A Research Agenda for Prediction Markets

Patrick Buckley[1]

[1]Kemmy Business School, University of Limerick, Ireland
Patrick.Buckley@ul.ie

Abstract. This paper describes the use of prediction markets as tools for enabling collective intelligence. Their benefits are explored and current applications are elucidated. Moving on from this, key open research questions from the literature are identified, and a research agenda that can address these issues is introduced.

Keywords: Prediction Markets, Collective Intelligence

1 Introduction

Prediction markets are a relatively novel form of decision making. The core insight upon which they are based is that a market mechanism can be used to enable two processes which are crucial to effective decision making. First, the provision of individual rewards to participants prompts truthful information revelation. Second, asset price movement within a market provides a mechanism that can be adapted to support information aggregation. When deployed using Information Technology (IT), prediction markets can trivially scale to hundreds or even thousands of participants. This scalability enables collaborative decision making on a scale that many other group decision making mechanisms would find prohibitive. They provide a method of generating collective intelligence that can draw upon the wisdom of large, disparate crowds.

This paper is structured as follows. In section 2, we introduce the concept of prediction markets. We particularly focus on the theorised benefits of prediction markets from a decision making perspective and elucidate current applications of prediction markets. As befits a relatively novel innovation, there are many open research questions regarding prediction markets, which are discussed in section 3. In section 4 we present a brief description of a methodology which can provide data to investigate a research agenda in prediction market that can address some of the previously identified issues. We conclude in section 5 by calling for help in operationalizing this research agenda.

2 Prediction Markets

2.1 Prediction Markets

Prediction markets are "markets that are designed and run for the primary purpose of mining and aggregating information scattered among traders and subsequently using this information in the form of market values in order to make predictions about specific future events." [1, p. 75]. The theoretical roots of prediction markets can be found in Hayek's conceptualization of markets as near perfect transmitters of information [2]. This perspective on market operation led to the formulation of the efficient market hypothesis, which has been expressed as stating that stock "prices at any time 'fully reflect' all available information" [3, p. 383]. There are a number of forms of the efficient market hypothesis, including the weak, semi-strong and strong form, which make more or less demanding claims as to the efficiency of information transmission within markets [4], [5]. While it is relatively trivial to point to specific examples of market failure, in general, speculative markets such as those in stocks, commodities and future options do a credible, if imperfect job of aggregating relevant information into market prices [6]. This position is backed by a substantial body of empirical evidence [5], [7, 9].

A prediction market is created by offering a contract on the outcome of a future event of interest for sale to a group of participants. For example, suppose an organisation wishes to forecast whether or not a project will reach its next milestone on time. The organisation could create a contract PROJ, which will pay a holder €1 on the date of the milestone if the milestone is reached or €0 otherwise. The organisation would set the initial price of the contract at 50 cents and then offer it for sale to individuals participating in the project. Under these circumstances, if an individual believes that the project is likely to reach its milestone, they will buy the contract in the expectation of receiving a greater reward in the future. Equally, if a rational individual believes the project will not reach its milestone, then they will sell (or 'short') the contract, taking the profit immediately. Individuals buying or selling the contracts being offered will have the effect of moving the price of the contract.

This two-outcome model can be easily extended to allow for the creation of contracts across a range of disjoint outcomes. For example, a prediction market can be created which asks participants to forecast what will be the most successful product from a range of products. They can also be used to allow participants to forecast values rather than select from a particular set of options. As an example, participants may be asked to forecast the total sales of a particular product.

Prediction markets differ from traditional financial markets in two important ways. First, prediction markets operate by enabling participants to trade contracts, whose value is dependent upon the outcome of a future uncertain event [10]. In a prediction market, the trade of contracts in a market place allows participants to exchange information. The trade of contracts also acts as a decision mechanism, since the price of the contract at any point in time can be viewed as the consensus opinion of all the participants in the market as to the likelihood of an event occurring. In this way, the

trade of contracts enables the underlying processes of communication and decision making that is required to allow group decision making to occur [11].

