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Prediction markets for foresight

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ABSTRACT

To navigate turbulent business environments, organizations have to develop foresight capacities that enable them to anticipate probable futures, respond rapidly to emerging changes, and support future oriented action. However, there are remaining barriers that impede a wider implementation of foresight. In particular, the necessities to deal with the future, anticipate change, enhance participation and reduce costs and complexity call for new methods to improve current foresight activities. In this paper, we introduce prediction markets to the field of foresight. Prediction markets are a structured approach to collect and aggregate information from groups and have recently gained attention in forecasting. Prediction markets go beyond simple forecasting and can contribute to foresight by providing advantages in terms of continuous and real-time information aggregation, motivation of participation and information revelation as well as cost-efficiency and scalability. We suggest four promising fields of application for prediction markets to enhance foresight: (1) continuous forecasting and environmental scanning, (2) combining with deliberative approaches, (3) continuous idea generation and (4) expert identification. We conclude by considering prediction markets as a nascent and promising method for foresight and advocate for further research.

1. Introduction

In order to navigate turbulent environments, organizations have to develop capacities of future thinking that enable them to anticipate and respond to rapidly emerging challenges and chances. In the literature, the capacity to perceive and understand probable futures, detect rapid changes in the environment, and support strategic future oriented action is referred to as *foresight* [1–5]. Foresight cannot be described by any single act or action. In fact, foresight is a systematic process [4] "which broadens the boundaries of perception through careful scanning of possible futures and the clarification of emerging situations" [1]. To generate foresight capacities in organizations, the literature suggests using a variety of approaches like, for example, environmental scanning, scenario techniques, idea generation, strategic management, or forecasting [6].

In this paper, we aim to extend this list by introducing a new method to the field of foresight: *prediction markets*. Thus ironically, while the dynamic complexity of the market economy is held responsible for the unpredictability of the future and for the need to develop foresight capacities [3], we actually suggest harnessing the "marvellous" [7] capabilities of a market system in aggregating information to improve foresight. Prediction markets are a structured approach to collect and

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aggregate information from groups and have recently gained attention in the area of forecasting. Yet, prediction markets go beyond being just a forecasting tool but possess characteristics that appear to be valuable in overcoming remaining challenges to a wider implementation of foresight. In particular, besides their high performance in forecasting, prediction markets contribute to foresight by providing an easy-to-implement and cost-efficient approach to continuously detect changes in the organizational environment by acquiring information from a preferably large number of people. In addition, we describe potentials of combining prediction markets with deliberative approaches, using them for continuous idea generation as well as for identifying experts.

2. Challenges for a wider implementation of foresight

Although organizations increasingly recognize the importance of looking into the future [8], challenges remain for wider implementation of foresight. In the following, without exhausting the field, we discuss some of the barriers that need to be overcome in order to develop foresight capacities in organizations.

2.1. Deal with the future

The literature agrees that the future is basically unknown and that there will never be a foresight method that allows us to accurately predict the future [9–12]. The resultant uncertainty often entices managers to simply ignore the long-term but to focus on forecasting short-term developments which are measurable and comprehendible [1]. Without question, applying methods of quantitative (business) forecasting to examine trends is and will remain an important task of foresight [13]—in particular as organizations prefer "the numbers" [14]. However, simple forecasting "can distort our ability to understand the future" [15]. Firstly, forecasting requires a prior decision on what to forecast which leads to business-as-usual thinking and hinders organizations from exploring new opportunities [16]. Secondly, traditional forecasting methods aim to predict future developments and trends by using and analyzing historical data, for example, by extrapolating trends. Thus, as solely feeding on past experiences, forecasting assumes the business environment to be continuous and is unable to deal with the uncertainties of a fundamentally unpredictable future. As a consequence, such forecasts are frequently erroneous and become increasingly worthless the more distant future one tries to predict [15,17].

Yet, uncertainty entails dangers as well as opportunities [12] which makes it necessary for organizations to also deal with what is not known [18]. Thus, foresight has undergone a change from predictive approaches to more exploratory studies [19], i.e. the goal of foresight is not to predict what will happen but to engage with whatever may happen [3,10]. One method that does not aim to obtain forecasts but to enable organizations to think of probable futures is the scenario technique [12,15,17,18]. By writing stories about how the future may evolve, scenarios allow one to think about the unthinkable and to cope with the complexities of turbulent business environments. Nonetheless, although the scenario technique is "most likely to experience a boost in interest in the future" [8], scenarios neither provide a direct link between decision and action [20] nor a measurable or quantifiable assessment of the future, which may be problematic if there is a need for "hard decisions" [14].

