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Endogenous convention, prejudice, and trust in demographic summary games☆

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ABSTRACT

Many economic environments exhibit payoff discontinuity and indeterminacy, particularly those involving factors that are not under the deliberate control of players, such as prejudicial bias and trust. Simon and Zame (1990) introduce the concept of sharing rules as a means for endogenously resolving such indeterminacy when the player set is finite. We extend the Simon and Zame methodology to environments including large players whose individual actions may be felt economy-wide as well as infinitesimal players whose actions impact others only through the aggregate behavior of the demographic groups to which they belong. In effect, our analysis endogenizes the equilibrium actions of economic agents as well as the social conventions and personal beliefs that prevail.

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1. Introduction

Payoff discontinuity and indeterminacy are well-known to the fields of game theory and economics. Classic examples of models that include one or the other of these features range from spatial competition (Hotelling, 1929), to auction theory (Shubik, 1971), to oligopolistic price competition (Bertrand, 1883). Such discontinuity and indeterminacy is often chalked up to the deliberate actions of "small players" that have not been fully incorporated into the model. However, it is important to note that factors such as anticipatory expectations, prejudicial bias, superstitious beliefs, feelings of guilt, trust, etc., also impact player utility. As such factors may lie outside of the deliberate control of any agent or group of agents and need not be exogenously fixed, they also represent a source of payoff indeterminacy. This paper seeks to examine the endogenous resolution of payoff indeterminacy, irrespective of its source. As both large and small players are subject to such payoff indeterminacy, we explicitly allow for contexts that may include large players with measurable market power as well as small players who are individually insignificant but wield non-negligible market power in aggregate.

This paper merges two important strands of literature, namely the nonatomic games literature initiated by Schmeidler (1973) and the indeterminate games literature founded by Simon and Zame (1990) (S&Z). As in S&Z, we seek a "solution" that includes both a selection of payoff functions from the correspondence of payoff possibilities, along with a profile of strategies that constitute a Nash equilibrium under this payoff selection. A solution thus effectively amounts to the endogenous determination of both strategic behavior and the social conventions/personal beliefs (e.g., sharing/prejudice/trust) that induce the payoff selection. The presence of infinitely many small players, who may themselves have indeterminate payoffs (small players need not be immune to the payoff distorting effects of prejudice, trust, etc.), prohibits direct application of the solution existence results that have been previously presented in the literature. Even so, our analysis demonstrates that the S&Z methodology can be reformulated so as to achieve a solution existence result even in the presence of multiple demographic groups of infinitesimal players.

At this juncture, it may prove helpful to elaborate further on the underlying causes of payoff indeterminacy. S&Z, for instance, suggest that it should be viewed as being caused by "unseen agents whose behavior is not modeled explicitly". Although payoff indeterminacy can be induced by exogenous decision makers, it is important to note that there are many other avenues by which it may arise, even in the finite S&Z framework. Consider, for instance, a setting in which the utility that an employee derives from taking a vacation may depend on the "guilt" that the employee realizes from this decision. Guilt, however, need not be fully determined by the actions of agents, whether they be seen or unseen. Instead, such "animal spirits" may embody indeterminacy of "moral standards" that is only resolved in equilibrium. To make this discussion

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more concrete, let $\boldsymbol{x} \in \{0, 1\}^N$ represent a given profile of vacation decisions made by a finite population N of employees, let $G(\boldsymbol{x}) \subseteq [0, 1]^N$ represent the profiles of guilt that can feasibly be experienced given the strategy profile $\boldsymbol{x}$, and let $\boldsymbol{u}(\boldsymbol{x}, \boldsymbol{g}) \in \mathbb{R}^N_+$ represent the utility profile realized given $\boldsymbol{x}$ and $\boldsymbol{g} \in G(\boldsymbol{x})$, then $U(\boldsymbol{x}) = \{\boldsymbol{v} | \boldsymbol{v} = \boldsymbol{u}(\boldsymbol{x}, \boldsymbol{g})$ for some $\boldsymbol{g} \in G(\boldsymbol{x})\}$ represents the set of all feasible utility profiles given $\boldsymbol{x}$. The symbiotic relationship between equilibrium strategies and guilt is apparent when considering the notion of equilibrium in this model. Such an equilibrium is jointly captured by a strategy profile $\boldsymbol{x}^*$ along with the standards of morality embodied by the guilt selection $\boldsymbol{g}^*(\bullet) \in G(\bullet)$, where $\boldsymbol{x}^*$ is a Nash equilibrium for the game induced by the payoff function defined by $u^*(\boldsymbol{x}) = \boldsymbol{u}(\boldsymbol{x}, \boldsymbol{g}^*(\boldsymbol{x})) \in \mathbb{R}^N$ for each strategy profile $\boldsymbol{x}$. Although this simple example is not the most general that can be formulated, it nonetheless serves to illustrate the fact that social and psychological phenomena such as anticipatory expectations, prejudicial biases, superstitious beliefs, trust, standards of fairness, and any other payoff influential factor that is not fully determined by player actions is likewise capable of inducing payoff indeterminacy.