The second distinguishing characteristic of a prediction market is that its primary concern is the elicitation of information [12]. In the modern world, many markets exist that allow participants to trade assets whose value is dependent upon an uncertain future event. While these markets can be viewed as prediction markets from a certain perspective, in general this paper will follow the guidelines proposed by Wolfers and Zitewitz [13]. It steers away from markets where the primary role is enhancing the enjoyment of an external event through taking on risk. Similarly, markets whose primary rationale for existence is that they enable the hedging of financial risk will not be considered prediction markets.

2.2 Benefits of Prediction Markets

Researchers have identified a number of theoretical benefits of prediction markets over comparable information aggregation mechanisms such as polls or expert groups [14]. First, prediction markets provide incentives for truthful information revelation. Second, they provide an algorithm for automatically communicating and aggregating information. Third, prediction markets implicitly weight the information supplied by participants. Fourth, prediction markets can scale efficiently to very large groups, a major advantage over other forms of group decision making, particularly where relevant information is widely dispersed. Fifth, prediction markets can operate in real-time over a long period of time. Finally, prediction markets can be designed in such a way as to allow for trader anonymity.

Prediction markets are instantiated by offering contracts for trade whose value is dependent upon the outcome of a future event. Contracts are specified in the format, "Pay €X if event Y occurs". Individual participants buy and sell these contracts. Rewards for correct forecasts accrue to the individual who holds the contract. This individualization of reward creates an incentive for individuals to hold contracts in events they believe are likely to occur [15]. By providing an individualized incentive some of the challenges associated with information revelation in other domains can be ameliorated [10]. In a deliberative group, individuals may have little incentive to reveal private information, since any benefits will accrue to the group as whole. By providing information to the group, they bestow benefits on others without any reward to themselves, and possibly facing high private costs [16]. The provision of a direct financial incentive to an individual can serve as a counter weight to the emotional, political and professional factors that may inhibit truthful information revelation in a group setting. Since participants are rewarded for accurate decisions, all other things being equal, the provision of individualized incentives should promote information search [17]–[19].

The second characteristic of prediction markets is that they implicitly contain an algorithm for information aggregation. The operation of the market in contracts, and the trading it facilitates automatically creates the equilibrium price which is used as a proxy for estimates about the event of interest [10]. By allowing experts to trade with each other, prediction markets allow disparate opinions and beliefs to be aggregated

into a coherent, consistent whole [18]. As well as providing a mechanism for aggregating the private beliefs of individuals, prediction markets can also enable individual participants to extract information from observing market estimates [20], and correct biases in publicly available information [21].

Several authors point out that prediction markets implicitly weight the information supplied by participants [18], [22], [23]. If participants are more confident of their beliefs in a particular topic, they will be willing to buy more of the relevant contracts, and vice versa. The ability of participants to choose the level of their investment allows them to indicate their confidence in their information in a manner which is automatically accommodated by the aggregation algorithm.

The nature of the market structure also means that prediction markets can scale to very large groups [15]. When considering a market that utilizes information technology to enable trading, the only real limits on the number of participants are computational. This means that prediction markets potentially have lower running costs, particular if they are in operation over a period of time [24]. Most of the overheads in deploying prediction markets are involved in setting up the market and attracting participants. It also means that prediction markets can be created that can utilize participants from outside traditional organizational boundaries, recruiting participants from suppliers, customers and other stakeholders in order to improve the decision making process.

Prediction markets can operate in real-time [10], [24]. This gives them a significant advantage over other comparable information aggregation methods such as polls. Finally, prediction markets can be designed in such a way as to allow trader anonymity [25]. Power relationships and social interactions in group decision making are often seen as responsible for some of the weaknesses of group decision making [11]. The utility of this attribute can vary, but the ability to enable it demonstrates the flexibility of prediction markets.

2.3 Applications of Prediction Markets

Markets which share the defining characteristics of prediction markets have existed for hundreds of years. Specific examples from the literature include markets on Papal elections in 16th century Italy, parliamentary elections in 18th and 19th century Britain and American presidential elections [26], [27]. Modern interest in prediction markets is generally held to have begun with the establishment of the Iowa Electronic Market (IEM) in 1988, which is often seen as the first implementation of a prediction market. (Joyce Berg et al. 2008a). Since then academic and practitioner interest in prediction markets has continued to grow [1].