2.2. Anticipate change

Besides dealing with the uncertainty of probable futures, organizations have recognized the need to constantly scan their business environment to be able to instantly react to rapid changes [8]. This is based on the assumption that evolutionary shifts do not occur without a "repeated and persistent trail of early warning signals" [21] and goes back to Ansoff's concept of strategic issue management to detect "weak signals" [22]. A weak signal is unstructured information that foreshadows changes in the environment [23,24]. By continuously retrieving weak signals, strategic issue management – or environmental scanning, respectively – enables organizations to "prepare in such a way that a strategic discontinuity loses its suddenness, urgency, and unfamiliarity" [25]. In particular, strategic issue management aims for continuous scanning of fast issues as well as for real-time identification and response to important trends and events [22]. Thus, strategic issue management implies an important move away from episodic one-off activities like forecasting, strategic planning, or scenario techniques, but towards a continuous observation of possible future developments, challenges, and opportunities. However, strategic issue management is a sophisticated approach that requires trained staff and considerable investment in time [22]—two limitations that may be problematic if one aims for enhancing participation (Section 2.3) and reducing costs and complexity of foresight (Section 2.4).

2.3. Enhance participation

Foresight activities are often conducted as top-down approaches by only a single person or a department in an organization [8]. However, problems arise when narrowing future thinking to certain people such as managers or potential experts. This is because, firstly, managers' are focused on day-to-day business and filter out much of what is going on [16], especially in turbulent business environments. Moreover, managers often do not have a microscopic view of "the many activities that take place everyday in an organizational setting" [11]. As a consequence, highly important information that

indicates change may remain unnoticed [16]. Secondly, participation should not be limited to internal "think tanks" since they are often locked in prevailing mindsets and power structures of the organization [11,26]. Thirdly, evidence from the literature disputes the value of expert judgment in foreseeing change, especially in situations involving high uncertainty. Providing a review of empirical research on this problem, Armstrong [27] developed the "Seer-sucker Theory", stating that "no matter how much evidence exists that seers do not exist, seers will find suckers". Recently, Tetlock [28] published results from a longitudinal study in which he analyzed more than 28,000 forecasts of long-term political and economic trends, showing that experts barely if at all outperformed non-experts.

2.3.1. Involve all relevant stakeholders

Although foresight is seen as a "human capacity" [13] and therefore "all normal persons are fundamentally capable of foresight" [6], there is an increasing insight in the idea that a single person cannot have the enfolding information that would be necessary to make the right decisions. Rather, decision-makers recognize the "wisdom of crowds" [29] and the literature emphasizes the need for enhancing participation in the foresight process [4,11,12,30]. Foresight should harness both the knowledge of external networks [5] as well as ideas that are "mostly available within the individuals in the organization already" [12]. This knowledge that is "acquired by people – at all levels of the organization, including the lowest – as a by-product of their day-to-day duties" [31], is of immense value in foreseeing future potentials, challenges, and risks. Besides harnessing the knowledge of those "people on the spot" [11], non-experts from outside the organization may equally contribute for a successful foresight process. While a few years ago it would have been extremely costly and time-consuming to involve even a small external group, the rise of the Internet dramatically simplified accessing distributed knowledge of people from all over the world. In their 2006 book *Wikinomics*, Tapscott and Williams [32] give a number of examples of how organizations already harness knowledge from social and collaborative networks for strategic planning, innovation, and product development.

2.3.2. Maintain divergent views

Future thinking cannot take place in isolation. Thus foresight can only benefit from enhanced participation if one manages to establish a futures discourse [6] or strategic conversation [12] that elicits and aggregates all available information concerning the organization's position in the business environment. Without a process of constructive criticism and feedback, individual insights will remain private and unavailable, and thus people will simply not think about the future [6]. However, even encouraging a strategic conversation does not guarantee access to all available information or necessarily prevents an organization from "being caught in the future of desire" [12] since divergent views or new ideas may be filtered out by "groupthink" [33]. For example, group members often fail to disclose information due to a public announcement by others which made them uncertain about their own beliefs. If individual interpretations differ from the official future, group members tend to ignore their private information. Furthermore, people often silence themselves because other group members impose social pressure on them. Although they might believe that they know better, they will not share their information because they are aware of sanctions by other group members. This may be problematic in strictly hierarchical organizations where group members are often dominated by seniors. This may be even more problematic if foresight aims for broad involvement of members from lower levels of the organization, who may be more reluctant to reveal inconvenient information or to directly and honestly communicate with seniors. According to Burt and Wright [2], groupthink in organizations "will limit, or even prevent, any opportunity to explore their business environment". In order to cope with change, organizations need to be tolerant of independent thinking [12] and "consciously maintain enough divergent views of the situation around them" [16].