To illustrate the manner in payoffs can be endogenously determined in a game with infinitely many small players and indeterminate payoffs, let us consider infinitesimal variations of the Hotelling problems presented in S&Z. Let $A = B = [0, 1]$ represent two infinite demographic groups of infinitesimal players where each player must select a location on the interval $I = [0, 4]$. Let $x: A \to I$ and $y: B \to I$ denote measurable mappings that characterize location strategies of players in A and B respectively and let $x(A)$ and $y(B)$ denote the average location of A and B populations. Define the payoff correspondence of each $a \in A$ as follows. For each measurable strategy profile (x, y),

$$u_a(x, y) = \left\{ \frac{x(a) + y(B)}{2} \right\} \quad \text{if } x(a) < y(B),$$

$$u_a(x, y) = \left\{ 4 - \frac{x(a) + y(B)}{2} \right\} \quad \text{if } x(a) > y(B), \text{ and}$$

$$u_a(x, y) = [0, 4] \quad \text{if } x(a) = y(B).$$

Note that a's payoffs are indeterminate (multi-valued) only when a's location is identical to the average location of players in B.

Similarly, define the payoff correspondence of each $b \in B$ as follows. For each measurable strategy profile (x, y),

$$u_b(x, y) = \left\{ \frac{x(A) + y(b)}{2} \right\} \quad \text{if } y(b) < x(A),$$

$$u_b(x, y) = \left\{ 4 - \frac{x(A) + y(b)}{2} \right\} \quad \text{if } y(b) > x(A), \text{ and}$$

$$u_b(x, y) = [0, 4] \quad \text{if } y(b) = x(A).$$

Thus, if a player's location is distinct from the population average of its "opposing" demographic group then the player's payoff is single valued and equal to that it would receive if it were engaged in a Hotelling game with the population average of the opposing demographic group. However, if the player's location is equal to the population average of its opposing demographic group then its payoff is indeterminate within the interval $[0, 4]$. One natural resolution to this indeterminacy is to assume that a player's payoff should be set at 2 whenever it selects a location equal to its opposing group's population average.

Analogous to S&Z, let us also consider a variation of this structure in which the players in A are only able to locate in $[0, 3]$ while players in B are only able to locate in $[3, 4]$. In this variant, it seems natural to resolve indeterminacy by assigning a payoff of 3 to an A player when its location and that of the B population average are both at 3. Moreover, it seems natural to assign a payoff of 1 to a B player when its location and that of the A population average are both at 3. As in S&Z, our formal analysis will extend this notion that resolution of payoff indeterminacy should be context dependent by letting indeterminacy resolution be endogenously determined in the equilibrium solution itself.

Note that the illustration above is explicitly selected because of its transparent similarity to the familiar Hotelling model. The isolated nature of indeterminacy in these examples certainly should not be interpreted as being somehow reflective of all applications in which small players are present. For instance, in the case of "superstitious belief" systems, there may be a wide range of circumstances that may be consider "bad omens" as well as a wide range that may be considered "good omens" or anything else in between. More generally, any range of social conventions or of personal beliefs that directly impact player utility can be indirectly modeled via the range of payoffs that they induce on strategy profiles. To the extent that one feels that an appropriate "social solution" in such a setting is one in which social conventions/personal beliefs and selected strategies should symbiotically support equilibrium, then one can think of both strategies and convention/beliefs as being endogenously determined.

As noted above, this paper merges the literatures of nonatomic games and indeterminate games. This statement should certainly not be interpreted as suggesting all of the cutting edge results derived in these separate literatures can be directly applied in this merged context. For instance, if one were to put aside the issue of indeterminacy and embrace separability and completeness of nonatomic player spaces, then Balder (2002) presents a general framework that even includes pseudo-games and confirms existence of equilibria in which nonatomic players pursue pure strategies. This already remarkably general framework and results are even further generalized in Carmona and Podczeck (2013), which also pushes even further in the direction of discontinuous payoffs. The reason that the frameworks of these earlier papers is not adopted in the current paper is that in order for the process by which we resolve indeterminacy in the presence of infinite player sets to be effective, certain structural constraints must also be satisfied.

If we were instead to put aside the issue of nonatomic players, there have also been papers which have established impressive results in regards to endogenous resolution of indeterminacy, examples of which of course include S&Z and when considering continuation payoffs in extensive form games with infinite strategy sets there is also the work of Harris et al. (1995). Balder (2011) provides an alternative approach to the proof of S&Z's main result. None of these papers address the issue of infinite player sets. This current paper adopts the S&Z framework and extends it to allow for infinite players sets. It remains a matter for future research whether or not the approaches adopted in related papers will allow for the extension to infinite player sets in a useful manner.

Before turning to our formal modeling and analysis, it may be helpful to highlight the two primary contributions of this paper. First, this paper draws attention to a largely ignored source of payoff indeterminacy. In particular, the previous literature is often interpreted as suggesting that indeterminacy of payoffs should be thought of as being induced by the actions of economic agents that have been left out of the model. This view has the potential to unnecessarily blind readers to the myriad of applications that involve important social phenomena such as discriminatory bias, trust, and general belief dependent utility (see for instance, Rabin, 1993 and Dufwenberg, 2008). Shining a light on the fact that such phenomena can be viewed as being endogenously determined in of itself opens up a wide range of research opportunities for readers.

This paper's second primary contribution is the direct confirmation that the endogenous resolution of payoff indeterminacy is not a methodology that is exclusively reserved for games with discrete players sets and it can be applied to settings that include either or both of "macroscopic" and "microscopic" players. This is

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