumin Yenmez, proposes a framework to study externalities in matching; auctions, one-to-one, and many-to-one matching with and without wages are special cases of our framework, and our results are new in these special cases. Externalities mean that an agent's choice behavior may depend on the contracts signed by other agents. For instance, a worker's preferences over jobs might depend on the job of the spouse, or a university may benchmark its hiring, tenure, and salary decisions on relative comparisons with other universities.

Our main results show that, despite the presence of externalities, the deferred acceptance algorithm and many of the classical insights of matching theory remain valid (with appropriate adjustments), provided agents treat the contracts they sign and the contracts signed by other agents on the same side of the market as substitutes. This substitutes condition is satisfied in examples such as the joint search and relative comparisons above, and the conceptualization of this condition for the setting with externalities is at the core of the paper. We also make first steps in showing how markets react to changes in the strength of externalities.

As an auxiliary conceptual contribution to the matching literature, we synthesize several of its strands with and without externalities. In analyses of matching, the equilibrium concept is stability: a matching is stable if no agent or pair of agents can improve their outcomes by rematching. The standard formulation of stability presupposes that the blocking agents evaluate their gains from blocking assuming that the remaining agents are unable to react to the blocking. Other stability concepts, referred to as far-sighted stability, postulate that blocking agents expect certain reactions to the block. We point out that by studying agents' choices that reflect both agents' preferences and their assumptions about the reactions of others, one can treat uniformly standard stability along with many far-sighted stability concepts.

Additional papers. An *American Economic Journal: Microeconomics* paper (joint with my two former undergraduate students, Peter Chen and Michael Egedal, and with Bumin Yenmez) establishes an equivalence between incentive and welfare properties of any stable matching or auction mechanism. Yet another paper with the same co-authors constructs and analyzes matching mechanisms that balance the welfare of the two sides of the market. In “Non-Existence Result for Matching Games with Transfers,” I show that the existence of stable matchings in environments with transfers is more precarious than it is in environments without transfers.

2. Allocation without Transfers

The allocation and exchange of many discrete resources—such as school seats or kidneys—is constrained by rules that prohibit the use of monetary transfers. My work in this area focused on understanding the efficient frontier (the best outcomes that can be achieved) in such problems, usually in the canonical environments in which each participating agent obtains at most one object.

The paper “**Incentive Compatible Allocation and Exchange of Discrete Resources**,” joint with Utku Unver, analyzes the two primary concerns in designing allocation mechanisms: efficiency and incentives. We construct the class of all deterministic mechanisms that are Pareto efficient and group strategy-proof (which are basic efficiency and incentive postulates). In doing so, we uncover the underlying structure of all such mechanisms: agents in all such mechanisms can be thought of as having control rights over objects, and the control rights are of two types that we call ownership and brokerage; ownership was known before, brokerage is our contribution. Our language of control rights structures became not only a basis for the subsequent literature but also a standard in descriptions of some of the earlier classes of mechanisms, such as Papai's top trading cycles.

In our mechanisms, which we called Trading Cycles, agents swap objects over which they have control rights; unlike in previous constructions some of the agents—agents with brokerage rights—are constrained in what swaps they can perform. In simple asymmetric examples the new broker-based mechanisms are more fair than previously known deterministic mechanisms. In 2013-2014 drafts of the paper (still available online) we show that group strategy-proof and Pareto efficient mechanisms exactly coincide with mechanisms that are individually strategy-proof and always select the efficient outcome with respect to some Arrovian social welfare function.

