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Abstract

Prediction markets are a form of collective intelligence that leverage market mechanisms to incentivise large numbers of individuals to make forecasts about future uncertain events. Since their origin in the 1980's, they have been the subject of a small but steady stream of academic research. Proponents suggest that they have several advantages over comparable information aggregation mechanisms such as polls or expert groups. More recently the rise of blockchain, cryptocurrencies and decentralised finance (DeFi) has excited new interest in prediction markets. The characteristics of this triad of technologies has particular resonances with prediction markets. This research identifies the potential impact of blockchain technology on prediction market design and performance with a view to informing a research agenda to investigate those potential impacts.

Keywords: Prediction Markets, Group Decision Making, Blockchain, Decentralised Finance

1.0 Introduction

Prediction markets are a form of collective intelligence that leverage market mechanisms to incentivise large numbers of individuals to make forecasts about future uncertain events. Since their origin in the 1980's, they have been the subject of a small but steady stream of academic research (Wolfers & Zitzewitz, 2004). Proponents suggest that they have several advantages over comparable information aggregation mechanisms such as polls or expert groups (Hahn & Tetlock, 2006; Sunstein, 2006). More recently the rise of blockchain, cryptocurrencies and decentralised finance (DeFi) has excited new interest in prediction markets. The characteristics of this triad of technologies has particular resonances with prediction markets. This research identifies the potential impact of blockchain technology on prediction market design and performance with a view to informing a research agenda to investigate those potential impacts.

The rest of this paper is structured as follows. We begin by introducing prediction markets and the current extant literature, followed by a brief introduction to blockchain technology. Following that, we outline the specific research questions addressed by this paper. In the analysis section, we perform a qualitative analysis to identify the attributes of blockchain based prediction markets that differ from more traditionally constructed prediction markets. Finally, in the Discussion and Summary section, we analyse how these characteristics may impact upon the design of prediction markets in their various operational contexts.

2.0 Literature Review

2.1 Prediction Markets

Prediction markets are a Group Decision Support System (GDSS) that use collective intelligence to make forecasts about future, uncertain events. They are often defined as “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” (Tziralis & Tatsiopoulos, 2007). This definition emphasises their use of a market mechanism to aggregate the information held by a group of participants regarding future uncertain events (Spann & Skiera, 2003). It also distinguishes them from other markets, such as those whose primary purpose is investment, the hedging of risk or enjoyment (Wolfers & Zitzewitz, 2004). In modern incarnations, prediction markets are usually deployed and supported using information technology. Participants reveal information through buying and selling contracts on a website, which uses an algorithmic market maker to enable trading.

Prediction markets are credited with several advantages over comparable information aggregation mechanisms such as polls or expert groups (Servan-Schreiber et al., 2004). First, prediction markets encourage information revelation (Hahn & Tetlock, 2006b; Hall, 2010). Second, they reward participants for searching for relevant information (Berg & Rietz, 2003; Hahn & Tetlock, 2006a; Sunstein, 2006). Third, they automatically communicate and aggregate information through the use of a market (Hahn & Tetlock, 2006c). A fourth benefit is that the market provides an inherent weighting mechanism for the information provided. 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 (Berg & Rietz, 2006; Graefe & Weinhardt, 2008; Hahn & Tetlock, 2006a). Fifth, markets, particularly those implemented using information technology, can efficiently scale to very large groups (Hahn & Tetlock, 2006c) Rather than providing point estimates like polls, prediction markets can operate in real-time over and extended period of time (Spann & Skiera, 2003). Finally, in contexts where there are concerns that social dynamics and power relationships may affect the truthful revelation of information (Ellis &

Fisher, 1994) prediction markets can be designed to maintain the anonymity of participants (Remidez & Joslin, 2007).

Markets which share some of the characteristics ascribed to prediction markets have existed for hundreds of years, with the literature noting markets on Papal elections in 16th century Italy, parliamentary elections in 18th and 19th century Britain and American presidential elections (Rhode & Strumpf, 2004, 2008). Modern academic 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. (Berg & Rietz, 2006). Since then, academic and practitioner interest in prediction markets has continued to grow (Tziralis & Tatsiopoulos, 2007).

