

# EXTENDED RESEARCH STATEMENT

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I am a microeconomic theorist specializing in mechanism design and theory-driven experiments.

Mechanism design studies how the designer (she) should construct incentive rules to best align the actions of self-interested agents (he) with her objectives. It has wide applications, including auctions, public good provision, and electoral system design. For example, how should an antique auctioneer choose the auction format to maximize her profit, given that bidders aim to win without overpaying? How should a local government design a tax scheme for a public project, given that citizens may wish to free-ride on others' contributions? What electoral system should be adopted to elect a city council, given that voters may engage in strategic voting? In these problems, uncertainty is prevalent—the designer lacks knowledge of the agents' private information (*e.g.*, a bidder's evaluation of the antique, a citizen's evaluation of the public project, and a voter's sincere ranking of the candidates), and one agent does not know other agents' private information. Achieving the designer's objective necessitates a carefully tailored mechanism to elicit the agents' private information.

Since joining TAMU, I have also applied insights from my theoretical research to theory-driven experiments that test and refine our understanding of decision-making under uncertainty. This research area complements my interest in mechanism design, as understanding how people make decisions is fundamental to developing effective mechanisms.

My research portfolio consists of six publications (including two solo-authored ones) in peer-reviewed journals and four completed working papers. My published papers appear in top microeconomic theory journals, such as the *Journal of Economic Theory*, *American Economic Journal: Microeconomics*, *Games and Economic Behavior*, and *Economic Theory*, as well as an interdisciplinary journal, *Pure and Applied Functional Analysis*. Two of the working papers are collaborated with peers. The other two, including one undergoing a second round revision at the *Journal of Economic Theory*, are collaborated with former Ph.D. students and a faculty member in our experimental group. My papers have been cited by top general-interest economic and business journals such as *American Economic Review* and *Management Science*, as well as top field journals such as the *Journal of Economic Theory* and *Games and Economic Behavior*. Furthermore, I have presented my research forty-three times at leading conferences and seminars.

Below I elaborate on my research findings and how they contribute to the literature.

## 1 Mechanism Design

I expand the canonical approaches of modeling uncertainty in mechanism design by adding two novel features.

Feature 1: Ambiguity (*i.e.*, non-probabilistic uncertainty). The literature often assumes that decision-makers (*e.g.*, the auctioneer and bidders) correctly understand all uncertainties they face and evaluate them probabilistically, which has been questioned by numerous

critiques and empirical findings. Alternatives have been studied by decision theorists and macroeconomists, but remain inadequately explored in mechanisms. My research aims at bridging this gap by considering decision-makers who adopt robustness criteria, *e.g.*, those basing decisions on the worst-case payoff rather than probabilistically.

Feature 2: Information control. Classical mechanisms focus on a one-way elicitation of agents' private information by the designer, overlooking channels for her to control information flown to the agents. My research allows the designer to conceal or provide information instead. For example, the designer may vaguely describe the mechanism to conceal its true nature, or provide agents with information through offering trials. These novel mechanisms achieve previously unattainable objectives.

## 1.1 Ambiguous Mechanisms

I am proud of my two independent publications, which best showcase my interest in exploring both Features 1 and 2. There are real-life examples with ambiguous rules, *e.g.*, taxpayers face vague chances of being audited and residents do not know the precise fine amount for littering beyond a maximum of \$2,000. General intuition suggests that such ambiguity may result in greater rule compliance. Inspired by these examples, my papers allow the designer to leverage a novel tool, the ambiguous mechanism, which announces multiple potential mechanisms to obscure the true one. Consistent with this intuition, I show that introducing ambiguity can improve social efficiency. Essentially, an ambiguity-averse agent tends to focus on the mechanism that delivers him the worst-case payoff, which deters him from misreporting private information.