The paper “**Ordinal Efficiency, Fairness, and Incentives in Large Markets**,” with Qingmin Liu (revision requested at the *Review of Economic Studies*) analyzes random ordinal allocation mechanisms. We focus on markets that are large in the following sense: there are many agents but relatively few object types, each object type may be represented by multiple copies as in school choice, and in the mechanisms studied the impact of any single agent on the outcome of other agents is small. We establish the asymptotic allocational equivalence of all mechanisms that are asymptotically ordinally efficient, asymptotically strategy-proof, and satisfy a basic fairness property called symmetry: agents who submit the same requests (that is the same preference rankings) obtain the same distribution over objects. The closer the mechanisms are to exactly satisfying these properties, the more indistinguishable their allocations are. As an auxiliary result,

the paper shows that mechanisms that uniformly randomize over Pareto efficient outcomes are asymptotically ordinally efficient; such uniform randomization is a property shared by many common mechanisms, and these mechanisms are also strategy-proof and symmetric.

Taken together, the two results in this paper imply that the common ordinal mechanisms all asymptotically coincide; this insight is corroborated by and explains the results of empirical studies on Boston and NYC school choice. In a complementary note, “**The Cost of Ordinality**,” I show that the welfare gains that can be achieved by eliciting information on intensities of agents' preferences (or, their von Neumann-Morgenstern utilities) do not vanish in large market (in contrast to welfare advantages of ordinally efficient mechanisms, which—in light of the above auxiliary result—do vanish in large markets).

Together the two papers above imply that to improve upon the status quo we need to develop mechanisms that elicit agents' utilities, not only their ordinal rankings. The development and study of such mechanisms is the subject of the following two recent papers. In “**Prices and Efficient Assignments without Transfers**,” joint with Antonio Miralles (revision requested by the *Journal of Economic Theory*), we show that all efficient assignments can be implemented via prices as in Hylland and Zeckhauser's pseudomarkets. In this way, we characterize expected-utility efficient mechanisms. The result shows that the counterpart of the Second Fundamental Welfare Theorem holds true in allocation without transfers. In contrast to the earlier instances of the Second Welfare Theorem, which relied crucially on the assumption that agents are locally non-satiated, we study single-unit demand agents who are locally satiated. In “**A Pseudo-Market Approach to Allocation with Priorities**,” joint with Yinghua He, Antonio Miralles, and Jianye Yan, we establish that pseudo-market mechanisms are asymptotically incentive-compatible. We also show how one can accommodate school priorities in pseudo-market mechanisms.

Additional papers. In “Large vs Continuum Assignment Economies,” with Antonio Miralles (revision requested by *Games and Economic Behavior*), we provide a critique of the standard approach to studying large markets by modeling them as continuum economies; while this simplifies the analysis, we show via an example that some qualitative properties of continuum economies are different from those of large finite economies. In our *Journal of Mathematical Economics* paper, Utku Unver and I show when it is possible to decompose a strategy-proof random mechanism into a lottery over strategy-proof deterministic mechanisms. In another paper with U. Unver (revision requested by *Social Choice and Welfare*), we analyze allocation problems in which agents have outside options. Notes linked next to the Trading Cycles paper extend this class of mechanisms to environments with copies. Notes linked next to the ordinal large market paper extend its insights beyond the canonical single-unit demand setting.

3. Auctions

Billions of dollars worth of divisible goods—such as treasury securities and many commodities—are sold through auctions every year. These auctions primarily employ two standard formats: pay-as-bid and uniform price. In two completed projects (and several projects in progress), I analyze these important auctions.

“**Demand Reduction and Inefficiency in Multi-Unit Auctions**” is a merger of Larry Ausubel and Peter Cramton's paper on demand reduction and my paper with Marzena Rostek and Marek Weretka on revenue comparisons; the merged paper was published in the *Review of Economic Studies* in 2014. Among other results, the paper compares the revenues of pay-as-bid and uniform-price auctions. In particular, we construct linear Bayesian Nash equilibria of both auctions assuming that symmetrically-informed bidders have linear marginal demand and the distribution of supply follows a generalized Pareto distribution. We show that in these equilibria the pay-as-bid auction raises more revenue than the uniform-price auction.