2.2 Categories of Prediction Markets

Prediction markets can be broadly divided into three categories, public prediction markets, private prediction markets and ideas markets (Buckley, 2016). A public prediction market is one which invites participation from the general public. Within this category, some prediction markets operate using real currency. Examples of this type of prediction market would include Betfair (www.betfair.com) and the Iowa Electronic Markets (https://iemweb.biz.uiowa.edu/) Participants invest their own money in the market, and gain or lose according to their performance. Other public prediction markets such as HyperMind (https://predict.hypermind.com/) or Foresight Exchange (http://www.ideosphere.com/) use virtual currency to enable trading.

A private prediction market is one where a sponsor seeks to recruit participants from a specific, albeit potentially very large population. Organizations can use prediction markets to tap the private information held by employees and other stakeholders (Gruca & Berg, 2007). A range of academic studies describe the utilization of prediction markets as GDSS. Ortner (1997) describes their use in project management in Siemens in Austria, with another example of their use in project management offered by Remidez and Joslin (2007). Their use as sales forecasting tools is described in a number of papers (Chen et al., 2003, 2004). Waitz and Mild (2009) provide a case study of their use in forecasting market share in the Austrian mobile phone market. Hopman (2007) describes the use of prediction markets for demand forecasting in Intel, with other authors offer examples from the medical domain (Polgreen et al., 2006; Rajakovich & Vladimirov, 2009). 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 (Hahn & Tetlock, 2006c). 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 (Tziralis et al., 2009).

The third type of prediction market is called an ideas market. They have been proposed as a tool for the generation, filtering and evaluation of new product ideas and concepts (McDonagh & Buckley, 2014). There are a number of differences that distinguish a prediction market from an ideas market. First, an ideas market stock value is not automatically resolved at the close of the trading period (Slamka et al., 2008). The concepts and ideas traded on an Ideas Market may range from relatively concrete to quite abstract. Participants use judgement and intuition to value stocks in ideas markets (Chen et al., 2004) The difference between the underlying assets being traded on a prediction market versus an ideas market is important. In a prediction market, the outcome being traded will eventually either occur or not occur. In contrast, in an ideas market, where participants are trading on concepts such as "Which of these will be the most successful product?" or "Which of these process improvement ideas will be most effective?", no objectively correct answer can be identified, particularly in a case where contingent actions occur as a result of the ideas market. For this reasons, ideas markets need to use an alternative mechanism to reward participants (Slamka et al., 2008), placing an additional burden of designing the payoff mechanism on market makers (Soukhoroukova et al., 2012). The number of stocks in an ideas market is usually not determined in advance. In an ideas market, individual participants can add new stocks to the market at any stage. This functionality improves the ability of ideas markets to generate innovative proposals. Participants can suggest new solutions which can then be both evaluated by the group and may also prompt new suggestions from others.

2.3 Blockchain and Cryptocurrencies

A blockchain is a list of temporally ordered data storage units usually referred to as blocks (Gorkhali et al., 2020). A distributed blockchain is one where the copies of the blockchain are stored and synchronised between multiple computing nodes. This model of a distributed blockchain can be used to create an immutable ledger of irreversible transactions, which in turn allows for the secure transfer of digital assets and ultimately the creation of digital tokens that can be used as cryptocurrencies. The most famous implementation of this model to date is Bitcoin, which is a cryptocurrency that enables users to transfer value pseudonymously without the need for a central authority regulating the transactions. Bitcoin's whitepaper (Nakamoto, 2008) has been used as the basis of many other blockchain-based technologies. One prominent example, Ethereum, is a multipurpose blockchain platform. A particular feature of Ethereum is that developers can write small fragments of code, called smart contracts, which can executed on a distributed virtual machine called the Ethereum Virtual Machine (EVM) (Wood, 2014) Smart contracts offer a way of digitizing and automating the execution of trustless agreements between parties (Szabo, 1997). Taken together these technologies allow for the development of Decentralised Finance (DeFi) applications, which are applications that replicate existing financial services, but in a decentralised, trustless environment without gatekeepers or central authorities (Zheng & Lu, 2021). One type of financial service that can be re-engineered using these technologies is prediction markets.

3.0 Research Question

This paper aims to address two high level research questions. The first question is, "What are the characteristics of blockchain based prediction markets, as opposed to prediction markets using more traditional approaches." The answer to this question will partially inform the second research question, which is "what are the implications of these characteristics for the deployment of prediction markets?"