2.3.3. Motivate information revelation

Besides the barriers of groupthink, how one can initiate and maintain active collaboration in foresight activities remains challenging. Since for most stakeholders participation will be voluntary, it cannot be expected that they will be motivated to invest time and share expertise. It is a well-known problem in foresight studies that people generally refuse to participate or drop out early due to other commitments they consider more important [10]. Although incentives may help [34], it is still an open questions how a large number of people can be continuously motivated to participate in a permanent and ongoing process.

2.4. Reduce costs and complexity

Establishing foresight capacities in organizations can be complex and expensive [1]. Since organizations do not want to be encumbered with a new set of costs, they expect foresight to be "simple, less time-consuming, less academic and easier to implement into corporate processes" [8]. Thus, existing methods can be improved for better usability and cost-efficiency [35].

2.5. Need for new methods

To sum up, there is evidently room for new methods to improve current foresight activities. In particular, forecasting should move away from extrapolating historical data to more evolutionary approaches that take into account the uncertainties of long-term developments [3,10,19]. Although scenarios appear to be superior for thinking about alternative

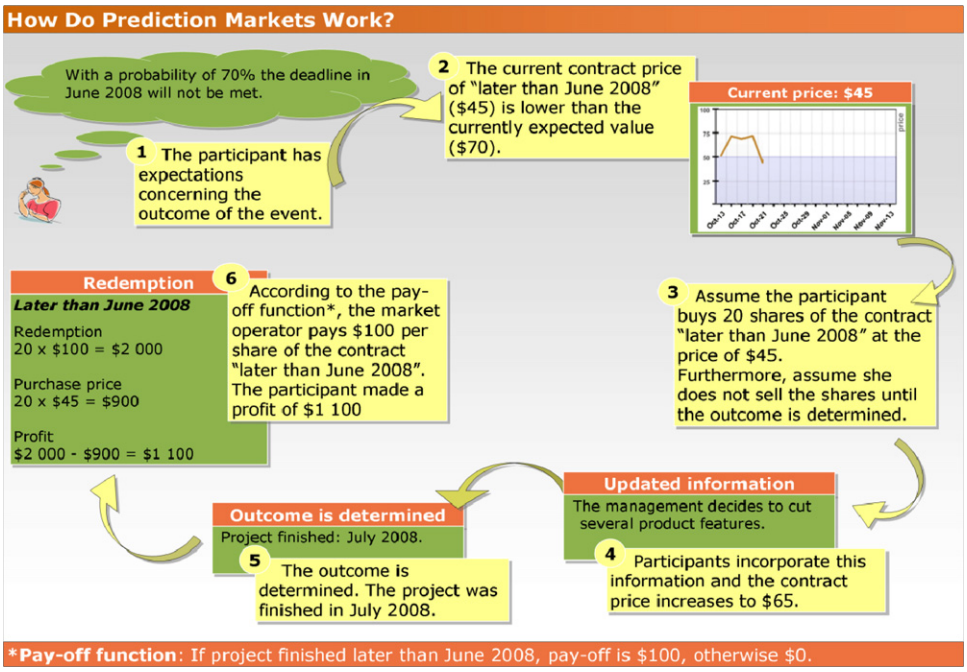

Fig. 1. How do prediction markets work?

futures, evolutionary forecasting approaches can be beneficial in terms of providing measurable and quantifiable assessments of the future, a widely emphasized need of managers [8,14]. Furthermore, foresight can be improved by applying easy-to-use, less time-consuming and cost-efficient approaches [8,35] that can continuously detect rapid changes in turbulent business environments. Finally, there is a need for methods that enable for and motivate preferably broad participation of stakeholders [4,11,12,30] without being afflicted with biases of groupthink. Although new information and communication technologies provide promising opportunities for reducing traditional barriers like budget constraints or other resource limitations, it remains unsolved how a large number of people can be continuously motivated to participate in a permanent and ongoing process especially over longer periods [10,34]. In the literature this view is endorsed by a somehow dynamic, emergent, or process-oriented understanding of foresight [36]. For example, Cunha et al. [11] suggest a change in the nature of foresight "from a technical–rational episodic activity to a socially embedded, process-based and permanent competence". Martin's [4] well-known five 'Cs' (i.e. communication, concentration, coordination, consensus, and commitment) also call for a process of intensive collaboration and interaction between stakeholders.

