RESEARCH STATEMENT

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My research agenda primarily focuses on two areas of economic theory: strategic interaction in networks and market design. In network economics, I analyze trade in decentralized markets as well as intermediation and social status. My research in market design studies allocation problems in which individuals are matched to resources in the absence of monetary transfers. In earlier work, I addressed issues in mechanism design, cooperative games, and decision theory.

1. Economic and Social Networks

Networks are ubiquitous in modern society and have undeniable effects on human activity. Over the past two decades, economists have started to recognize and systematically study the impact of networks on economic and social interactions [25, 31, 32]. The field of *network economics* is currently flourishing, and I am an enthusiastic contributor to this literature.

1.1. **Decentralized Markets.**

My initial interest in network economics focused on revising the predictions of general equilibrium theory for markets in which buyers and sellers need specific relationships, or *links*, in order to trade. Competitive equilibrium analysis relies on a number of assumptions: no individual trader has market power and all traders take prices as given; the goods traded are homogeneous and infinitely divisible; and the *law of one price* holds—that is, identical goods have the same price. Moreover, the market clearing conditions implicitly assume that all buyers can trade freely with all sellers without delays or transaction costs. The theory predicts that *efficient* allocations emerge in such frictionless *competitive* economies.

However, the assumptions that underpin general equilibrium theory do not reflect the realities of many economic activities. Price-taking behavior is unrealistic in markets that involve a small number of traders. Social and business relationships, geography, and technological compatibility determine which pairs of traders can engage in exchange. Some trades may entail prohibitive transaction costs or require intermediation. Certain goods and services are tailored for specific segments of the market. Trade is dynamic and market conditions change over time. These departures from the foundations of general equilibrium theory give

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rise to complex market interactions. “Local” demand and supply influence the market power of every trader, yet trading activity in remote areas of the economy may have significant spillover effects. Hence, the *bargaining power* of every trader depends on both the local topology of trading opportunities and the global market architecture. The varying nature of competition in different parts of the economy leads to deviations from the law of one price. Moreover, decentralized bargaining may generate *inefficient* outcomes because local incentives for trade are not aligned with global efficiency.

The asymmetries among both traders and goods described above naturally call for a network formulation. A link between a pair of traders indicates that they can trade (or form a partnership) with each other. My first paper in this area [**1**] investigates how local competitive forces shape trading outcomes and the balance of bargaining power at different locations in a network. I consider a non-cooperative model in which pairs of linked players are randomly matched to bargain and the positions left vacant following agreements between players are filled by new traders ([6] provides theoretical foundations for this steady state assumption). My analysis reveals that network asymmetries give rise to unequal bargaining power among players and lead to systematic departures from the law of one price. Indeed, some groups of players face higher demand in the network and exert more market power relative to others. Such players use their oligopoly power to capture a significant fraction of the gains from trade.

To quantify *oligopoly power*, consider any set of players who are pairwise disconnected—which I refer to as *mutually estranged*—and the set of all their neighbors in the network—the *partners*. Define the *shortage ratio* of a mutually estranged set as the ratio of the number of partners to the number of mutually estranged players. I prove that the largest mutually estranged set that achieves the lowest shortage ratio drives market outcomes. Specifically, as players become patient, these mutually estranged players and their partners trade exclusively with one another in equilibrium at a common price that reflects a division of the gains from trade according to the shortage ratio. The corresponding partners form the oligopoly with the greatest market power. If we remove all players connected in this oligopoly from the network, we can treat the remaining network as a separate market and apply the same result to identify the second most powerful oligopoly that emerges in equilibrium. Iterating this procedure generates a decomposition of the network into a series of oligopolies that reflects the endogenous structure of trade and the corresponding *local prices*. I show that the law of one price holds for bipartite buyer-seller networks only if the decomposition consists of a single oligopoly, which is equivalent to the condition that the shortage ratio of any group of buyers is not smaller than the overall seller-buyer ratio in the network. Intuitively, this condition requires that no group of sellers has more market power than the entire set of sellers.