4.0 Analysis

There are a number of current efforts ongoing to design and build blockchain based prediction markets, with most being in the early stages of development. To identify their key distinguishing characteristic, a qualitative review of extant blockchain based prediction markets was conducted. A list of all the cryptocurrencies identified as being used in prediction markets was downloaded from www.coingecko.com. After filtering duplicate coins (i.e. two multiple coins being used on the same platform) and incorrectly categorised results, the following prediction markets were analysed in depth: Augur, Gnosis; Polkmarkets, PlotX and PolyMarket. For each market, a number of items were reviewed, including

- The stated purpose of the prediction market
- The trade matching mechanism
- What tokens/cryptocurrencies were used to facilitate trading
- How markets are resolved
- How disputes are resolved.

From this analysis, commonly shared factors that distinguish blockchain based prediction markets from more traditionally constructed ones can be identified.

4.1 Crypto-economic Primitives

DeFi applications and cryptocurrencies are built from and are commonly associated with a range of crypto-economic primitives, including a shared, tamper proof ledger and some digital asset that can be exchanged between participants via the ledger. There are obvious parallels between these crypto-economic primitives and the components required to create a prediction market. The exchange of tokens or cryptocurrencies of value can serve the same purpose as fiat currencies in traditionally constructed prediction markets. Similarly, the blockchain, an itemised, ever-increasing list of transactions can be trivially re-purposed into a list of exchanges made by participants in the prediction market, obviating the need for a separate database, while delivering the additional benefits of being shared and immutable, an important consideration in establishing and building trust in a trading environment.

All the markets examined used crypto-economic primitives to implement the core functionality associated with prediction markets. However, some variance arose in the precise details. For example, Augur, which pitches itself as a prediction market platform uses the Ethereum blockchain to record trades between participants and uses the ETH cryptocurrency to facilitate trading. A second cryptocurrency, called REP has also been created, but this is used for dispute resolution rather than trading directly. Gnosis is also based on the Ethereum blockchain, but has created two coins, one called GNO which allows holders to participate in the governance of Gnosis, while OWL is used to trade in contracts. PolyMarket has a different model again, using the PolyGon blockchain to record trades, but maintaining central control over individual participants funds (i.e. participants have to deposit and withdraw fund from the platform).

4.2 Decentralisation

Many of the best known blockchains such as Bitcoin or Ethereum are permissionless public networks. This means that anybody in the world can download and add records to the public blockchain, albeit subject to practical limitations such as available processing power, network speed, etc. An alternative model of ledger construction called permissioned blockchains is also available. In this model, only nodes that have been granted permission to access the network can download the blockchain and add records. Prominent examples of such networks include HyperLedger and Ripple. Such networks may still be decentralised, in the sense that many nodes from many different organisations in many locations may participate, and no individual node has a veto on adding transactions to the ledger etc. In these cases, the degree of decentralisation is a design decision in the hands of the access permission granting authority.

In generally, decentralisation lends two important characteristics to blockchain based prediction markets. The first is fault tolerance. The distribution of data and computing across many nodes means the system as a whole has fewer points of failure. This fault tolerance is a function of the degree of decentralisation across the network. A permissionless public network like Bitcoin is essentially as resilient as the Internet itself, while, for contrast, a private blockchain consisting of nodes inside a single organisation is vulnerable to any failure that affects that entire organisation.

The second major characteristic of blockchain based prediction markets is that ledger is generally considered to be immutable, in that no single party can arbitrarily change a record once it has been added to the ledger. Of course, this immutability is not absolute. Attacks such as a 51% attack, whereby a group of malicious nodes acting together can conspire to alter the ledger are theoretically possible. From a practical perspective however, such attacks are extremely difficult, and are again a function of the degree of decentralisation of the network, in that the more nodes that store a copy of the ledger, the harder it is to mount such attacks.

The immutability of the ledger which records trades is an important consideration for prediction markets. An individual entity with the power to alter the history of trades has essentially unlimited power to manipulate the market, particularly in the case where automated market makers are being used. That a single point of failure like that could be exploited either through malice or incompetence will always be a concern for market participants.

4.3 Designable Anonymity and Privacy

One of the challenges with information flow within organisations is the presence of numerous social and power dynamics that may stop individuals from truthfully revealing information they privately possess. A suggested advantage of prediction markets is that they can be notionally anonymous, allowing individuals to reveal information without revealing their identity. However, in a centralised prediction marker, such anonymity was always notional to a degree. In corporate settings or in public prediction markets using fiat currency, the market controller would always have the ability to identify participants, even if they chose not to use it. Furthermore, it is to be expected that most participants would be aware of this.

