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Abstract

Over the last couple of years, interest in prediction markets as a forecasting method has continuously increased in the scientific world and in industry. Markets provide incentives for information revelation and can be used as a mechanism for aggregating information. So far, prediction markets have done well in every known comparison with other forecasting methods. Whereas information aggregation is only a byproduct of most traditional markets, prediction markets are set up with the explicit purpose of soliciting information. Engineered carefully, prediction markets can directly guide decision making. This paper describes the fundamentals of prediction markets as well as their key design elements. We thereby aim at giving insights into design decisions which have to be made by prediction market operators. Moreover, we contribute to the literature by giving an extensive overview on fields of application of prediction markets which have been discussed in academic literature.

Keywords: Prediction Markets, Forecasting, Market Engineering

Introduction

In recent years, a relatively new approach for information aggregation has gained importance in the area of forecasting, namely prediction markets. Prediction markets bring a group of participants together and let them trade contracts whose payoff depends on the outcome of uncertain future events. The contracts thus represent a bet on the outcome of those future events. Once the outcome is known traders receive a cash payment in exchange for the contracts they hold. Several studies describe how such markets have been applied for predicting future events or developments in different fields of application. This paper describes the fundamentals of prediction markets as well as their key design elements. We thereby aim at giving insights into design decisions which have to be made by prediction market operators. Moreover, we contribute to the literature by giving an extensive overview on fields of application of prediction markets which have been discussed in academic literature.

The remainder of the paper is structured as follows: Firstly, Section 0 presents the fundamentals of prediction markets. We give a definition of the term prediction markets and describe their operational principle as well as their theoretical foundations. Secondly, in Section 0 we discuss the key design elements of prediction markets which have to be considered by market engineers. Thirdly, Section 0 presents a comprehensive overview on previous fields of application of prediction markets before Section 5 finally concludes.

Fundamentals of Prediction Markets

In the academic literature, there is no universal definition of the term "prediction market". Alternative terms used for the same concept include information markets, decision markets, idea futures, forecasting markets, artificial markets, electronic markets, and virtual stock markets. According to Berg et al. (Berg and Rietz, 2003, Berg et al., 2003), prediction markets are defined as markets that are run for "the primary purpose of aggregating information so that market prices forecast future events". Moreover, prediction markets can also serve as decision support systems by providing information about the current situation or by evaluating effects of decisions over time (Berg and Rietz, 2003, Hanson, 1999).

Although prediction markets that are designed for information aggregation and revelation are at the focus of this work, the distinction between these markets and stock markets or betting markets can become fuzzy. In contrast to prediction markets, however, stock markets are established with the primary purpose of allocating resources, trading risk, and raising capital. Information aggregation is only a pleasant byproduct of stock markets. Betting markets, on the other hand, are first and foremost set up for entertainment.

Operational Principle of Prediction Markets

Prediction markets are a new form of financial markets where contracts whose payoff depends on uncertain future events are traded. Traders buy and sell contracts based on their expectations regarding the likelihood of future events. Trading prices thus reflect the traders' aggregated expectations on the outcome of uncertain future events and can be used to predict the likelihood of these events.

An example for the operational principle of prediction markets is shown in Figure 1. Suppose that the board of directors of a small deluxe car manufacturer needs reliable sales forecasts to adapt operational processes and minimize operational costs. All employees who have access to relevant information are given an initial endowment and access to the prediction market. Several contracts can be traded on this market. For example, the contract "500-600 cars in 2008" pays off 100 € if the company actually sells 500 to 600 cars in 2008; otherwise the pay-off is 0 €. Assume that at a certain point in time the contract trades at a price of 45 €. In this case the trading price denotes that the probability that the car manufacturer will sell 500 to 600 cars in 2008 is assumed to be 45%. If a trader believes that the likelihood of selling 500 to 600 cars in 2008 is 70%, he should buy (sell) contracts for any price lower (higher) than 70 €. In this way, the trading price should reflect all the traders' information.

Depending on their performance, traders can either win or lose money. Therefore, prediction markets motivate participation and well-designed incentive schemes motivate traders to reveal their beliefs instead of their preferences. To give an example, even an enthusiastic supporter of a deluxe car among the employees of the above-mentioned car manufacturer would rather not try to boost the sales forecasts of his favorite car since he would lose money in case he was overestimating sales figures.