Guo (2019) shows that ambiguous mechanisms outperform unambiguous (standard) ones by achieving first-best outcomes in two important problems *more often*. One is the full surplus extraction (FSE) problem, where the designer aims to implement socially efficient outcomes while obtaining all gains from trade. The other one is the balanced implementation problem, where the designer aims to implement the efficient outcome via interim individually rational and ex-post budget balanced mechanisms. I show that (1) FSE can be guaranteed via ambiguous mechanisms, if and only if the belief structure (*i.e.*, agents' common prior) satisfies the Beliefs Determine Preference (BDP) property; (2) balanced implementation of any efficient allocation rule can be guaranteed via ambiguous mechanisms, if and only if the belief structure satisfies the BDP property. The BDP property requires that every agent should hold different beliefs toward other agents' types under different types of himself, implying correlated types among agents. However, the BDP property is weaker than the necessary and sufficient condition for FSE via unambiguous mechanisms established by Cremer and McLean (1988) and that for balanced implementation established by Kosenok and Severinov (2008). Namely, with the assistance of ambiguous mechanisms, FSE and balanced implementation can be achieved under less restrictive conditions on the belief structures, *i.e.*, more often.

To highlight the significant improvement brought by ambiguous mechanisms, let me take a two-agent benchmark as an example. There is a non-negligible set of belief structures failing to satisfy the condition of Cremer and McLean (1988) when one agent has a larger

type set than the other. More crucially, the condition of Kosenok and Severinov (2008) does not hold for any belief structure when there are only two agents, leading to an impossibility result. However, given any number of players and any number of types that each agent has, the BDP property almost always holds. This opens up new possibilities for fundamental settings, *e.g.*, bilateral trade.

Guo (2024) further investigates how collusion affects the FSE problem in unambiguous and ambiguous mechanisms. Most canonical mechanism design works overlook collusion despite its relevance in practice. In this paper, I consider a scenario where any group of agents can collusively misreport members’ private information under the coordination of a third-party mechanism that is individually rational and budget balanced. The designer is only interested in using collusion-proof mechanisms, *i.e.*, those such that her payoff is protected against collusion of any coalition. My first result shows that it is impossible to guarantee FSE via collusion-proof unambiguous mechanisms under almost all belief structures. Hence, the lack of knowledge on which agents can collude imposes excessively demanding requirements on unambiguous mechanisms, making FSE virtually impossible. This suggests that the classical FSE result of Cremer and McLean (1988), which can be viewed as a paradox, is resolved by the lack of knowledge of agents’ collusion opportunities. To explore the limit and scope of ambiguous mechanisms studied in my earlier paper, I allow both the designer and the third party to adopt ambiguous mechanisms. My second result shows that FSE can be guaranteed via collusion-proof ambiguous mechanisms if and only if the belief structure satisfies a property that slightly strengthens BDP but still holds under almost all belief structures. Hence, deliberately engineering ambiguity in mechanisms can turn a generic impossibility result into a possibility regarding collusion-proof FSE. Put differently, the use of ambiguous mechanisms can restore the FSE paradox even if one requires the mechanism to be collusion-proof.

## 1.2 Ambiguity in the Environment

In my works above, the designer intentionally creates ambiguity. But in my four other works exploring Feature 1, the designer or agents face pre-existing ambiguities in the environment.

### 1.2.1 Ambiguity Faced by the Agents

Two of my papers in this category focus on agents who have “ambiguous beliefs” and adopt the maxmin expected utility. Namely, they do not know the distribution that other agents’ private information is drawn from, believe that multiple distributions are relevant, and base decisions on the worst-case one. The general form of maxmin expected utility includes some important benchmarks: it reduces to the standard subjective expected utility when the set of ambiguous beliefs is a singleton; it reduces to Wald’s preference when the set of ambiguous beliefs includes all possible distributions, which is a useful benchmark when agents are unfamiliar with each other.

Guo and Yannelis (2021) explore the full implementation problem. Namely, given a set of desirable social choice functions (SCFs), does there exist a mechanism whose equilibria coincide with the set? We provide necessary conditions as well as sufficient ones on imple-

mentable SCFs under the general maxmin expected utility framework. Since beliefs may not have full support (think of Wald’s model), we cannot employ the mechanisms used for Bayesian implementation as in Jackson (1991), but adopt a stochastic mechanism instead. In the special case that agents have Wald’s preferences and private valuations, full implementation can be obtained under weak and easy-to-check conditions, contrary to the observation that the conditions for Bayesian implementation are usually difficult to verify and satisfy. For example, the set of interim individually rational and interim Pareto efficient SCFs are fully implementable, and so are the set of interim core allocations, and the set of interim value allocations. Their counterparts are not fully implementable under Bayesian beliefs.

