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Interpreting the predictions of prediction markets ☆

Charles F. Manski *

Department of Economics and Institute for Policy Research, Northwestern University, 2001 Sheridan Road, Evanston, IL 60208, USA

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Abstract

Prediction markets are futures markets in which prices are used to predict future events. I present the first formal analysis of price determination supposing traders have heterogeneous beliefs, deriving the equilibrium when traders are risk-neutral price takers.

Keywords: Beliefs; Efficient markets hypothesis; Futures markets; Prediction markets; Subjective probabilities

JEL classification: D84; G10

1. Introduction

Prediction markets are futures markets in which prices are used to predict future events. Consider an all-or-nothing contract paying a dollar if a specified event occurs and nothing otherwise. Proponents of prediction markets have interpreted the price of such a contract as a "market probability;" that is, a market-generated likelihood that the event will occur. Yet the arguments for this interpretation have been imprecise.

Introducing the Iowa Electronic Markets (IEM) to the research community, Forsythe et al. (1992) sought authority in Hayek (1945), who argued broadly but vaguely that market prices aggregate

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* Tel.: +1 847 491 8223; fax: +1 847 491 8223.
E-mail address: cfmanski@northwestern.edu.

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information. Hayek put it this way (p. 526): "The mere fact that there is one price for a commodity .... brings about the solution which .... might have been arrived at by one single mind possessing all the information which is in fact dispersed among all the people involved in the process."

In a recent review article, Wolfers and Zitzewitz (2004) wrote (p. 108): "In a truly efficient prediction market, the market price will be the best predictor of the event, and no combination of available polls or other information can be used to improve on the market-generated forecast." The expression "efficient prediction market" refers to the *efficient markets hypothesis* (EMH), which posits that price is a sufficient statistic for all private information held by traders. However, the EMH is only a hypothesis that may hold in some settings; it is not a universal truth.

This paper presents the first formal analysis of price determination in prediction markets where traders have heterogeneous beliefs. I consider a simple and illustrative setting, where traders are risk-neutral price takers with finite trading budgets. I report three findings: (a) the equilibrium price of a prediction-market contract is a particular quantile of the budget-weighted distribution of traders' beliefs; (b) price does not reveal the mean belief that traders hold but does yield a bound on the mean belief; (c) the equilibrium price remains the same if traders use price data to revise their beliefs in some ways.

Although these findings are new to the study of prediction markets, finding (a) has previously been obtained in a study of pari-mutuel betting on horse races. Considering races with two horses, Ali (1977) reported the equilibrium condition (1) that I independently derive below. He suggested that this may explain the "favorite-longshot bias," where horses with high equilibrium prices (i.e., favorites) empirically tend to win more often and those with low prices (i.e., longshots) tend to win less often than they should if their prices are interpreted as market probabilities of race outcomes.

2. Price determination

Consider a prediction market offering all-or-nothing contracts on the occurrence of a binary event; one contract pays a dollar if event m occurs and the other pays a dollar if the contrary event n ≡ (not m) occurs. Let the contract prices be π_m and π_n, where $\pi_m + \pi_n = 1$. It will be shown below that equilibrium prices satisfy this "no-arbitrage" condition.

Suppose that a large population J (formally a continuum) with heterogeneous beliefs participate in this market; without loss of generality, let the unit interval index the members of J. Let each person j have a fixed trading budget of y_j dollars and a subjective probability q_{jm} that event m will occur. Let $P(q_m, y)$ denote the cross-sectional distribution of beliefs and budgets. Let the distribution of beliefs be continuous, with budgets initially being statistically independent of beliefs. Finally, let traders be price takers who maximize the subjective expected value of their contracts.

Under these assumptions, the equilibrium price for contract m in a prediction market such as the IEM solves the equation

$$\pi_m = P(q_m > \pi_m). \tag{1}$$

Thus, most persons have beliefs higher than price when price is above 0.5, and most have beliefs lower than price when price is below 0.5. The equilibrium price is unique and generically equals the $(1-\pi_m)$-quantile of the distribution of beliefs. Eq. (1) has a unique solution because $P(q_m > \pi_m)$ is a