In the following section, we introduce the concept of prediction markets which we consider to be capable of enhancing current foresight activities by meeting these requirements, or at least lessening some of the remaining barriers to a wider implementation of foresight.

3. Prediction markets

While having already been popular for forecasting the outcome of elections in the late 19th and early 20th century [37], the rise of the Internet finally leveraged prediction markets.[1] Prediction markets are a structured approach to collect and aggregate information from groups and have gained particular importance in the area of forecasting over the last years. In the literature, there are a several studies that explain the concept of prediction markets and provide useful summaries of the method (e.g. [38–40]).

3.1. Concept of prediction markets

Prediction markets are web-based applications that work like traditional stock markets as expectations about future events are mapped as contracts, whose trading prices can be interpreted as a probability for the underlying event to come true. An example is depicted in Fig. 1. This market aims at predicting the completion date of a new product, i.e. providing information whether the product will be finished in due time (by June 2008) or not. Several contracts can be traded on this

[1] Although "prediction" may be disturbing in the context of foresight, we stick to the term "prediction markets" as it prevails in the literature. Less common descriptions of the method are "information markets" or "virtual stock markets".

market. For example, the contract "later than June 2008" pays off $100 if the product will eventually be finished later than June 2008; otherwise the pay-off is $0. This way the contract price can be interpreted as the probability of not meeting the project deadline in June 2008. If a participant believes that the project deadline in June 2008 will not be met with a probability of about 70%, she should be willing to buy (sell) these contracts for any price less (more) than $70. Thus she will become active if the current forecast – which is an aggregated group opinion – differs from her individual assessment. We assume that the participant accordingly buys 20 shares of this contract at the current price of $45. Since participants get active only if they disagree with the current forecast, the trading price of the contract "later than June 2008" always reflects all available information of all participants.

Depending on their forecasting or trading performance, participants can win or lose money. Therefore, by the anticipation of profit, markets motivate participation and revelation of information. Imagine a participant who is a proponent of continuing the development of the new software product but knows that the development cannot be completed by June 2008. If acting rationally, she will buy the contracts "later than June 2008", risking that the forecasts may advise the management to cut the project. Hence the incentive mechanism can motivate participants to reveal their true beliefs instead of preferences. Furthermore, since participation is only beneficial if one does *not* agree with – and is able to improve – the current market forecast, *prediction markets tricks participants into constantly challenging the group opinion and to look for superior information*. Thus, prediction markets can incite participants to actively think about the future.

This way prediction markets can also outwit problems of group tendencies or groupthink. Group tendencies often occur in traditional consensus development methods like Delphi and entice participants to follow the herd [41]. For example, Woudenberg [42] argues that consensus in Delphi is mainly achieved by group pressure to conformity or attrition of participants. An example of an internal market implemented at Microsoft [43] to predict the launch date of a certain software product illustratesd how prediction markets can overcome groupthink: After trading has started, this market instantly predicted that the product will not be finished in due time, revealing information that no member of the developer team has directly communicated to the project manager before. Evidently, this is a strong example of groupthink. Finally, the management trusted the market forecast and cut some features that were considered to slow down the development process. As a consequence, this decision was again immediately reflected by the market indicating higher probabilities that the product can still be finished in time (cf. Fig. 1). In the end, when the customers demanded the features back, the market again predicted that the product would be finished late—and was finally right.

Up to now, most prediction markets are applied for forecasting short-term events whose outcome will be eventually known as this makes it easy to define a clear pay-off function for the remuneration of participants. Yet, an analysis of the long-term prediction market "foresight exchange" has shown that the market forecasts "strongly correlate with outcome frequencies" [44]. Furthermore, two small prediction markets have proven to generate similar results to a large-scale Delphi study for forecasting long-term technological developments [45]. Although these approaches are promising, further empirical studies are necessary to evaluate the applicability of prediction markets for suchlike problems.