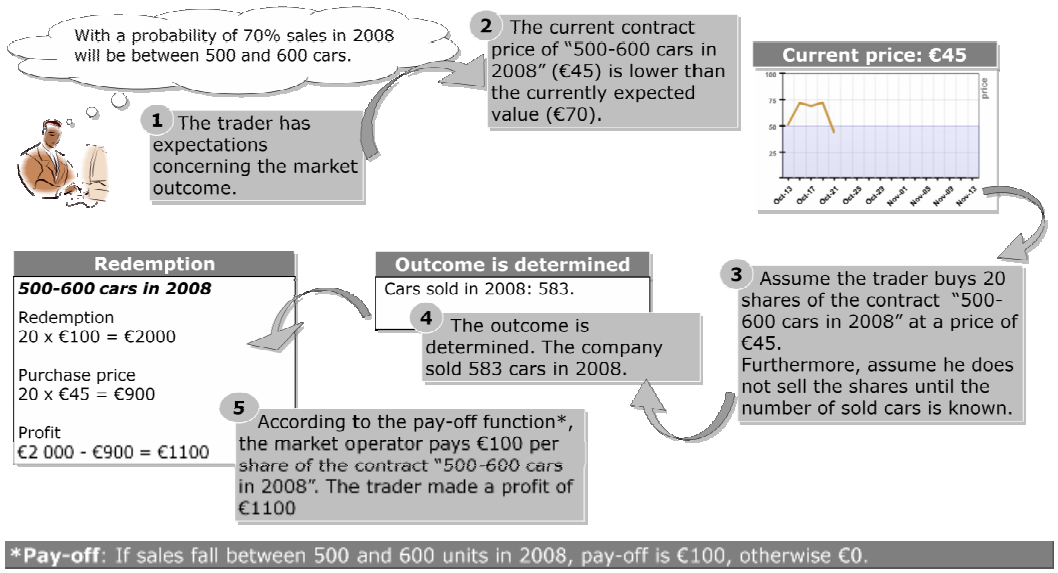

Figure 1: *Operation principle of prediction market*

Hayek and Efficient Market Hypothesis

The idea that trading mechanisms could be used to aggregate information dispersed among traders traces back to Hayek (Hayek, 1945). Hayek argued that planners in centrally-planned economies do not have enough information to calculate an optimal solution for resource allocation since central planners need information about all available resources and the preferences of people. He claimed that an efficient distribution of resources can only be maintained through the use of price signals in open markets. Accordingly, Hayek hypothesized that markets are the most efficient instrument to aggregate all the dispersed information of traders. Prices thus help to coordinate the separate actions of people.

The efficient market hypothesis formulated by Eugene Fama states that stock "prices at any time 'fully reflect' all available information" (Fama, 1970, p. 383). This implies that no additionally available information can be combined with efficient prices to improve the prediction accuracy of a market. Much of the enthusiasm for prediction markets derives from the efficient markets hypothesis due to the fact that contract prices reflect all information on the corresponding future event in an efficient prediction market and thus are the best predictor of future events.

Key Design Elements of Prediction Markets

Like any market, prediction markets have to be designed and implemented very carefully in order to ensure that they are suitable for aggregating traders' information (Weinhardt et al., 2006). The key design elements comprise the specification of *contracts* traded in a prediction market, the *trading mechanism*, and the *incentives* provided to ensure information revelation (Spann and Skiera, 2003). Moreover, diversity of information is required in order to provide a basis for trading (Wolfers and Zitzewitz, 2004). Disagreement among traders is desirable and the selection of *traders* is thus also considered a key design issue (Tziralis and Tatsiopoulos, 2007b). The following subsections describe these design elements in more detail.

Contracts

Prediction markets can be used to predict absolute numbers such as sales in a fiscal year, relative numbers such as market share, and the occurrence or non-occurrence of a particular event such as

a natural disaster in a certain geographic region. The transformation of the forecasting goals into contracts should be carried out in a way that the contracts are clear and easily understood. Wolfers and Zitzewitz distinguish three basic types of contracts, namely "winner-take-all", "index", and "spread" contracts (Wolfers and Zitzewitz, 2004).

