



## Empirical models of discrete choice and belief updating in observational learning experiments<sup>☆</sup>

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### ABSTRACT

Subjects in economics experiments are often asked to choose an action from a set of discrete choices. The logit-QRE approach to analyse these data places strong restrictions on how subjects in information cascades experiments extract information from observed outcomes and how they update beliefs in response to new information. We add a belief elicitation procedure to the experimental design that allows us to measure directly both the inferences drawn from publicly announced decisions and how beliefs are updated in response to new information. The reported beliefs tend to be well calibrated to frequentist probabilities and also predict individual choices. Contrary to previous conclusions, we find that respondents do not tend to overweight private information when updating beliefs. Our analysis suggests that the earlier findings arise because identification of the discrete choice model relies on a misspecified model of belief updating in response to preceding announcements.

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### 1. Introduction

Subjects in economics experiments are often asked to choose an action from a set of discrete choices. Experimental economists were slow to apply econometric models of discrete choice to their data, but these methods are now frequently employed (Goeree et al., 2005). A prominent approach incorporates the *quantal response equilibrium* (QRE) concept. The standard QRE arises with subjects whose behavior can be described by a random utility model with logit choice probabilities where it is common knowledge that all subjects behave according to this model with known structural parameters (McKelvey and Palfrey, 1995, 1998). This approach has proven to be very successful in fitting the data produced in numerous experiments where other equilibrium concepts do not appear to fare so well. Recently, attention has been paid to the extent to which QRE models imply any falsifiable restrictions (Goeree et al., 2005; Haile et al., 2006).

Our interest here arises from one type of experiment (known as the information cascades experiment) in which application of behavioral models based on QRE places strong restrictions on how subjects extract information from observed outcomes and how they update beliefs in response to new information. Initially conducted by Anderson and Holt (1997), henceforth AH, information cascades experiments involve sequential games of incomplete information. In particular, players are sequentially asked to guess which of two mutually exclusive events has occurred. In order to help them make their decisions, players

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are given privately observed but noisy information about which event occurred. Furthermore, these decisions are publicly announced, so that when a player is making her decision, she can also consider all the decisions by those who preceded her.

To analyse the choices made in these experiments, standard decision-making models require either data or assumptions on (1) the inferences subjects draw from the publicly announced decisions of others and (2) how subjects update beliefs on the uncertain events in response to new information. AH applied the logit-QRE approach, which models players as Bayesian updaters who are subject to independent and identically distributed “payoff disturbances.” These players are modeled as using the logit-QRE choice probabilities and Bayes rule to make inferences on the private information available to preceding decision makers.

Goeree et al. (GPRM 2007) nest the standard logit-QRE model within one that allows for subjects to deviate from Bayesian updating by placing too much or too little weight on private information. At the individual level, we show that this discrete choice model is quite similar to the *general decision weight model* proposed by Grether (1980) and applied by Hung and Plott (HP 2001) to the analysis of data from information cascades experiments. HP, however, model players as *naive Bayesians* who draw strong inferences from public announcements because they naively believe that preceding decision makers ignore the announcements of everyone before them.<sup>1</sup> Regardless, both GPRM and HP find that subjects overweight private information when updating beliefs. In the GPRM model, knowing that the preceding players also overweight private information, subjects draw stronger inferences from public announcements than in the standard logit-QRE, conditional on their priors.

We report here on information cascades experiments that replicate the experimental design and results of HP. We also supplement the experiment with a belief elicitation procedure that allows us to measure directly both the inferences drawn from publicly announced decisions and how beliefs are updated in response to new information. That is, unlike GPRM and HP, our analysis relies on reported beliefs rather than beliefs that we would infer based on observed outcomes and strong behavioral assumptions.

The reported beliefs tend to be well calibrated to frequentist probabilities and also predict individual choices. Importantly, these data indicate substantial heterogeneity in belief formation, whereas the standard QRE and naive Bayesian models invoke strong homogeneity restrictions. Contrary to previous conclusions, we find that respondents do not tend to overweight private information when updating beliefs. Our analysis suggests that the earlier findings arise because identification of the discrete choice model relies on a misspecified model of belief updating in response to preceding announcements.

Section 2 describes the basic design of information cascades experiments and summarizes previous findings. In Section 3, we discuss models of discrete choice that have been applied to experimental data, as well as the restrictions on beliefs that have been used to identify the models. Our experimental procedures are detailed in Section 4. Section 5 presents the empirical findings. Section 6 concludes.

## 2. Information cascades experiments

### 2.1. Experimental design

The experiments reported here are based on an  $n$ -player game of incomplete information in which players sequentially make a binary decision. In each stage  $t$ , each player receives a binary private signal about which of two mutually exclusive and exhaustive events has occurred. Event  $A$  occurs with probability  $p_A \in (0,1)$  and event  $B$  occurs with probability  $p_B = 1 - p_A$ . The private signals,  $s_t \in \{s^A, s^B\}$  are independently and identically distributed, conditional on the state of the world (i.e., event  $A$  or event  $B$ ). Signals are informative in that

$$\Pr(A|s^A) > \Pr(A|s^B)$$

and

$$\Pr(B|s^B) > \Pr(B|s^A),$$

but are not fully revealing in that

$$\Pr(A|s^A), \Pr(A|s^B) \in (0, 1)$$

An individual's information set at his decision node will include not only his private signal, but also the decisions of the players who moved before him:  $H_{t-1} = \{h_1, \dots, h_{t-1}\}$  is the history of decisions  $h$  of the  $t-1$  players who moved before him.

Payoffs  $r(\cdot)$  to individual  $i$ , who makes a decision  $c_{it} \in \{a, b\}$  are

$$r(c_{it} = a|A) = r(c_{it} = b|B) > r(c_{it} = a|B) = r(c_{it} = b|A).$$

All players face the same payoffs.

<sup>1</sup> This belief formation process might fit well within the experimental economics literature on “cognitive hierarchies” begun by Camerer et al. (2004), with each player believing the others are one step down the hierarchy. For example, Kübler and Weizsäcker (2004) use a logit-QRE approach to model cognitive hierarchies in information cascade experiments. See also recent work on heterogeneous QRE (HQRE) by Camerer et al. (2008), who identify a link between HQRE and a cognitive hierarchy model.

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