3.2. Performance of prediction markets

The number of studies that verify the forecasting performance of prediction markets is constantly increasing[2] and currently encompasses examples from the fields of politics [46,47], sports [48–50], business [39,51], medicine [52], and entertainment [53]. Besides providing accurate forecasts, prediction markets also proved to be superior to traditional approaches like polls or expert judgments. For example, comparing the accuracy of the *Iowa Electronic Markets* (IEM) to 964 polls over five US presidential elections from 1988, Berg et al. [46] showed that the market forecasts outperformed the polls 74% of the time. For predicting the results of NFL games, the forecasts of two markets have been compared to those of 1947 self-selected individuals. At the end of the season, the markets ranked 6th and 8th among the individuals. By comparison, the human average – which would be the outcome of a traditional survey – ranked 39th [54]. Finally, besides having beaten the individual and average forecasts of five columnists from the movie business [53], the *Hollywood Stock Exchange* (HSX) almost perfectly predicted the Oscar award winners for the last three years [55]. This performance of prediction markets led researchers to further analyze and to discuss their relative merits compared to other approaches of information aggregation. For example, Sunstein argues that prediction markets have substantial advantages to group deliberation processes [56]. Recently, by comparing prediction markets and Delphi, Green et al. conclude that both approaches are superior to traditional meetings [41].

3.3. Business applications of prediction markets

Most academic research has focused on the analysis of prediction markets for forecasting election outcomes or sports events for which data are easily available and uncritical for publication. In contrast, due to the reluctance of organizations in disclosing confidential information, only few academic studies on how companies harness the power of prediction markets have been published. Nonetheless, there is evidence that prediction markets increasingly find their way into the business sector. Recent articles published in *BusinessWeek* [57] or *IEEE Spectrum* [43] name various companies (e.g. Microsoft, Yahoo,

[2] As a response to increasing researcher interest, the *Journal of Prediction Markets* has been launched in 2007.

Intel, or Nokia) that use prediction markets to improve their internal decision-making processes, for example by forecasting the success of new products, commodity prices, or sales figures.[3] In addition, business consultancies such as McKinsey are just starting to recognize prediction markets as a major business trend [58].

Successful examples of markets in the field of new product development are the simExchange,[4] a market predicting the sales of console hardware and upcoming video games, and an internal market run by Eli Lilly to find out which drugs will be most successful [59]. Here, prediction markets can be seen as an alternative to traditional marketing research techniques. For forecasting sales figures, an internal market at Hewlett-Packard beat the official forecasts of the company in 6 out of 8 events [51]. In an early implementation at Siemens, software developers predicted the completion date of a huge software project [60]. A market for predicting long-term developments was the Tech Buzz Game by Yahoo Research to predict future high-tech trends [61]. Finally, with almost 1500 employees participating between 2005 and 2007 the largest known internal prediction market ran at Google [62]. Google used these markets for instance to predict future demand (e.g. "number of Gmail users by the end of the quarter"), performance (e.g. "Google Talk quality rating"), company news (e.g. "Google's Russia office to open by..."), or industry news (e.g. "Will Apple release an Intel-based Mac?").

As a response to the increasing demand of prediction markets for business use, the number of software providers offering complete market system solutions for business applications is constantly growing. Examples of these include Consensus Point,[5] Inkling,[6] and GEXID.[7]

3.4. Prediction markets and manipulation

As manipulative attacks can be critical for the implementation of prediction markets, they have been analyzed by researchers more precisely. Empirical studies indicate that attacks on result accuracy have not been successful historically [37], in the laboratory [63], and in the field [64]. Summarizing these studies, Wolfers and Zitzewitz [40] state that, besides a short transition phase, none of the known attacks had a noticeable influence on the prices. Furthermore, Hanson [65] argues from a theoretical point of view that there is not much need to worry about the effect of manipulation on prices in prediction markets. In his view, manipulation is just another form of "noise trading", which is a characteristic of all known speculative markets and only enables informed participants to make profit from these uninformed trades. Thus, more informed participants should enter the market, scale up the size of their trades, or increase their efforts to gain relevant information—which altogether can compensate for potential price distortions through manipulation.