A winner-take-all contract pays of certain sum of money if an event occurs and doesn't pay anything otherwise. As a result, the price of a winner-take-all contract can be interpreted as the traders' aggregated expectation of the probability of the occurrence of a future event. Index contracts link the payoff directly to a number such as the percentage of the popular vote that a candidate will receive in a political election. Thus, the trading price for such a contract represents the mean value that the market assigns to an outcome. Spread betting establishes a cutoff that defines the occurrence of an event such as whether a candidate receives more than a certain percentage of the popular vote. In consequence it reveals the market's median expectation if contracts are designed in such a way that winners double their money while losers do not receive any payment.

These are only the basic types of contracts and real-world prediction markets are making use of all kinds of variations of them. One important aspect with regard to the design of contracts is to provide contingency resolutions if the underlying facts that determine the contract change or if the results become non-verifiable. To give an example, a prediction market could be employed to predict product sales in an accounting year. What happens if the company decides to stop selling the product due to a liability suit before the end of the year? Suchlike cases have to be considered when setting up a market.

Trading Mechanisms

The most integral aspect of any trading platform is how buyers and sellers are matched. The most widely used trading mechanism in the field of prediction markets is the continuous double auction (CDA). Alternative mechanisms are call auctions (CA), dynamic pari-mutuel markets (DPM), as well as market scoring rules (MSR). These mechanisms are briefly described in the following. Table 1 summarizes their advantages and disadvantages with regard to three desirable properties of trading mechanisms for prediction markets, namely continuous incorporation of information, guaranteed liquidity, and avoidance of financial risk for the market operator (Pennock, 2004).

***Table 1**: Comparison of trading mechanisms*

	CDA	**CA**	**DPM**	**MSR**
Continuous information incorporation	Yes	No	Yes	Yes
Guaranteed liquidity	No	No	Buying: yes Selling: no	Yes
Risk for operator	No	No	No	Yes (bounded)

Continuous Double Auction (CDA)

So far, the continuous double auction (CDA) is the most commonly used trading mechanism in prediction markets. Traders submit buy and sell orders which are executed immediately if they are executable against orders on the other side of the order book (Madhavan, 1992); if not, orders are queued in an order book and remain there until they expire, are matched with a counteroffer, or are removed. Usually, orders are executed according to price/time priority, i.e. buy orders with a

higher limit and vice versa sell orders with a lower limit take priority. In case several orders were placed with the same limit the orders which were submitted earlier are executed first.

One of the main advantages of using a CDA is the fact that markets with a CDA pose no financial risk for the market operators. Since it only matches willing traders all markets can be implemented as a zero-sum game (Spann and Skiera, 2003). As a consequence, this mechanism is especially popular among real-money exchanges. The Iowa Electronic Markets (IEM), for example, have started using the CDA in their markets in the late 1980ies (Forsythe et al., 1992). Moreover, the CDA allows for continuous information incorporation into prices and consequently traders are capable of quickly reacting to events in case of liquid markets.

However, with few traders the markets may suffer from illiquidity. Offers can then not be matched with counteroffers and therefore the bid-ask spread can be huge or order queues are empty (Hanson, 2003). Since most prediction markets have fewer participants than traditional financial markets, this limitation is particularly relevant for them.

Call Auction (CA)

In financial markets call auctions are used as an alternative trading mechanism. While orders are executed immediately in continuous markets they are accumulated for simultaneous execution at a pre-determined point in time according to a priority rule, e.g. the principle of the highest executable volume, in call auctions (for an overview, see (Madhavan, 1992)). Liquidity in illiquid low-volume markets can consequently be accumulated and focused on pre-determined execution times. Call auctions also make it more difficult to move trading prices and thus influence the price formation with small transactions compared to continuous markets. Just like the CDA mechanism call auctions also pose no financial risk for the market operator. Due to periodic trading in call auctions, however, new information is not reflected immediately in trading prices.

Dynamic Pari-Mutuel Market (DPM)

Dynamic pari-mutuel markets (DPM) are a hybrid between the above-mentioned continuous double auction and pari-mutuel markets. In pari-mutuel markets money goes into a central pool and is later divided among the winners. This provides infinite liquidity and circumvents the thin-market problem of double auctions. There is no need for a matching offer from another trader. But one shortcoming of pari-mutuel markets is that there is no incentive to buy contracts early, especially not if new information is expected before the market closes. Purchasing contracts will also inform other traders. As a result, it is the best strategy to wait until the last possible moment to buy.