In subsequent research with Dilip Abreu [**2, 3**], we analyze *non-stationary* markets in which every pair of traders that reaches an agreement is removed from the network without replacement. In particular, we consider a *decentralized* random matching process that selects a single pair of linked traders for bargaining at every date. In this setting, traders need to anticipate how the network of trading opportunities will evolve and how their future bargaining position will improve or deteriorate when other players forge agreements in different parts of the network. Prior work in this area [27, 34, 39] assumes that linked traders are simultaneously matched in pairs according to *centralized* mechanisms that maximize the total surplus available from exchange. This assumption leads to the conclusion that all trades take place at the beginning of the game and equilibrium outcomes are *efficient*. By contrast, our paper [**2**] shows that decentralized bargaining leads to richer market dynamics even when attention is restricted to Markov perfect equilibria (MPEs). Specifically, we discover that not all matches result in agreement, a pair of linked players may decline to trade at some stage yet agree to trade at a later one, and multiple equilibria may coexist. Another important departure of our analysis from the existing literature is the finding that in many networks, all MPEs are asymptotically *inefficient* as players become patient. Indeed, under decentralized random matching, incentives for bilateral agreements are not necessarily aligned with global welfare maximization.

Since decentralization creates incentives for inefficient trade in MPEs, it is natural to inquire if decentralized bargaining is compatible with efficiency when we allow for non-Markovian behavior. In [**3**], Abreu and I investigate whether it is possible to structure incentives using non-Markovian strategies in order to construct asymptotically efficient subgame perfect equilibria. The tension between the *global* organization of efficient trade and the *local* nature of bilateral interactions lies at the core of this question. Pairs of players who reach inefficient agreements leave the network permanently, so cooperative behavior that maximizes welfare cannot be enforced via standard repeated game threats. Furthermore, the notion of efficient agreements is history-dependent: when multiple efficient matchings exist, links that belong to an efficient matching in the network prevailing at any given stage may cease to have this property after a series of efficient agreements takes place. Nonetheless, we construct asymptotically efficient equilibria for every network. In our equilibrium construction, players who resist the temptation to complete inefficient transactions are rewarded by certain neighbors, and players who do not conform to the rewarding procedure are punished via sequences of trades that *isolate* them from the network. Implementing these intuitive incentive schemes is delicate due to the evolving nature of the network as prescribed agreements take place and play proceeds.

In an ongoing project [**4**], Francis Bloch, Bhaskar Dutta and I study efficient partnership formation in a network economy with non-transferable utility. In our model, players ask neighbors for favors at random times. Receiving a favor generates a benefit, while granting a favor carries a cost for every player. If a neighbor refuses a player's favor request, then the link between the two players disappears. When a neighbor agrees to provide a favor to a player, the two players form a partnership and support each other with favors as needed in the future. In stark contrast to the bargaining model of [2, 3], we find that there is a unique MPE, which is efficient. The intuition for this divergence in conclusions is that unlike in the model of [2, 3], here players do not enjoy immediate benefits from entering partnerships (via doing favors) and are only concerned with the long-term prospects of being matched. A player provides the first favor in a partnership only if refusing to do so jeopardizes his ability to find a partner when he needs a favor himself. Since vulnerability to isolation is directly related to efficient matching, incentives for forming partnerships are aligned with efficiency. Somewhat paradoxically, the absence of bargaining and transfers and the binary nature of long-term outcomes—forming a partnership or remaining isolated—lead players to coordinate on efficient matchings.