4. Promises of prediction markets for foresight

Prediction markets possess several characteristics that appear to be beneficial to overcome remaining challenge of a wider implementation of organizational foresight. In particular, prediction markets are a cost-efficient and highly scalable forecasting tool that feeds on all available sources of information, continuously incorporates new information and motivates participation as well as information revelation. In the following, we describe these characteristics in more detail.

4.1. Evolutionary forecasting

Since forecasting[8] is one important task of foresight [10,13], prediction markets may already contribute by providing accurate forecasts. Furthermore, while traditional forecasting approaches often rely solely on historical data, assume for stable conditions, and are therefore not able to deal with unexpected changes, prediction markets are an evolutionary approach that is capable of actively anticipating the future. In fact, prediction markets are a judgmental meta-forecasting tool, i.e. participants feed on all available sources of information – for example, historical data, forecasts from other approaches, news, individual expectations, etc. – and incorporate them into their judgment. Thus, due to the performance-based incentives provided (Section 4.3), market participants may not be caught in thinking of the past but are constantly induced into thinking about unexpected changes and new developments.

4.2. Continuous and real-time information aggregation

As described in Section 2.2, the early detection of weak signals to anticipate change is a major task of foresight and the literature emphasizes the need for a shift away from one-off activities to a permanent and process-based approach [4,10,11,66]. However, continuous scanning for weak signals is difficult to implement. Ansoff's strategic issue management

[3] Other companies whose internal prediction markets have been mentioned in the public include Abbott Labs, Arcelor Mittal, Best Buy, Chrysler, Corning, Electronic Arts, Frito Lay, General Electric, InterContinental Hotels, Masterfoods, Motorola, Pfizer, Qualcomm, and TNT.
[4] http://www.thesimexchange.com.
[5] http://www.consensuspoint.com.
[6] http://inklingmarkets.com.
[7] https://www.gexid.com.
[8] Understanding forecasting in a corporate context primarily as (quantitative) business forecasting.

[22,25] is complex, time-consuming and resource-intensive and traditional methods have a rather episodic character (like e.g. brainstorming techniques, Delphi studies, scenarios, etc.). This is because the results of such approaches usually have to be manually analyzed, evaluated, and summarized by a facilitator *at a certain point in time*. In contrast, the price mechanism of the market automatically aggregates all available information of all participants and, thus, prediction markets can reflect the aggregated group opinion *at any time*. This has two positive effects. Firstly, automatic information aggregation reduces the workload of the operator (cf. Section 4.4). Secondly, the market ensures real-time and continuous information aggregation and feedback since price changes immediately react to the availability of new information. Thus, the implications of sudden events can be incorporated almost instantly in the forecast. Therefore, the availability of results is not tied to certain points in time but the market functions like a dynamic system that instantly reacts to new information revealed by participants and the aggregated information is fully available in the market and always up-to-date.

This capability of prediction markets enables continuous scanning of ongoing as well as ex ante assessment of future developments. In Section 3.3 we pointed out how businesses already harness the power of prediction markets to continuously generate information in order to inform strategic decision-making. However, foresight goes beyond merely informing decision-makers about ongoing developments but attempts to dealing with different futures and assessing the implications of today's decisions on the future. By introducing the concepts of *decision markets*, Hanson [67] describes an approach that allows assessing the implications of current decisions on future developments and vice versa. For example, he suggests a market in which participants can trade a company's stock price depending on whether the CEO of the company will be fired at a certain point in the future. If the stock price of such a "dump-the-CEO" market is higher than the original stock price of the company, this would advise the company to fire their CEO [68]. Needless to say, this proposal is provocative and implementing such a market seems unthinkable. But it nonetheless illustrates the endless possibilities of how prediction markets can be designed to link decision and action. Another example comes from the political field, where Intrade.com launched political decision markets which provide highly valuable information for voting decisions. For example, these markets forecasted the number of US troops that would be in Iraq by 2010 or whether the US government debt would increase *given* a Democrat will be elected as president in 2008. Other markets were designed to predict the impact the respective candidates will have on factors like economic growth, unemployment, or crime *given* they would be elected president.