Pennock has developed the DPM mechanism in order to combine the infinite liquidity of pari-mutuel markets with a trading mechanism in which prices continuously react to new information (Pennock, 2004). The DPM offers infinite buy-in liquidity and thus acts as a one-sided market maker always offering to sell at some price and moving the price according to demand. Prices are computed using a price function which can differ depending on the properties that are desired. The DPM also does not exhibit any risk of losses for the market operator due to its redistribution of money. Selling still has to occur through a CDA mechanism because there is no market maker accepting sell offers. The DPM has been implemented in Yahoo's Tech Buzz game[1], a prediction market for high-tech products, concepts, and trend (Mangold et al., 2005).

Market Scoring Rules (MSR)

Hanson's market scoring rule (MSR) acts like a two-sided market maker that also provides infinite liquidity for the sell side of the market with a variable but bounded maximum loss that can be

[1] http://buzz.research.yahoo.com

regarded as a subsidy for the market (Hanson, 2003). Market scoring rules can be thought of as sequentially used proper scoring rules. An MSR maintains a probability distribution over all events. Any trader who believes the probabilities are wrong can change the current prediction by replacing it with a new prediction as long as the trader agrees to pay off the most recent person. If traders improve the prediction by moving the prices into the right direction they can expect a positive payoff, otherwise they will lose money. New information is hence reflected immediately. This MSR has already been implemented by exchanges such as InklingMarkets[2].

Incentives

Appropriate incentives schemes are required to motivate participation and to ensure information revelation in prediction markets. The traders' remuneration is crucial for the success of a market and consequently a key design element. Previous research in the field of prediction markets has shown that play-money as well as real-money markets can predict future events to a remarkable degree of accuracy. One relevant question is how much difference it actually makes whether markets are run with real money or with play money (Wolfers and Zitzewitz, 2004). A study of the predictions of the 2003 NFL football season has shown that the real-money market TradeSports and the play-money market NewsFutures predicted outcomes equally well (Servan-Schreiber et al., 2004).

Due to the legal restrictions on gambling many prediction markets nowadays rely on play money. Some traders may be intrinsically motivated but even in play-money markets the market operators can provide incentives such as a flat fee for participation or prizes for the largest play-money fortunes to remunerate traders.

Traders

In the end, prediction markets only work if traders with relevant information join the market and trade. Market operators in consequence have to make sure they select traders with relevant information. One straightforward approach could be to invite experts who have access to information concerning the under study claims. However, inviting experts only has at least two downsides. Firstly, most prediction markets have very few participants compared to traditional financial markets. As a result, the lack of offers to buy and sell limits the incentive for traders to reveal new information. Replacing the widespread CDA by another trading mechanism is one approach to ensure that traders can profit from new information without having to find a trading partner. Secondly and even more important, it is rather unlikely that there is a lot of disagreement among fully rational experts trading in a market. Overconfident traders as well as an increase in noise trading should actually improve the accuracy of trading prices because this increases the rewards to informed trading – provided informed traders have deep pockets relative to the volume of noise trading.

Instead of limiting the pool of traders to knowledgeable experts one should thus try to attract more traders. If traders self-select to join a market they usually have relevant information. Nevertheless, one should avoid running markets on topics where insiders may possess substantially superior information or where information is concentrated on very few people. Such markets have historically attracted very little attention (Wolfers and Zitzewitz, 2004).

Fields of Application

This section gives an overview of previous fields of application of prediction markets that have been reported in the literature. Since it is all but impossible to consider the totality of earlier applications, the list of applications given in Table 2 was compiled based on an extended literature

[2] http://inklingmarkets.com

review which was recently published in the Journal of Prediction Markets in an attempt to collect the totality of academic work related to prediction markets (Tziralis and Tatsiopoulos, 2007a).