Modern operational prediction markets can be broadly divided into three categories. The first subdivision is that between public and private prediction markets. A public prediction market is one which invites participation from the general public. A private prediction market is one created by a sponsor which seeks to recruit participants from a specific, albeit potentially very large population. Within public prediction markets, some prediction markets operate using real currency. Participants invest their own money in the market, and gain or lose according to their performance.

Other public prediction markets use virtual currency to enable trading. Table 1 lists some exemplars of these prediction markets.

Type	Example
Public (real currency)	Intrade, http://www.intrade.com Betfair, http://www.betfair.com Iowa Electronic Market, http://tippie.uiowa.edu/
Public (virtual currency)	The Hollywood Stock Exchange, Hub-dub, http://www.hubdub.com Newsfutures, http://www.lumenogic.com Foresight Exchange, http://www.ideosphere.com
Private	Qmarkets, http://www.qmarkets.com Inkling markets, http://inkling.com Crowdcast, http://www.crowdcast.com Prokons, http://www.prokons.com

Table 1. Selected operational prediction markets

Private prediction markets are most pertinent to this discussion. Organizations are interested in using prediction markets to tap the valuable private information held by employees and other stakeholders in the organization [21]. Academic references and analyses on the use of prediction markets as internal decision support tools for various organizational functions is still limited, although increasing all the time. Ortner [28] describes the use of prediction markets in a project management process in Siemens in Austria, with another example of prediction markets use in project management offered by Remidez and Joslin [25]. A number of papers discuss the use of prediction markets as sales forecasting tools [29], [30]. A similar case study, forecasting market share in the Austrian mobile phone market is described by Waitz and Mild [31]. Hopman [32] describes the use of prediction markets for demand forecasting in Intel, with other authors offering examples from the medical domain [24], [33]. Hahn and Tetlock report Eli Lilly have used prediction markets to evaluate what drugs will be successful, while Microsoft have used them to forecast sales of software [18]. Other organizations that are reported in the literature as having used prediction markets include Motorola, Qualcomm, Infoworld, MGM, Chiron, TNT, EA Games, Yahoo, Corning, Masterfoods, Pfizers, Abbott, Chrysler, General Mills, O'Reilly and TNT [34].

Other authors have focused on providing theoretical descriptions of the applications of prediction markets in organizations. Passmore et al. [35] describe how prediction markets can be used to support the Human Resource function in organizations. Other authors have suggested prediction markets can have applications in the domain of risk management [36]–[39]. Sunstein [16] offers a list of possible applications of prediction markets, while other authors point out the power of prediction markets as communication tools in an organizational setting [40,41].

3 Open Research Questions

Much of the academic work on prediction markets to date has focused on assessing their accuracy, both relative to comparable methods and in absolute terms. Academic research to date suggests that prediction markets "can provide more accurate forecasting and effective aggregation than other predictive technologies" [10, p. 45]. Empirical work has demonstrated their effectiveness versus competing mechanisms [42]. Other authors caution against drawing definitive conclusions, but summarise the existing empirical evidence as cautiously optimistic [43]–[45].

The establishment of the basic credibility of prediction markets as information aggregation tools has to lead to calls for studies which move beyond assessing predictive accuracy [46]. A number of research questions emerge from the literature. Much of the predictive power of prediction markets is derived from having large numbers of traders. A key question that emerges from the literature is how traders can be attracted to participate in prediction markets [45]. Related to this question is the concern that as a group decision making tool, prediction markets may be more attractive to individuals who possess certain personality traits. If prediction markets only attract individuals with a high risk tolerance, this may potentially limit their usefulness, particularly in organisational decision making contexts.

Another major concern noted in the literature is the theoretical possibility that prediction markets can be adversely affected by manipulation [10], [45], [47]. In this context, manipulation is an attempt by an individual or group of traders to affect the outcome of the prediction market in a manner which contradicts their own privately held information. Individuals may be motivated to manipulate a prediction market if their utility for determining the outcome of a prediction market outweighs the incentives offered for truthful information revelation.

