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Eliciting and estimating valid subjective probabilities: An experimental investigation of the exchangeability method

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ABSTRACT

Using a laboratory experiment, we investigate whether incentive compatibility affects subjective probabilities elicited via the exchangeability method (EM), an elicitation technique consisting of several chained questions. We hypothesize that subjects who are aware of the chaining strategically behave and provide invalid subjective probabilities, while subjects who are not aware of the chaining state their real beliefs and provide valid subjective probabilities. The validity of subjective probabilities is investigated using de Finetti's notion of coherence, under which probability estimates are valid if and only if they obey all axioms of probability theory.

Four experimental treatments are designed and implemented. Subjects are divided into two initial treatment groups: in the first, they are provided with real monetary incentives, and in the second, they are not. Each group is further sub-divided into two treatment groups, in the first, the chained structure of the experimental design is made clear to the subjects, while, in the second, the chained structure is hidden by randomizing the elicitation questions.

Our results suggest that subjects provided with monetary incentives and randomized questions provide valid subjective probabilities because they are not aware of the chaining which undermines the incentive compatibility of the exchangeability method.

1. Introduction

During the last two decades, many social scientists have become more interested in investigating and eliciting subjective probabilities of everyday events. The main reason to pursue this line of inquiry is because many choices in the real world involve future outcomes and take place under uncertainty. Hence, people often behave and make decisions according to their beliefs and expectations. Manski (2004) demonstrates the importance of subjective probabilities in several branches of applied economics, ranging from the influence of households' probabilistic income expectations on their consumption and saving decisions, to the impact of students' probabilistic expectations of the returns (again, in income terms) to education on schooling choices.

Expectations on risky and uncertain outcomes, which lie outside of the financial domain, are potentially complex, but also important to deal with. These have been neglected in economics until quite recently, perhaps, because they pertain to issues which are more difficult to address than financial risk and uncertainty, such as stock market activity. Early work on subjective probability pertained to another issue that is relatively simple to understand and for which outcomes are readily

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observable with short delays: the weather, specifically, temperature and precipitation forecasts (e.g., Brier, 1950; Baillon, 2008).

A domain where subjective probabilities have been recognized to be crucial in understanding and predict people's choice behavior is food safety, but little in this area has been done to explore subjective probability elicitation. Despite the fact that many studies have shown how consumers' probabilistic expectations of food safety might affect purchases (e.g., Buzby et al., 1998; Williams and Hammitt, 2001), they often use very simple and rough methods for eliciting subjective probabilities, which often consist in directly asking subjects a guess of the probability that given outcomes will occur in the future. The key problem with issues such as food safety is that the nature of the uncertainty is less accessible to laypeople, and the primary outcome, the health effect, may be unobservable for quite some time to come.[1] However, a recent study suggests that uncertainty in food safety decisions may be quite important (Kivi and Shogren, 2010).

In this paper, we investigate and elicit consumers' perceptions of the probability that given levels of pesticide residues will be present in apples produced in the future in the Province of Trento (Italy). Pesticide residues pose health risks to people who eat apples, and, thus, people's perceptions of their presence can affect their preferences for agricultural policies that local authorities are planning to incentivize the production of healthy apples. The investigation of this topic might be very important to this region as apple production is a key sector of its economy (P.A.T., 2010). Generally, the presence of pesticides in food is quite important, as we all must eat; several studies have shown that human exposures to chemicals are associated with risks to human health, they may even produce very severe illnesses as cancer (Alavanja et al., 2004).

There are many different ways to elicit subjective probabilities and several are briefly discussed below. We use an innovative technique for eliciting probabilities, known as the exchangeability method (EM), recently used by Baillon (2008). He elicited subjective probabilities for future daily temperature in Paris, the euro/dollar exchange rate, and the daily variation of the French stock index CAC 40. His subjects were asked to estimate these for a given day about four weeks after the experiment was conducted. The same technique was further developed by Abdellaoui et al. (2011) to elicit subjective probabilities and investigate ambiguity attitudes related to similar topics.[2]

The EM consists of a set of binary questions where subjects are asked to bet a certain amount of money on a given outcome rather than on an alternative outcome. In each question, the outcomes which are presented to the subject result from a bisection procedure of the whole state space of the random variable under study. When subjects become indifferent between the two outcomes, they are assumed to perceive both as equally likely and subjective probabilities can be estimated. The sequential splitting process behind the EM makes this elicitation procedure chained, in the sense that the outcomes presented in each question depends on the outcome that has been chosen in the previous one.

The incentive compatibility of the EM might be questioned because previous experimental studies have shown that chained elicitation mechanisms are not necessarily incentive compatible. In fact, the provision of monetary incentives to subjects, based on their choice behavior during the experiment, might induce them to not state their real beliefs, but, instead, to strategically behave to be better rewarded upon completion of the tasks for the experiment (e.g., Harrison, 1986).

In this paper, we investigate whether the lack of incentive compatibility of the EM due to both the presence of chained questions and no provision of real monetary incentives, affects the validity of subjective probabilities elicited by such a technique. We determine and measure the validity of subjective probabilities elicited via the EM implementing a method based on de Finetti's notion of *coherence* (1937). By using this approach we essentially aim to identify the best way for eliciting subjective probabilities via the EM, in terms of validity.[3]

The remainder of the paper is laid out as follows. We first highlight the main strengths and limitations of the EM by comparing it to other techniques for eliciting beliefs. Next, we describe our testable hypotheses and the methodology used to measure validity of subjective probabilities. Finally, we offer some conclusions based on the experimental results we have obtained.

2. Methods for eliciting subjective probabilities

The simplest way to elicit subjective probabilities consists of asking people to directly state the chance that a specific magnitude of the outcome will happen in the future (Spetzler and Stael Von Holstein, 1975). Asking simple, direct questions is common in a host of previous health-risk studies, such as those involving smoking cigarettes (e.g., Viscusi, 1990; Gerking and Khaddaria, 2011), drinking contaminated water (e.g., Jakus et al., 2009; Shaw et al., 2012), or eating unhealthy food (e.g., Buzby et al., 1998; Williams and Hammitt, 2001).

However, unless subjects are asked to state a chance for each of all possible specific magnitudes of outcomes, the information gathered from such an easy question is very limited. Using a direct approach like this, we might learn about only one point, or about a very narrow range, in the individual's subjective probability distribution.

[1] Short-term food sickness is perhaps observable after a short delay, but ethics in experiments preclude subjecting subjects to this.

[2] They elicited subjective probabilities related to the daily variation of the French stock index CAC 40, temperature in Paris and also in a randomly drawn remote country for a given day about 3 months after the experiment.

[3] Since this experiment is conducted in the lab, with a controlled environment and real monetary incentives, we only refer to the internal validity of elicited risk estimates. Hence, we cannot analyze the external validity of our results, being aware that elicited estimates in the lab might be different from those elicited in the field, where it is impossible to control for many confounding factors (for instance, background risk) (Harrison et al., 2007).