***Table 2**: Fields of application of prediction markets*

	Market	**Focus**	**Reference**
Political stock markets	Iowa Electronic Markets	US presidential elections, non-US elections (e.g. Austria, France, Korea, Germany)	Berg et al. (2001), Berg et al. (1996), Berg et al. (1997), Berg and Rietz (2003), Berg et al. Berg and Rietz (2006), Bondarenko and Bossaerts (2000), Erikson and Wlezien (2006), Forsythe et al. (1994), Forsythe et al. (1992), Forsythe et al. (1999), Fowler (2006), Kou and Sobel (2004), Oliven and Rietz (2004)
	UBC election stock market	Provincial and federal elections in Canada	Antweiler and Ross (1998), Forsythe et al. (1995), Forsythe et al. (1998)
	Swedish EU PSM	Swedish 1994 EU referendum	Bohm and Sonnegard (1999)
	GEM 90, GEM 91, GEM 94, GEM 98	Federal and regional elections in Germany	Brüggelambert (2004)
	Wahlstreet, Wahlboerse	State elections in Germany	Hansen et al. (2004)
	Passauer Wahlbörse	Federal elections in Germany	Beckmann and Werding (1996)
	NP02, TE03	National assembly and regional elections in Austria	Huber and Hauser (2005)
	"Die Presse" Election Market	Elections for the national assembly in Austria 2002	Filzmaier et al. (2003)
	Austrian Political Stock Market	Austria's membership in the EU, federal elections, governing coalition	Ortner et al. (1995)
	PAM94	European Parliament and municipal councils in the Netherlands	Jacobsen et al. (2000)
Sports prediction markets	TradeSports	Worldwide sports prediction market, e.g. baseball, soccer, football	Chen et al. (2005), Rosenbloom and Notz (2006) , Servan-Schreiber et al. (2004)
	NewsFutures	Sports (e.g. baseball, football, soccer), political elections	Chen et al. (2005) , Rosenbloom and Notz (2006), Servan-Schreiber et al. (2004)
	World Sports Exchange	Football, baseball, hockey, basketball etc.	Debnath et al. (2003)
	Betfair	Soccer, tennis, horse racing, etc.	Smith et al. (2006)
Other applications	Hollywood Stock Exchange	Box office performance of movies	Gruca et al. (2003), Pennock et al. (2001b), Pennock et al. (2001a)

	Market	Focus	Reference
	CMXX	Success of movies, music CD's and video games in Germany	Skiera and Spann (2004)
	Economic Derivatives	Retail sales, GDP, international trade balance, growth in payrolls	Gürkaynak and Wolfers (2006)
	Tech Buzz Game	High-tech products, concepts, and trends	Mangold et al. (2005)
	Foresight Exchange	Future developments in science and technology	Pennock et al. (2001b), Pennock et al. (2001a)

Table 2 comprises all applications of the prediction market concept that were reported in journal articles, books or book chapters, and conference proceedings papers referenced in the aforementioned literature review. Pure lab experiments where signals are e.g. drawn from an urn were not taken into consideration. The applications were grouped into three categories: political stock markets, sports prediction markets, and other applications. The following subsections provide some more information on the three categories of applications.

Political Stock Markets

Most of the literature on prediction markets up until 1998 is on political stock markets. The most cited and earliest application of a political stock market on the internet, the Iowa Electronic Markets (IEM[3]), was established in 1988 by the University of Iowa. The first academic article on the IEM was published in 1992 (Forsythe et al., 1992). IEM focussed on US presidential and state elections, but the platform was also used to run political stock markets on elections e.g. in Austria, France, Korea, and Germany. Predictions derived from IEM trading prices have been more accurate than their natural benchmark, namely polls, although traders exhibit biases (Berg et al., 2001, Forsythe et al., 1999). Moreover, trading prices react extremely quickly to new information (Berg and Rietz, 2006). Beside predicting uncertain future events the IEM were also studied as a decision support system where decisions are made based on trading prices (Berg and Rietz, 2003).

Other political stock markets in Canada (e.g. Antweiler and Ross, 1998), Sweden (Bohm and Sonnegard, 1999), Germany (e.g. Beckmann and Werding, 1996), and Austria (e.g. Ortner et al., 1995) have been set up with a similar research focus. Furthermore, these markets were also used to study manipulation in prediction markets (Hansen et al., 2004). Due to their convincing performance they have received quite a lot of attention in the media and several publishing houses have already been running their own markets (Filzmaier et al., 2003).

Sports Prediction Markets

Sports prediction markets like Betfair.com[4], the World Sports Exchange[5], NewsFutures[6], and TradeSports[7] are among the most popular prediction markets. These markets focus on forecasting the outcome of sports tournaments and events. Among popular sports are e.g. baseball, soccer, football, hockey, basketball, tennis, and horse racing. Although NewsFutures, for instance, does also operate markets on politics, financial markets, or the movie business, contracts on sports events are usually the most popular topics. Earlier studies on sports prediction markets show that these markets provide at least as accurate predictions as experts (Chen et al., 2005, Servan-Schreiber et al., 2004). In accordance with the efficient market hypothesis game events are quickly

[3] http://www.biz.uiowa.edu/iem/
[4] http://www.betfair.com
[5] http://de.wsex.com
[6] http://us.newsfutures.com
[7] http://www.tradesports.com

resulting in changes of trading prices. Smith et al. (2006) find that markets on UK horse racing exhibit both weak and strong form of market efficiency.