Guo and Yannelis (2022a) further study a setup where any group of agents can form a coalition, make side payments to each other, and jointly misreport private information whenever it is common knowledge that doing this is profitable. When agents have Wald’s preferences and private valuations, we characterize SCFs that are immune from any individual and collusive manipulations — surprisingly, they coincide with the set of interim Pareto efficient SCFs. Namely, if the designer wishes to (partially) implement an SCF without worrying about unilateral and collusive misreporting, the only candidate is an interim Pareto efficient SCF; also, every interim Pareto efficient SCF is immune from individual and collusive misreporting.

These papers contribute to the understanding of how pre-existing ambiguity facing the agents may also be leveraged to attain efficiency that is otherwise impossible. The above two results could be interpreted in multiple ways. Since Wald’s preference is crucial in resolving the conflict between efficiency and incentive compatibility, as in de Castro and Yannelis (2018), the assumption imposed on the environment to implement interim Pareto efficient SCFs is restrictive. However, given that extreme ambiguity can be endogenously generated by the designer’s use of an ambiguous communication device, as in Bose and Renou (2014), the Wald’s preference assumption is not as restrictive as it appears.

### 1.2.2 Ambiguity Faced by the Designer

Two of my publications in this category focus on designers who face ambiguities in the environment. Namely, they are concerned about misspecifying details in the environment and wish to employ mechanisms that are “robust” to potential misspecifications.

In Guo and Yannelis (2022b), the designer encounters three ambiguities simultaneously. First, she does not know agents’ belief structure. Second, she cannot predict agents’ equilibrium selection criterion. Thirdly, she has no knowledge of agents’ collusion opportunities. Put differently, even if it would be profitable for a group of agents to pool their private information and jointly misreport, she does not know whether this group can feasibly collude; factors such as partisanship, cultural differences, and geographic isolation can affect this feasibility. Hence, she wishes to robustly coalitionally implement her desired SCF, namely, to design a mechanism for which all equilibria are “good” (*i.e.*, leading to this SCF) irrespective of agents’ belief structure and collusion opportunities. We provide necessary conditions as well as sufficient ones to describe robustly coalitionally implementable SCFs. As applications, we identify a simple public good provision rule and a modified second-price auction rule that are robustly coalitionally implementable. As a further investigation, we

also explore implementable SCFs when the designer knows which collusion opportunities shall arise. Interestingly, some SCFs that are unimplementable when collusion is absent become implementable with collusion, because a coalition may be able to jointly dissolve “bad” equilibria.

Rather than constructing new mechanisms, in Cornet et al. (2023), we examine the robustness of the long-standing allocation mechanism — the market mechanism — when dealing with infinitely many goods. An infinite-dimensional commodity space is important as it provides a foundation for studying uncertain markets with infinitely many states or dynamic markets with an infinite time horizon, which are commonly used in macro finance. Yet, most classical results on the existence of an equilibrium are based on an economy with finitely many goods. This paper applies a generalization of the Knaster–Kuratowski–Mazurkiewicz Lemma, allowing us to extend the equilibrium existence result of Gale (1954) to this less-explored infinite-dimensional environment. Due to its potential to appeal to a broader audience, such as mathematicians, we chose to publish this paper in an interdisciplinary journal.

### 1.3 Endogenous Information Provision

Apart from the published papers, I am also excited about my ongoing papers with peers. Exploring Feature 2, these papers study how the designer should optimally provide information. This topic is currently among the most active research areas in microeconomic theory.

Guo et al. (2023) study how a seller (designer) should optimally sell one unit of divisible experience good in no more than two stages. For example, the seller may wish to sell the lifespan of a car with a new technology or a month-long course package. The buyer (agent) is born with some private information on his valuation of this good. The only way for him to refine his valuation is by consuming a proportion of the good. We assume that a bigger portion of the good leads to more accurate information. This paper characterizes the optimal selling mechanism, which consists of a menu of try-and-decide contracts. Each contract specifies three elements — the down payment, the stage-one allocation, and the strike price. In particular, a buyer pays the down payment to enter this contract, is allocated a certain amount of stage-one consumption, and obtains the option for buying out the remainder of the good at the pre-determined strike price. In the end, the buyer with a higher initial valuation will self-select a contract with a higher down payment, a higher stage-one consumption which provides more information, and a lower per-unit strike price. This optimal mechanism rationalizes practices seen in the business world, *e.g.*, leasing contracts of cars, houses, yachts, *etc.*, and contracts for selling gym course packages.