4 Proposed Research Agenda

Addressing the research question outline above requires a research methodology which can provide data which has a number of properties. A research agenda investigating these concerns requires the use of psychometric instruments to measure personality traits of individuals and the correlation of those measurements with observed behaviours in a prediction market. It would be necessary to collect data across a temporal period. This would allow gathering data on how trading patterns and behaviours such as attempted manipulations impact upon the market as a whole. By collecting data across a temporal window and correlating that data with measurements of individual participant's personalities, it becomes possible to investigate how different individuals respond to different types of feedback.

One potential source of data that can be used to investigate these issues is prediction markets which are used in a pedagogical setting. This application of prediction markets has recently begun to receive academic interest [39], [48], [49]. The benefits of prediction market participation to learners in the cognitive and affective domains of

learning makes a powerful case for their inclusion in curricula, particularly in large group teaching environments. This in turn opens up the possibility of prediction markets that are run in an educational setting being used as research tools.

A prediction market that is ran as part of a large course will have a stable pool of participants. The participants can be accessed directly by researchers, and prompted to complete psychometric instruments. The prediction market will be a relatively controlled environment in that the questions asked, the duration of the trading periods and the incentives offered are all under the control of the researcher. The data that is collected by the market, including price movements and trading decision are all captured by the market and can be correlated with data on specific individuals through the use of an identifier. Of courses it is necessary to ensure that the pedagogical justification for using prediction markets in an educational design is not undermined by the research programme, but with careful design it should be possible to both provide learners with a valuable educational experience and at the same time drive a research agenda forward.

5 Conclusions

Prediction markets have been positioned in the literature as tool for enabling collective intelligence and group decision making. Their potential has led to calls in the literature for more nuanced research programmes which move beyond evaluating their accuracy to investigate issues such as participant behaviour and the effect of manipulation.

We have pioneered the use of prediction markets as pedagogical tools, and have published extensively in the area. In this paper, we propose that this specific application of prediction market is a potentially useful research methodologies that can be used in investigate a number of issues of concern to prediction markets researchers. We believe that we can make a contribution to the larger study of collective intelligence by providing a more nuanced understanding of the strengths, weaknesses and characteristics of prediction markets. We would welcome collaborators and partners who would be interested in developing this research agenda. We would be delighted to offer our expertise in deploying prediction markets in an educational setting to partners, with a view to developing a research agenda that could both investigate the research questions outlined above and also investigate the effect of culture on prediction market performance.

6 References

[1] G. Tziralis and I. Tatsiopoulos, “Prediction Markets: An Extended Literature Review,” *J. Predict. Mark.*, vol. 1, no. 1, pp. 75–91, Feb. 2007.

[2] F. A. Hayek, “The Use of Knowledge In Society,” *Am. Econ. Rev.*, vol. 35, no. 4, pp. 519–530, 1945.