Blockchain based prediction markets offer a more subtle palette of design choices to market makers. We can consider this along two dimensions, that of anonymity (can the participants in a market be tied to a specific "real world" identity) and privacy (can all the positions taken by a particular participant be identified).

At one extreme, a permissionless, public blockchain utilising a privacy orientated cryptocurrency like Monero essentially allows completely anonymous and private participation in a prediction market. Both the identity of the participant and the positions they take can be provably untraceable. Public permissionless prediction markets may also be designed in such a way that all the transactions undertaken by a particular account are publicly visible. In this case, participants have anonymity (subject to features of the cryptocurrency being used on the prediction market), but not privacy. Extant prediction markets like Augur, Gnosis and PolyMarket work in this manner.

Other configurations are also possible. A permissioned blockchain requires that participants identify themselves to a gatekeeper before they can use the blockchain and participate in the network. A permissioned blockchain can be constructed in a decentralised manner, retaining the advantages of decentralisation, while at the same time insisting that participants prove their identity. In many situations, this management of participants is a legal or regulatory necessity. However, it is also possible in this situation to construct the blockchain in such a way that transactions cannot be tied back to a particular participant. This allows for the construction of prediction markets which are not anonymous, but are private, thereby implementing the original goal of allowing participants to truthfully reveal information without fear of social or power dynamics.

4.4 Oracles

Within their own context, blockchains are used to create an immutable ledger of irreversible transactions. It is these guarantees that allows them to be used to exchange value in the form of Bitcoins and other cryptocurrencies. However, these guarantees only extend to data that is directly recorded on the blockchain ledger. The challenge for creating blockchain applications and decentralised applications is that they will often require information from the "real world". For example, to implement a simple futures contract, two participants may agree to a smart contract that will automatically pay the second participant funds from the first participant's account if a particular stock price exceeds a particular value. The challenge here becomes providing the smart contract with the stock price in the real world. Both of the participants in the smart contract have an obvious vested interest in misleading the smart contract, and such incentives can theoretically extend to any third-party providing information to a smart contract. This is referred to as the Oracle problem and can be simply rephrased as “How can smart contracts access reliable information about the real world?”

This problem is analogous to a common problem in prediction market design. In order to be able to resolve the market and reward accurate forecasters, market makers need to be able to identify which specific outcome arose from the event being forecast on a particular market. This creates a number of challenges. First, if an individual is responsible for determining the outcome, that person may through malice or incompetence identify the wrong outcome. More plausibly, it can often be challenging to select the outcome. A loosely defined contract may mean an outcome that was not available for selection occurs, or there may be reasonable grounds for alternative interpretations of an outcome. All these potential results can damage the credibility of the prediction market. They also place definite constraints on what kind of questions can be asked on a prediction market, since any question posed must have a set of exhaustive, mutually exclusive outcomes.

This information challenge is being addressed in several ways using blockchain technology. Broadly speaking there are three approaches that are being used. The first, and simplest, is that an independent third party is appointed as arbitrator and judge of the outcome of contracts and that entities decision is final. This is the model used by PolyMarket.. This approach has the virtue of simplicity, and given a suitable third party, it is a plausible, pragmatic solution to the problem. However, it does not ultimately resolve the challenge of incentive misalignment and is contrary to the animating spirit of decentralised finance.

Other approaches seek to use the principles of decentralisation and incentive alignment that have guided the development of many cryptocurrencies and decentralised finance applications to develop Oracles. A number of models exist. The first is simple voting. In this model, after a market has closed, individuals are asked to vote on what outcome actually occurred. Two further elements are included to improve reliability. First, individuals who did not participate in the markets are allowed to vote to indicate what outcome occurred. In some implementations, individuals who participated in a market are precluded from voting on the outcome. Second, in order to vote, individuals must stake their own cryptocurrency. If they vote for the outcome that the majority vote for, they receive their own stake back, plus a percentage of the combined stakes of everyone who voted for an option that was not selected.