In [**5**], I explore economies with more general buyer and seller asymmetries in match values as well as matching processes and non-stationary inflows of new traders. The structure of equilibria in such *dynamic* environments involves a complex relationship between several objects of infinite dimension. A player's payoff at any point in time depends on the anticipated path of matching frequencies, the bargaining power of potential trading partners, and feasible agreements at future dates. The balance of bargaining power and incentives for agreements depend in turn on the composition of the market at every stage and the induced path of matching frequencies. The evolution of market conditions is determined by the departure rates of players who reach agreements and the arrival rates of new players. I characterize the formal connections between these equilibrium variables and prove that the bargaining game always admits an equilibrium. The existence result complements Gale's (1987) research, which explores properties of equilibria abstracting away from existence issues. One key step in my equilibrium analysis establishes that payoffs at every date are uniquely determined by the composition of the economy over time and can be computed using iterated conditional dominance. This finding is of independent interest as it generalizes the classic uniqueness result from stationary two-player bargaining settings to non-stationary markets with multiple player types. I also show that multiple self-fulfilling beliefs about the trajectory of the economy, generating starkly different equilibrium dynamics, may coexist.

My paper [**6**] provides theoretical foundations for *steady states* in the context of the bargaining model developed in [5]. The literature on bargaining in markets often assumes that steady states exist and characterizes stationary equilibrium outcomes [1, 29, 35, 40]. For this reason, it is important to understand how the distribution of trader types is determined in steady states of economies with costly entry. Entry decisions hinge on how payoffs achievable in the market compare to entry costs. Equilibrium payoffs and incentives for agreements depend on the underlying market composition and the matching probabilities it generates.

Hence, both the inflows of players joining the market and the outflows of players reaching agreements are endogenous in the model. In a steady state, the inflows must balance the outflows for every player type. I prove that the bargaining game admits a steady state for every configuration of small entry costs. Then, I use similar methods to demonstrate the existence of stationary equilibria in *search* models with random matching. Shimer and Smith (2000) and Noldeke and Troger (2009) establish the existence of steady states in settings with strict super- or sub-modular production functions for *quadratic* and *linear* search technologies, respectively. I prove a general version of the result for any production function and all continuous search processes.

I recently wrote a chapter [**7**] for *The Oxford Handbook on the Economics of Networks* [25] that surveys the growing body of research on bilateral trade in networks. The chapter explores the relationships between existing theoretical models and explains what modeling choices account for discrepancies in their predictions. I argue that different assumptions regarding the matching process and the solution concept have significant implications for the dynamics of trade, the balance of bargaining power, welfare properties of market outcomes, and equilibrium multiplicity.

1.2. **Intermediation and Resale.** In the types of models discussed thus far, every trader has an intrinsic supply or demand. Network asymmetries also play an essential role in markets where middlemen, who are neither producers nor consumers, seek profits by acquiring and reselling goods. My paper [**8**] studies markets in which a single good is sequentially *resold* via bilateral bargaining between linked intermediaries until it reaches one of several buyers in a network. I find that a novel decomposition of the network into *layers of intermediation power* delineates the structure of equilibrium trading paths and determines the distribution of intermediation profits in the network. Layer boundaries separate monopoly power from intermediation power. Competitive forces allow intermediaries to demand the full surplus when they resell the good within the same layer, while trades between layers involve hold-ups in which downstream parties extract intermediation rents. Hence, only intermediaries who serve as *gateways* to lower layers earn profits. Traders in the same layer have identical resale values, which decline exponentially as higher layers are reached. Thus, layers provide the appropriate metric for *intermediation distance* in the network: a trader's intermediation power is measured by the number of layers the good traverses between the trader and buyers. Since this metric is not directly related to the length of intermediation chains, trade does not always proceed along the shortest path from the seller to buyers. This finding refutes the standard intuition that sellers have incentives to minimize intermediation.

The study offers a systematic characterization of the interrelated structure of hold-ups and their effect on *intermediation inefficiencies*. The fact that hold-ups cause inefficiencies—even in markets with a single intermediary—is well known. My analysis reveals how hold-ups arise endogenously in relation to competition in different parts of the network. This structure brings to light new types of inefficiency stemming from sellers' incentives to pursue intermediation chains that exploit competition and avoid hold-ups. Such chains may lead to low value buyers or entail large intermediation costs. By contrast, most existing work on intermediation in networks [23, 26, 30, 33, 42] predicts that trade will be efficient. My conclusions diverge from prior work because I analyze sequential resale via bilateral bargaining, while other authors consider markets with simultaneous price posting, multilateral bargaining, or sellers making all the offers.