[3] E. F. Fama, “Efficient Capital Markets: A Review of Theory and Empirical Work,” *J. Finance*, vol. 25, no. 2, pp. 383–417, 1970.
[4] G. Kamp and P. A. Koen, “Improving the Idea Screening Process within Organizations using Prediction
Markets: A Theoretical Perspective,” *J. Predict. Mark.*, vol. 3, no. 2, pp. 39–64, Aug. 2009.
[5] R. Kolb, *Understanding futures markets*, 5th ed. Malden MA: Blackwell Publishers, 1997.
[6] R. Hanson, “Logarithmic Market Scoring Rules for Modular Combinatorial Information Aggregation,” *J. Predict. Mark.*, vol. 1, no. 1, pp. 3–15, Feb. 2007.[7] B.. G. Malkiel, “The Efficient Market Hypothesis and Its Critics,” *J. Econ. Perspect.*, vol. 17, no. 1, pp. 59–82, Winter 2003.
[8] B. G. Malkiel, “Reflections on the Efficient Market Hypothesis: 30 Years Later,” *Financ. Rev.*, vol. 40, no. 1, pp. 1–9, Feb. 2005.
[9] R. Roll, “Orange Juice and Weather,” *Am. Econ. Rev.*, vol. 74, no. 5, pp. 861–880, 1984.
[10] C. Hall, “Prediction Markets: Issues and Applications,” *J. Predict. Mark.*, vol. 4, no. 1, pp. 27–58, May 2010.
[11] D. G. Ellis and B. A. Fisher, *Small Group Decision Making: Communication and the Group Process*, 4th ed. New York: McGraw-Hill Book Company, 1994.
[12] T. W. Bell, “Private Prediction Markets and the Law,” *J. Predict. Mark.*, vol. 3, no. 1, pp. 89–110, Apr. 2009.
[13] J. Wolfers and E. Zitzewitz, “Prediction markets,” *J. Econ. Perspect.*, vol. 18, no. 2, pp. 107–126, 2004.
[14] E. Servan-Schreiber, J. Wolfers, D. M. Pennock, and B. Galebach, “Prediction Markets: Does Money Matter?,” *Electron. Mark.*, vol. 14, no. 3, pp. 243–251, 2004.
[15] R. W. Hahn and P. C. Tetlock, “Introduction to Information Markets,” in *Information Markets: A New Way of Making Decisions*, Washington D.C: AEI-Brookings Joint Center for Regulatory Studies, 2006, pp. 1–12.
[16] C. R. Sunstein, “Deliberation and Information Markets,” in *Information Markets: A New Way of Making Decisions*, Washington D.C: AEI-Brookings Joint Center for Regulatory Studies, 2006, pp. 66–100.
[17] J. E. Berg and T. A. Rietz, “Prediction Markets as Decision Support Systems,” *Inf. Syst. Front.*, vol. 5, no. 1, pp. 79–93, Jan. 2003.
[18] R. W. Hahn and P. C. Tetlock, *Information Markets: A New Way of Making Decisions*. Washington D.C: AEI-Brookings Joint Center for Regulatory Studies, 2006.
[19] C. R. Sunstein, “Deliberating Groups vs. Prediction Markets (or Hayek’s Challenge to Habermas),” *Episteme J. Soc. Epistemol.*, vol. 3, no. 3, pp. 192–213, 2006.
[20] K. Kálovcová and A. Ortmann, “Understanding the Plott-Wit-Yang Paradox,” *J. Predict. Mark.*, vol. 3, no. 3, pp. 33–44, Dec. 2009.
[21] T. S. Gruca and J. E. Berg, “Public Information Bias and Prediction Market Accuracy,” *J. Predict. Mark.*, vol. 1, no. 3, pp. 219–231, Dec. 2007.
[22] J. E. Berg and T. A. Rietz, “The Iowa Electronic Markets: Stylized Facts and Open Issues,” in *Information Markets: A New Way of Making Decisions*, R. W. Hahn and P. C. Tetlock, Eds. Washington D.C: AEI- Brookings Joint Center for Regulatory Studies, 2006, pp. 142–169.
[23] A. Graefe and C. Weinhardt, “Long-Term Forecasting with Prediction Markets A Field Experiment on Applicability and Expert Confidence,” *J. Predict. Mark.*, vol. 2, no. 2, pp. 71–91, Sep. 2008.