A second model is based on the notion of allowing participants to challenge an Oracle. In this case, an oracle selects an outcome. As part of selecting the outcome, the oracle must stake its own assets on the outcome. After a period of time has elapsed, if no dispute is raised, then the market is closed and the oracle receives a percentage fee from all the successful market participants, as payment for the information they provided. In that period of time, other participants can challenge the oracle, by staking their own assets against an alternative outcome. If the value of the assets staked against an outcome exceeds a limit pre-determined by a mathematical formula, a voting process commences, and if the oracles outcome is rejected, the oracles entire stake is deemed forfeit and distributed amongst the disputers. On the other hand, if the oracles outcome is upheld, the disputer's stakes are forfeit. This approach attempts to avoid the temporal overhead associated with simple voting, while ensuring that incentivised collective oversight applies.

5.0 Discussion & Summary

The analysis of extant blockchain based prediction markets revealed a number of features that may have an impact upon the adoption of prediction markets in various use cases. Turning first to private prediction markets, which are prediction markets that are sponsored and organised by a particular entity, the characteristics of blockchain based prediction markets have a number of potential effects. First, the provision of crypto-economic primitives such as immutable ledgers, cryptocurrencies and incentive structures that is inherent in most blockchain implementations arguably makes it easier for organisations to deploy prediction markets. Rather than having develop these primitives from scratch, organisations seeking to deploy prediction markets can use existing, tested solutions to build upon. All things being equal, as easier path to implementation of an information system should lead to wider deployment.

The ability of blockchain prediction markets to provide more choices with regards to the trade-offs between anonymity and privacy is also a boon for private prediction markets. Permissioned and permissionless prediction markets have strengths and weaknesses, which will have to be considered by market makers with reference to their specific context. However, having the ability to make these design decisions makes prediction markets more flexible in a private context. Similarly, the degree of decentralisation of a private prediction market now becomes a design decision within the ambit of the market maker. The organisation can consider the advantages and disadvantages of decentralisation and pick a configuration that best suits their needs.

Turning to public prediction markets, the advent of blockchain based prediction markets also changes the dynamics of prediction market design and operations. In general, public prediction markets are a less trusting environment than that which exists in a permissioned environment or within organisational boundaries. In this context, the provision of provable guarantees around things like immutability and irreversibility become more important in ensuring trust and thereby participation by the general public. Similarly, the use of decentralised oracles is also important in alleviating concerns that markets may be manipulated by small numbers of privileged malicious operators. In general, anything that increases trust in a prediction market should lead to increased participation and thus increased forecasting performance. In addition, if the future hoped for by many crypto enthusiasts arrives, and cryptocurrencies become widely used, the inherent integration of these cryptocurrencies into blockchains should remove barriers to prediction market participation such as registration, funding accounts etc., which can act as deterrents in more traditionally constructed prediction markets.

The final category of prediction market is ideas markets, and it is here potentially that the technologies that have been built to support blockchains may have the greatest impact. Decentralisation and designable anonymity and privacy offer the same design choices to ideas market makers and should offer the ability to better customise an ideas market to a particular context. However, oracles also offer intriguing possibilities in terms of contract resolution. One of the biggest challenges of ideas markets has been that the outcomes being traded are by their very nature loosely defined. Ideas markets ask participants to, for example, rank the potential of various products, or predict the impact of taking or not taking a particular organisational action. Moreover, ideas markets are usually designed to allow participants to add potential outcomes while the market is executing. All of this has made resolving ideas markets and rewarding participants a difficult task. It is in this context that the techniques being developed to provide Oracles for decentralised finance applications in general and blockchain based prediction markets are particularly exciting. Fundamentally, these oracles are mechanisms for incentivising a large group of people to arrive at a consensus. While the absence of an objective metric – “This is the best product idea” remains, Oracle technology holds out the possibility of using a reasonably defined method to arrive at a group consensus. Of course, there is no guarantee that the group consensus arrived at will be correct, but the provision of a transparent process for arriving at a consensus provides a method that has face validity for both successful and unsuccessful participants.

As a tool for utilising collective intelligence, prediction markets have been under development since the late 1980's. While academic research has generally demonstrated their objective effectiveness in term of forecasting accuracy, their uptake in both public and private settings has remained limited. Blockchain based prediction markets do not fundamentally change how prediction markets operate, but the use of blockchain technology does offer a range of additional capabilities and design choices that increases the utility and flexibility of prediction markets. These blockchain prediction markets are still in their infancy and under active development, but the potential exists that the additional capabilities offered by them may make prediction markets a more attractive tool for organisational and public use.

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