In a new research project on intermediation and resale **[9]**, I investigate how *information* (e.g., digital goods, innovation, and insider trading tips) is priced and diffused over links in a network. In contrast to the setting of [8], this model assumes that information is a non-rival consumption good. Buyers have idiosyncratic consumption values for information and, after acquiring it, can replicate it and resell copies to uninformed neighbors. In this market, buyers act as intermediaries who may indirectly convey profits from consumers far away in the network to sellers. However, buyers who acquire copies of the good may also create competition for sellers of the original good, and this limits opportunities for indirect profit appropriation. My network formulation thus captures the antithesis between two central concepts in the research on copying and intellectual property—indirect appropriability and competition.

The main contribution of this paper is a network partition that reflects the effects of competition and the scope of indirect appropriability for every seller in the network. Sellers indirectly appropriate profits over intermediation chains only from buyers in their block of the partition. Links within blocks constitute bottlenecks for the diffusion of information. Removing such links disconnects the network and stops information from reaching some buyers. For this reason, bottleneck links confer monopoly power to sellers and generate positive externalities for all players. When trade takes places across a bottleneck link, the seller demands a fraction of the buyer's consumption and resale values, and the partition into profit blocks evolves to reflect the buyer's takeover of the submarket for which he provides essential intermediation in the block. Links between blocks are redundant for diffusion. Removing any such link does not affect the ultimate spread of information. However, redundant links create competition and have negative externalities for sellers. Sellers have incentives to sever redundant links. Information is sold at zero price over redundant links. My analysis indicates that sellers' profit blocks are small in networks that are sufficiently well-connected or clustered, as is the case for many large social and economic networks documented in empirical research [28, 32]. In such networks, the possibility of reproducing the good and its competitive effects severely obstruct indirect appropriability. Then, granting intellectual property rights fosters the creation of information goods. The graph-theoretic byproducts of this research—including the concepts of profit blocks, essential intermediaries, and bottleneck and redundant links—are relevant beyond the model under consideration and are likely to play an important role in other models of diffusion in networks.

1.3. **Social Status.** In a distinct strand of research, I study social comparisons and *status seeking* in an interconnected society. My paper with Nicole Immorlica, Rachel Kranton, and Greg Stoddard [**10**] analyzes a model in which individuals take costly actions, such as buying a car, contributing to a charity, or producing quality research in Economics, which have direct benefits and also confer social status. Individuals suffer status losses when their social contacts take higher actions. We find that a new measure of interconnectedness of sets of players—*cohesion*—captures the intensity of incentives for seeking status and underlies equilibrium outcomes. Members of a more cohesive group put greater weight on status comparisons with one another, which leads to a "rat race" and induces inefficiently high actions within the group. Equilibria generate a stratification of players into *social classes*, with each class's action determined by the cohesion of certain groups in the social hierarchy. We develop characterizations of the equilibrium that exhibits extreme status-seeking activity via a network decomposition with rich combinatorial properties. A top-down characterization builds on the finding that members of the largest maximally cohesive set form the highest class in the extreme equilibrium. The alternative, bottom-up, characterization relies on repeated use of the result that players who do not belong to any set more cohesive than the set of all nodes constitute the lowest class. Social classes can also be identified by iterating a cohesion operator over subsets of nodes. Moreover, we establish that each player's maximum equilibrium action is given by the greatest cohesion among all groups that include him.

The existence of *class equilibria*, in which players are segregated into several social classes, also depends on cohesion. We show that class equilibria arise if and only if there exists a group of players whose cohesion falls with the addition of any single player. Such a group serves as the highest status class in an equilibrium, and the condition above guarantees that no outside player has incentives to emulate the high class.