4.3. Motivating participation and information revelation

As discussed in Section 2.3, increasing participation is one of the main requirements for improving foresight. However, it is still unknown how a large number of people can be motivated to continuously participate in foresight activities [10]. Addressing this question, Salo [34] discusses several incentives for participating in foresight, such as the wish to influence results, the possibility of learning or networking, and the need to demonstrate compliance. These incentives are central in most foresight activities and hardly depend on the selected method. Salo also addresses the possibility of compensating participants for their efforts but mentions three drawbacks: Firstly, compensating participants may fail due to budget constraints. Secondly, payments may distort the sample as proportionally more people relying on reimbursement will participate. Thirdly, undue attention to compensation may lessen credibility and creativity.

These drawbacks of compensative incentives could be circumvented by prediction markets as they imply a more sophisticated incentive mechanism than simply compensating participants for their effort. By automatically calculating portfolio values, prediction markets allow for rewarding participants based on their performance, i.e. the quality of their contributions. This can be done in various ways. For example, the market operator can award prizes or money to the best $\times$ percent of the participants or the participants can be remunerated depending on their portfolio value [69]. Yet, it is not essential to provide monetary incentives to motivate participation. For example, in the internal markets at Google, participants did not seem to care about cash prizes but wanted to know about reputational prizes like shirts that would identify them as winners [70]. Furthermore, by simply announcing a user ranking, play-money markets have shown to perform well without providing any monetary or tangible incentives [71]. The social incentive of reputation and the possibility to match someone's personal expertise with others is often sufficient motivation for participation. This incentive of social competition may be even stronger within an organization where people know each other. In addition, there are concerns that providing monetary incentives may actually be counterproductive in internal corporate markets if the incentives are large enough to entice employees to work against the goals of the organization [70].

4.4. Scalability and cost-efficiency

The implementation of foresight is often limited by tight budgets and other resource limitations [1,35,36]. As already described, information aggregation in prediction markets is carried out automatically via the price mechanism, i.e. no manual intervention by the operators is required which significantly reduces the workload at runtime. This makes prediction markets arbitrarily scalable as the workload does not increase with the number of participants or the time horizon of the study. In fact, the hardware costs for running the market are negligible once the market platform has been designed [72]. Thus, it might not even be necessary to shut down a market. If motivation of participants can be maintained, prediction markets can continuously produce results and respond to changes in the environment without any additional workload for the operators.

5. Fields of application for prediction markets in foresight

The characteristics of prediction markets described in the previous section illustrate their potentials for enhancing foresight. Needless to say, we do not argue for a replacement of other foresight methods. Rather, we think of prediction markets as a supplement to existing foresight methods. In this section, we suggest four possible fields of application of prediction markets in foresight:

1. Using prediction markets for continuous forecasting and environmental scanning.
2. Combining prediction markets with deliberative approaches in order to harness strengths and to compensate weaknesses of the respective methods.
3. Designing prediction markets to continuously motivate creative thinking and idea generation.
4. Identifying highly innovative and knowledgeable participants in order to recruit them as experts for other foresight methods.

5.1. Continuous forecasting and environmental scanning

Nowadays, predominant means for forecasting, monitoring the business environment and informing decision-makers in organizations are often business intelligence software solutions or large corporate data warehouses that are able to manage and analyze huge amounts of data. Yet since these systems mostly work with historic or quantitative data and apply statistical models, they are not able to cope with high uncertainties and evolutionary changes of turbulent business environment, especially when looking at the long-term future. In order to enhance such systems with foresight capacities, we suggest an integration of prediction markets. For example, prediction markets can be used as an additional function to involve human thinking and thereby process qualitative information or analyze evolutionary changes. Vice versa, integrating prediction markets in corporate intelligence software may further improve the performance of prediction markets. For example, the software can provide relevant data (like statistics, charts, or figures) to participants, which again improve the quality of market results since better informed participants will make better judgments.

Based on the fact that prediction markets provide advantages in terms of future thinking, continuity, participation, and cost-efficiency, it seems beneficial to implement them as an ongoing tool for forecasting and environmental scanning within the organization. They could run besides the day-to-day business and generate information without having to be watched at all times. Moreover, once certain thresholds have been exceeded, markets could alarm decision-makers to take a closer look at certain developments or to undertake action. Such thresholds can be of different nature. Consider again the Microsoft market for predicting product launch dates. Such a market could for example send an alert if the price reaches a level which might indicate that the majority of the participants expects that a product will not be finished in due time. Furthermore, important information could also be drawn from the activity of the participants or the traded volumes on the market [45]. For instance, a high trading activity in a market which is usually known to be calm may indicate the availability of new information, i.e. something has happened that might be worth looking at. Of course, the same applies to abrupt price changes or large order spreads.