One precondition for exploiting the potential of prediction markets is to provide incentives for participation and information revelation. Two articles in the field of sports prediction markets, however, show that there is no significant difference in terms of prediction accuracy between play-money and real-money prediction markets (Rosenbloom and Notz, 2006, Servan-Schreiber et al., 2004).

Other Applications

Nowadays, prediction markets are increasingly employed in innovative fields of application beyond political stock markets and sports prediction markets. One popular example is the Hollywood Stock Exchange (HSX[8]), a prediction market where traders forecast box office revenues of films, both for opening weekends and beyond. CMXX.com was a similar market operated in Germany to predict the success of movies, music CD's, and video games (Skiera and Spann, 2004). Pennock et al. (2001a) demonstrate that trading prices in the HSX movie markets are good predictors of the box office performance of movies. Based on these forecasts the movie industry can then make decisions on how to allocate advertising based on expected box office revenues. This demonstrates how companies can use prediction markets to make better informed decisions.

Apart from predicting box office revenues markets can be used broadly for predicting the success of all kinds of new products (Gruca et al., 2003). Successful examples for such markets are the simExchange[9], a market for predicting the sales of console hardware and upcoming video games, or an internal market run by Eli Lilly to find out which drugs will be most successful (Kiviat, 2004). Prediction markets can thus be seen as an alternative to traditional marketing research techniques. Spann et al. (2007) show that prediction markets are also useful for identifying lead users with superior abilities to forecast the market success of new products. Their idea is that lead users perform better than average traders on prediction markets. The percentage of lead users among the best performing traders is similar to the percentage found in survey-based screening.

Another interesting field of application is the prediction of macroeconomic data such as retail sales, GDP, international trade balance, and the growth in payrolls. For this purpose a market called "Economic Derivatives[10]" was launched in 2002. A first analysis shows that the expectations reflected in trading prices are similar to survey-based predictions (Gürkaynak and Wolfers, 2006).

Up to now, prediction markets were mostly applied to forecast events in the near future. Determining the payoff of a particular contract is then straightforward as soon as the outcome becomes known. Yet, some of the earlier research also proposes the use of prediction markets for forecasting events in the distant future (Hanson, 1992). One market for predicting long-term developments in science, technology, and other fields of public interest is the Foresight Exchange[11] (Pennock et al., 2001a). Contracts traded in this market range from technical to socio-political issues. Another market for long-term predictions which is exploiting the potential of prediction markets to continuously update trading prices is the Tech Buzz Game. Yahoo Research sponsors this market which lets traders predict the technologies that internet users will be searching the web for in the future (Mangold et al., 2005). One market could be trading contracts on rival technologies such as web browsers. These contracts then pay a weekly dividend relative to the number of search requests. In the long term, the market closes if the topic becomes uninteresting and the contracts will then be liquidated for cash. One of the goals of the Tech Buzz Game is to test dynamic pari-mutuel markets which were discussed earlier in this paper.

[8] http://www.hsx.com
[9] http://www.thesimexchange.com
[10] http://www.economicderivatives.com
[11] http://www.ideosphere.com

Other prominent examples of companies using prediction markets internally are Hewlett-Packard where traders produced more accurate forecasts of printer sales than the company's forecasting team (Chen and Plott, 2002) or Siemens where software developers predicted the completion date of a huge software project (Ortner, 1997).

Conclusion

This paper gave a comprehensive introduction to the field of prediction markets. The term prediction market was defined. Moreover, we described the theoretical foundations as well as the operational principle of prediction markets. Like any other market, prediction markets have to be designed carefully. The key design elements, namely the contracts traded in a market, the trading mechanisms, incentives for traders to participate and reveal their expectations, as well as the selection of traders have been introduced. In addition, we briefly discussed several design alternatives for each of these design elements. The main contribution of this paper is to give a comprehensive overview on fields of application of prediction markets that have been reported in literature. So far, academic literature for a large part focussed on political stock markets although numerous companies have already made use of internal corporate prediction markets. This can probably be explained by the fact that companies do oftentimes not want to make their experiences public. Concerning the field of sports prediction markets there are up to now rather few research papers.

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