2. Market Design

My research on market design focuses on *assignment problems* in which a set of indivisible objects needs to be allocated to a number of agents without side-payments. Prominent examples include student placement in public schools and housing allocation. *Random serial dictatorship* is an assignment mechanism often used in applications. This mechanism provides straightforward incentives for truthful reporting of preferences, but may implement ex-ante inefficient assignments. The natural notion of ex-ante efficiency based on ordinal preferences is *ordinal efficiency* [24]. Bogomolnaia and Moulin (2001) proposed an alternative assignment procedure, the *probabilistic serial* mechanism, which achieves ordinal efficiency and has gained popularity in recent years.

Despite the extensive use of random serial dictatorship in practice, my research suggests that the probabilistic serial mechanism has more desirable properties. In [**11**], I prove that random serial dictatorship becomes ordinally inefficient as the economy grows. Furthermore, my joint work with Fuhito Kojima [**12**] shows that players have incentives to state preferences truthfully in large-scale implementations of the probabilistic serial mechanism. Hence, the vulnerability of the probabilistic serial mechanism to strategic manipulation—considered to be its sole drawback—is not an issue in large allocation problems. My work on serial dictatorship and ordinal efficiency also includes [**13, 14, 15**].

In a second piece co-authored with Kojima [**16**], we explore the properties of another commonly used assignment mechanism, the *deferred acceptance* algorithm. We develop several characterizations of deferred acceptance allocation rules. Two novel axioms—individually rational monotonicity and weak Maskin monotonicity—provide insights into the mechanics of deferred acceptance. *Individually rational monotonicity* requires that whenever players declare fewer objects to be acceptable and preferable to their respective allocations for a given preference profile, all players receive weakly better allocations for the modified preference report (with respect to the new preferences). This axiom formalizes the intuition that the efficiency cost of stability for the proposing side of the market stems from applications that are tentatively accepted, but subsequently rejected, in the course of the deferred acceptance algorithm. In other words, the "deferred" aspect of the algorithm is responsible for its *inefficiency*. Similarly, *weak Maskin monotonicity* requires that if a preference profile is a monotonic transformation of another profile with respect to the allocation at the latter profile, then the allocation for the former profile weakly Pareto dominates (under the former preferences) the allocation for the latter. Recall that Maskin's (1999) original axiom requires that the allocation should be invariant to monotone transformations. We use our axiomatizations to demonstrate that the inefficiencies of deferred acceptance rules can be attributed entirely to instances where Maskin monotonicity is violated.

In an ongoing project on market design [**17**] different in style from my previous work, Johannes Horner and I study a labor market where firms have private information about the quality of a worker. The worker's productivity at every job has a common value component. Each firm makes inferences about other firms' signals from the timing of job offers. Our goal is to compare different norms governing offer acceptance deadlines. Thus far, we have found that if firms make *exploding offers*, then informative and uninformative equilibria co-exist, and all players fare better when information is revealed. We next plan to analyze labor markets with *open offers* and identify the optimal market design.

3. Other Projects

I have also worked on two research projects on trade with independent discrete types in the mechanism design framework of Myerson and Satterthwaite (1983) in which a seller is endowed with one unit of a good. My paper with Eric Maskin [**18**] looks at the possibility that the destruction of the good or a reduction in its value for one of the traders may enhance welfare through changes in incentive constraints. We find that reducing seller values may improve welfare in the *optimal* mechanism, while (partially) destroying the good for some reports or reducing buyer values may not.

Joint work with Nenad Kos [**19**] considers a model with multiple buyers who have heterogeneous discrete-value distributions. Recall that the Myerson-Satterthwaite impossibility theorem does not apply to settings with discrete types. We characterize the distributions for which the negative result does not extend and efficient trade can be implemented. We also demonstrate that when multiple ex-post efficient allocations exist, some may be implementable while others are not. Moreover, we show that the efficient allocation whose implementation generates the greatest surplus awards the good to players with the *highest virtual values*.

I plan to finish both projects on mechanism design in the near future. During my college years, I wrote articles on core tâtonnement [**20**] and induced preferences [**21**]. More recently, I came up with a new axiomatization of the Shapley value [**22**] building on an invariance axiom derived from cooperative games with identical Shapley values.

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