“**Pay-As-Bid: Selling Divisible Goods to Uninformed Bidders**,” joint with Kyle Woodward, analyzes pure-strategy equilibria of pay-as-bid auctions in the general setting with symmetrically-informed bidders. We resolve the question of equilibrium existence by offering a mild and essentially tight sufficient condition for equilibrium existence, we establish that the equilibrium is essentially unique, and we develop a simple representation of the equilibrium bids: each bidder's bid on any unit is a weighted average of this bidder's marginal values on this and higher units, where the weighting function depends only on the number of bidders and distribution of supply. Surprisingly, this general representation is simpler than prior constructions of equilibria in parametric examples.

This general theory of equilibria allows us to analyze natural comparative statics and design questions. For instance, we show that the revenue-maximizing distribution of supply in pay-as-bid auctions is deterministic. This insight implies that with optimally designed supply distributions and reserve prices, pay-as-bid and uniform-price auctions are revenue equivalent. The unexpected revenue equivalence offers an explanation to the findings of many empirical papers that conclude that, in the data, revenues in the two auction formats are close.

Additional papers. My M.Phil. thesis shows that in multi-object screening—e.g. in auctions with one bidder—deterministic selling strategies may be suboptimal (notice the contrast to the pay-as-bid auction), and that it is so generically. The paper also assesses the cost of restricting attention to deterministic mechanisms. In the matching section I discuss my work on matching with contracts, which includes auctions. Work on auctions was the main part of my consulting appointment at the NY Federal Reserve Bank.

4. The Foundations of Market Design

In addition to the work in the main areas of market design, I contributed to the conceptual foundations of this field by showing that efficient bilateral resale markets are possible and that commitment emerges in dynamic Coasian environments.

In “**Efficient Bilateral Trade**,” with Rod Garratt, we address the question of whether two informed parties, a seller and a buyer, can trade efficiently if either of them might have the higher value for the traded object. Myerson and Satterthwaite (1983) conceptualized this problem as one of the existence of a Bayesian incentive-compatible and interim-individually rational unsubsidized mechanism that implements ex-post Pareto efficient outcomes. They show that such mechanisms do

not exist when traders have quasi-linear utilities. In contrast, we allow agents to be risk averse, which is an important consideration when trading valuable objects. We establish that efficient trade is possible provided the good is normal and agents' utility functions are not too responsive to private information. Furthermore, away from the quasilinear case, we show that efficient trade is possible even when agents' utility functions are highly responsive to their private information. This insight is the first result establishing the possibility of efficient trade between a rational seller and a rational buyer in the rich literature following Myerson and Satterthwaite's work.

To construct the ex-post Pareto efficient mechanism, we develop new methods that lend themselves to other analysis of mechanism design with risk-averse agents.

The paper “**Outside Options and the Failure of the Coase Conjecture**,” with Simon Board, *American Economic Review* 2014, analyzes sellers' ability to commit to a market mechanism. Ronald Coase conjectured that a monopolistic seller who lacks an exogenous ability to commit would compete with her own future offers, undermining the monopoly power. This conjecture, proven to be true in settings when the buyer's strategic choice is restricted to either buying or waiting for another offer, shapes how economists think about commitment and monopoly power. We point out that the conjecture fails when the buyer's choice is not restricted in this way, and the buyer has the option of leaving. In addition, we show that if it is costly for the buyer to wait for another seller's offer then the Perfect Bayesian Equilibrium of the resulting game is essentially unique and, in this equilibrium, the seller behaves as if she had full commitment power.

5. Other Research

In addition to research in market design, I also worked in behavioral economics and in mathematics. Roland Bénabou's and my note in *Economic Letters* reinterpreted the celebrated Gul and Pesendorfer's model of preferences with temptation in terms of a dual-self model; dual-self interpretations of Gul and Pesendorfer's temptation model have since become broadly accepted. My research in mathematics—for which I received Kuczma (twice), Marcinkiewicz, and Steinhaus awards—examined convexity and its relationship to probability theory.