Instead of studying a pricing problem, Guo and He (2024) study how the designer should design the information disclosing rule to persuade the agent who learns his private information gradually. Consider a scenario where a manager wishes to persuade the worker to work on a project — she can conduct an experiment that discloses information about the objective quality of the project. On the agent’s end, he has a private stage-one signal of his cost of working on the project before learning his accurate private cost in stage two — he will work on the project if and only if the posterior mean quality of the project exceeds his private cost. We find that the optimal disclosing rule either involves discriminatorily offering

different experiments to an agent with different private signals or offering one experiment to agents with all possible private information profiles. Namely, it may be optimal to screen the agent’s private signal but not his precise private cost. We provide a necessary and sufficient condition to characterize when discriminatory information provision is optimal, which requires the high private signal to dominate the low private signal in a sufficiently strong way. This result contrasts with the optimality of nondiscriminatory information provision when the agent has only one stage of private information, as shown by Kolotilin *et al.* (2017). Our model can also be applied to study how online platforms such as Pinterest and Instagram should recommend content to persuade a user with evolving tastes to purchase through their buy-now link. Therefore, our results provide a rationale for why businesses collect user data and offer personalized information.

## 2 Theory-driven Experiments

Collaborating with our experimental group has been an enlightening experience, as it allows me to examine human behaviors from both theoretical and empirical angles. My two working papers in this area study how information provision and concealment affect people’s behaviors, thereby sharing insights with my mechanism design papers.

Brown *et al.* (2023) provide the first experimental examination of the ambiguity resolution problem, *i.e.*, if individuals intrinsically prefer to learn the unknown probability earlier, later, or gradually without considering the instrumental value of information. This problem is related to the more classical problem on the preference of risk resolution, *i.e.*, if individuals have an intrinsic preference to learn the outcome of a lottery earlier, later, or gradually. In particular, we find that a plurality of the subjects (47.4%) prefer early resolution of risk and a majority (63.7%) prefer early resolution of ambiguity. Preferring early resolution of risk increases the likelihood of preferring early resolution of ambiguity by 43.6%, and being ambiguity seeking decreases this likelihood by 25.6%. Our findings not only contribute to the understanding of individual decision-making, but also serve as a test for several theories widely used in macro finance. Among the six commonly used models examined, we find that only the generalized recursive smooth ambiguity model of Hayashi and Miao (2011) can accommodate the above correlation. When we penalize models for being theoretically encompassing and compare the explanatory powers of different models, we find that the generalized recursive maxmin model of Hayashi (2005) explains subject data equally well. This paper received its first round revision invitation when our former Ph.D. student, Hyundam Je, was in the job market. As a part of his research portfolio, the paper helped him land a postdoc position at the University of Sydney.

In Liu and Guo (2023), we study a game of voluntary information provision where the information sender’s motive is opaque. To fix the idea, think of a rule enforcer (sender, she) who knows her ability to detect violations, *e.g.*, from the number of speed radars in use. She can voluntarily disclose this information to the public (receiver, he) by providing verifiable information at a small cost. When it is common knowledge that the sender aims to maximize compliance (by minimizing violation) or maximize revenue (by inducing violations), the receiver can unravel hidden information on the detection ability by a classical “no news is bad

news” reasoning, rendering the sender’s private information irrelevant. However, when the sender’s motive is opaque, we show theoretically and experimentally that this reasoning fails. Under the parameter range of interest, our theoretical model admits three equilibria, which are differentiated by the receiver’s action when the sender chooses to hide information. Our experimental findings support that the equilibrium being played out involves (1) the agent violating the rule when the sender chooses to hide information, and (2) only the revenue-maximizing sender with low detection ability disclosing her detection ability. Moreover, we find that the sender’s payoff is significantly higher in the opaque objective case relative to the transparent objective counterpart. Hence, with opaque objectives, the sender’s private information on her detection ability is no longer irrelevant. This paper served as the job market paper of our Ph.D. graduate, Jinliang Liu, who will start his tenure track faculty job at Shandong University.

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