

Research Report

STATED SECOND AND FIRST ORDER BELIEFS AND DECISIONS IN NORMAL-FORM GAMES

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This paper reports experiments designed to investigate the extent to which behavior in games reflects strategic considerations. Besides making decisions in a set of normal-form games with a unique pure Nash-equilibrium, subjects were asked to state their beliefs about their opponents' decisions, as well as asked to state their beliefs about their opponents' beliefs about their own decisions. The order of these three tasks was varied across different treatments to study what effects, if any, such direct belief elicitation procedures might have on subsequent stated beliefs and decisions. The data are used to examine the prediction accuracy of stated beliefs as well as how consistent stated beliefs and observed decisions are. Also, a set of eight belief-based behavioral models is estimated, using both the decision data and the belief statement data.

Keywords: Game theory, Normal-form Games, Experimental Economics, Beliefs

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EXTENDED ABSTRACT

In recent years, an increasing number of studies aim at eliciting the beliefs that subjects hold about the behavior of their opponents in experimental games. Virtually all of the studies use elicitation procedures that fall into one of two categories: direct elicitation procedures, where subjects are explicitly asked to state their expectations about their opponents' decisions, and indirect choice-based elicitation procedures, where players' decisions are used to make inferences about players' beliefs. This paper combines the two procedures, and systematically discusses how well or poorly the results yielded by the two elicitation methods go together, using a single set of normal-form games. We empirically extend the direct-belief elicitation procedures by asking subjects not only to state their first-order beliefs, but also to state their second-order beliefs using a proper scoring rule.

We use players' decisions and stated beliefs of our experiment to discuss several basic questions. By varying the order in which subjects state beliefs and make decisions, we ask what effects, if any, do earlier tasks have on the later ones. The accuracy of stated second and first order beliefs is also investigated: Can subjects' accurately predict what their opponents will predict about themselves? Can subjects' predict their opponents' decisions? We also study if players' decisions and stated beliefs are consistent. That is, we ask if subjects' stated first order beliefs are best responses to their stated second order beliefs, and if players' decisions are best responses to their stated first order beliefs, as well as if they reveal "fixed-point" reasoning.

To discuss these and other related questions, we present summary statistics and standard statistical tests, but also employ a rather general statistical model of imperfect (logistic) best responses to beliefs held by the subjects, which contains as special cases a large number of behavioral rules that were addressed by previous studies. Thereby, we can investigate a second set of questions that are related to these models of behavior: How can we incorporate belief statements into models of choice? Can the data from the direct belief elicitation help to

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discriminate between the models? Are the estimation results consistent with previous results when we only use the stated belief data, and not the choice data? Which data set allows the sharpest discrimination between the different behavioral models?

The behavioral models (“types”) considered are: *(i)* The Nash type, who chooses the Nash Equilibrium strategy, *(ii)* the L1 type (Stahl and Wilson, 1995), who best responds to a uniform prior, *(iii)* the D1 type (Costa-Gomes, Crawford, and Broseta, 2001), who best responds to an opponent that randomizes over her undominated strategies, *(iv)* the L2 type (Stahl and Wilson, 1995), who best responds to L1 behavior, *(v)* the Optimistic type, who aims at the highest possible payoff, *(vi)* the Logit Equilibrium type (McKelvey and Palfrey, 1995), who behaves as if both players are following the same noisy response function when responding to beliefs, and are both aware of this fact, so the decision noise is taken into account on all levels of reasoning, *(vii)* the Asymmetric Logit Equilibrium type (Weizsäcker, 2000), who relaxes the assumption that the players are aware of the other’s response precision, but otherwise is identical to the LE type, and *(viii)* the Noisy Introspection type (Goeree and Holt, 2000), who likewise takes into consideration the players’ decision noise on each step of reasoning, but assumes that the response precision gets smaller and smaller, with a constant ratio, on higher levels of reasoning. All of the types above make use of beliefs that are formed by the decision maker. Hence, all of the models can be re-estimated using only stated beliefs or both decisions and stated beliefs.

The rest of the paper is organized as follows. Section 2 discusses our experimental design. Section 3 reports preliminary tests using the stated beliefs and decision data. In particular, we use simple summary statistics to describe how well subjects’ stated beliefs and decisions conform to the game theoretic predictions. We describe the extent to which subjects’ average stated second and first order beliefs are accurate. Additionally, we describe the extent to which subjects’ individual stated second and first order beliefs and decisions are consistent with each other, or consistent overall. Section 4 discusses our structural and econometric approach to analyzing behavior using both decisions and stated beliefs. Section 5 reports the error rate estimates that best describe subjects’ behavior, first using decisions or stated second order beliefs or stated first order beliefs alone or, and then combining decisions and stated first order beliefs, and later combining decisions and stated second and first order beliefs. Section 6 concludes.

ran our experiments during the Spring and Summer of 2000.

Main References:

- Costa-Gomes, M., V. Crawford, and B. Broseta (2001): "Cognition and Behavior in Normal-Form Games: An Experimental Study," *Econometrica*, forthcoming.
- Goeree, J., and C. Holt (2000): "A Model of Noisy Introspection," *mimeo*, Univ. of Virginia.
- McKelvey, R. and T. Page (1990): "Public and Private Information: An Experimental Study of Information Pooling," *Econometrica*, 58, 1321-1339.
- McKelvey, R. and T. Palfrey (1995): "Quantal Response Equilibrium for Normal Form Games," *Games and Economic Behavior*, 10, 6-38.
- Stahl, D., and P. Wilson (1995): "On Players' Models of Other Players: Theory and Experimental Evidence," *Games and Economic Behavior*, 10, 218-254.
- Weizsäcker, G. (2000): "Ignoring the Rationality of Others: Evidence from Experimental Normal Form Games," *mimeo*, Harvard University.