[24] P. M. Polgreen, F. Nelson, and G. Neumann, "Using Prediction Markets to Forecast Trends in Infectious Diseases," *Microbe*, vol. 1, no. 10, pp. 459–465, 2006.
[25] H. Remidez and C. Joslin, "Using Prediction Markets to Support IT Project Management - Research in Progress," in *International Research Workshop on IT Project Management 2007*, Montreal, Quebec, Canada, 2007.
[26] P. W. Rhode and K. S. Strumpf, "Historical Presidential Betting Markets," *J. Econ. Perspect.*, vol. 18, pp. 127–141, May 2004.
[27] P. W. Rhode and K. S. Strumpf, "Historical Political Futures Markets: An International Perspective," Universtiy of Arizona, Oct-2008.
[28] G. Ortner, "Forecasting Markets - An Industrial Application," Technical University of Vienna, 1997.
[29] K.-Y. Chen and C. R. Plott, "Information Aggregation Mechanisms: Concept, Design and Implementation for a Sales Forecasting Problem," Hewlett Packard Labs, California, 2002.
[30] K.-Y. Chen, L. R. Fine, and B. A. Huberman, "Predicting the Future," *Inf. Syst. Front.*, vol. 5, no. 1, pp. 47–61, Jan. 2003.
[31] M. Waitz and A. Mild, "Improving Forecasting Accuracy in Corporate Prediction Markets A Case Study in the Austrian Mobile Communication Industry," *J. Predict. Mark.*, vol. 3, no. 3, pp. 49–62, Dec. 2009.
[32] J. Hopman, "Using Forecasting Markets to Manage Demand Risk," *Intel Technol. J.*, vol. 11, no. 2, pp. 127–136, 2007.
[33] D. Rajakovich and V. Vladimirov, "Prediction Markets as a Medical Forecasting Tool: Demand for Hospital Services," *J. Predict. Mark.*, vol. 3, no. 2, pp. 78–106, Aug. 2009.
[34] G. Tziralis, G. Vagenas, and S. Ponis, "Prediction Markets, an Emerging Web 2.0 Business Model: Towards the Competitive Intelligent Enterprise," in *Web 2.0*, Boston, MA: Springer US, 2009, pp. 271–291.[35] D. L. Passmore, E. D. Cebeci, and R. M. Baker, "Market-Based Information for Decision Support in Human Resource Development," *Hum. Resour. Dev. Rev.*, vol. 4, no. 1, pp. 33 –48, Mar. 2005.
[36] O. Bergfjord, "Prediction Markets as a Tool for Management of Political Risk," *J. Predict. Mark.*, vol. 2, no. 2, pp. 1–12, Sep. 2008.
[37] M. Berlemann and C. Schmidt, "Predictive Accuracy of Political Stock Markets Empirical Evidence from a European Perspective," Humboldt Universitat Berlin, 2001.
[38] G. Bruggelambert, "Information and efficiency in political stock markets: using computerized markets to predict election results," *Appl. Econ.*, vol. 36, no. 7, pp. 753–768, 2004.
[39] J. Garvey and P. Buckley, "Implementing control mutuality using prediction markets: a new mechanism for risk communication," *J. Risk Res.*, vol. 13, no. 7, pp. 951–960, 2010.
[40] P. Buckley and F. McGrath, "Managing prediction markets," in *Proceedings of the special interest group on management information system's 47th annual conference on Computer personnel research*, New York, NY, USA, 2009, pp. 217–220.
[41] M. Gebauer and D. Glienke, "Communicating Strategy with Information Markets," in *Analysis*, San Diego, CA., 2007.
[42] G. H. Van Bruggen, M. Spann, G. L. Lilien, and B. Skiera, "Prediction Markets as institutional forecasting support systems," *Decis. Support Syst.*, vol. 49, no. 4, pp. 404–416, Nov. 2010.
[43] T. S. Gruca, J. E. Berg, and M. Cipriano, "Incentive and Accuracy Issues in Movie Prediction Markets," *J. Predict. Mark.*, vol. 2, no. 1, pp. 29–43, May 2008.

[44] J. Ledyard, "Designing Information Markets for Policy Analysis," in *Information Markets: A New Way of Making Decisions*, Washington D.C: AEI-Brookings Joint Center for Regulatory Studies, 2006, pp. 37–66.
[45] J. Wolfers and E. Zitzewitz, "Five Open Questions About Prediction Markets," in *Information Markets: A New Way of Making Decisions*, Washington D.C: AEI-Brookings Joint Center for Regulatory Studies, 2006, pp. 13–36.
[46] T. S. Gruca, J. E. Berg, and M. Cipriano, "Consensus and Differences of Opinion in Electronic Prediction Markets," *Electron. Mark.*, vol. 15, no. 1, p. 13, 2005.
[47] C. Deck and D. Porter, "Prediction Markets in the Laboratory," *J. Econ. Surv.*, p. n/a–n/a, 2013.
[48] P. Buckley, J. Garvey, and F. McGrath, "A case study on using prediction markets as a rich environment for active learning," *Comput. Educ.*, vol. 56, no. 2, pp. 418–428, Feb. 2011.
[49] D. Raban and D. Geifman, "Designing Online Information Aggregation and Prediction Markets for MBA Courses," *Interdiscip. J. E-Learn. Learn. Objects*, vol. 5, pp. 247–262, 2010.