Thus prediction markets automatically produce a variety of information that could be used to continuously detect and respond to ongoing developments by pointing out sudden changes in the organizational environment. A capacity we consider highly beneficial in improving current foresight activities. Yet, although managers prefer measurability [8,14], prediction markets suffer the problem that information is only aggregated in numeric values. Hence, participants do not reveal their underlying reasons or arguments on why they buy or sell a certain contract—information that may be of particular importance to decision-makers [41]. In order to compensate this weakness, we suggest combining prediction markets with deliberative approaches.

5.2. Combining with deliberative approaches

We consider combining prediction markets with deliberative approaches to be useful for at least three reasons. Firstly, disclosing reasons and considerations underlying participants' judgments can improve the quality of predictions since participants will then know whether an argument is already incorporated in the forecast. Secondly, making information publicly available reduces the effort required to retrieve information. Thirdly, qualitative information is valuable for decision-makers that rather base their decisions on explanations and reasons than on simple figures.

Nowadays, prediction markets have already integrated communication platforms like forums, web-logs, or chat-rooms to facilitate the information exchange among participants (e.g. Intrade.com). However, their primary goal is likely to enhance the attractiveness of the market and to increase participation. There is still a lack of research examining whether such means of communication really improve the quality of results provided by prediction markets. It is conceivable that the possibility to directly communicate with other participants worsens market results by opening floodgates to deception or manipulation.

Nonetheless, we think that appropriately combining prediction markets with established approaches of information aggregation can lead to advances in the field of foresight. In particular, it may be desirable to combine the potential of

deliberative methods to produce arguments as well as complex and qualitative assessments and use the power of markets to convert these into a specific numeric value, to identify priorities, or to involve a large public to evaluate these assessments.

By introducing the term *deliberative information markets* and suggesting a combination of prediction markets with group deliberations, Abramowicz [73] has already discussed some of the merits of prediction markets. While group deliberations are one of the most widely used mechanisms to collect and aggregate information, they are vulnerable to the biases of groupthink (cf. Section 2.3.2). In contrast, prediction markets do not suffer from group pressures since the market reacts to individual trades through price changes and does not announce if, when, and what an individual has traded. Participants' actions are not traceable by others and therefore the mechanism is not vulnerable to groupthink. Participants can express what they think without having to worry about negative consequences.

Therefore we propose to run a prediction market in connection with group deliberations in order to validate whether the consensus that has been reached by the group really represents the actual state of knowledge of all participants. There might also be situations in which it would be helpful to let participants initially trade on a prediction market in order to sensitize them to the particular problem and to the prevailing group opinion before they attend the group deliberation. Spann and Skiera [39] proposed such an approach in combining prediction markets with focus groups. Since prediction markets are generally easy and cost-efficient to implement, they can be used in addition to basically almost any other method of information aggregation, either to validate the results by involving the same participants or to get an additional opinion from completely different people. This complies with Armstrong's [74] principle of "combining forecasts", the combination of substantially different methods in order to improve forecast accuracy and, therewith, decision-making.

5.3. Continuous idea generation

Another field where we see potential of using prediction markets is idea generation. Needless to say, we do not recommend the replacement of creative approaches like brainstorming sessions or future workshops which are most applicable for envisioning future developments. However, they are one-off instruments that are applied only occasionally. Again, to enhance foresight, it is necessary to *continuously* motivate people to think of new ideas, potential improvements, or necessary measures.

Therefore, we suggest designing prediction markets to enable continuous idea generation. Nowadays, most prediction markets do not facilitate idea generation since the contracts that can be traded are usually predefined by the operator. This makes it impossible for participants to introduce new aspects to the discussion and thus disables creating information and ideas that have not yet been considered. However, prediction markets can be designed in a way to allow for creation and definition of new topics to participants. Such *idea markets* have already been implemented for creating and evaluating new product ideas [75]. In these markets, every participant can add new product ideas as contracts which can then be collectively evaluated by all other participants. This provides important advantages for the process of new product development. Firstly, idea markets enable involvement of a large number of idea creators and, therewith, new ideas. Secondly, new ideas can be evaluated immediately by all other participants. Thus, idea markets combine the process of idea generation (divergence) and evaluation (convergence). Thirdly, new ideas are evaluated by a structured and interactive group process which increases the credibility of decisions. Of course, the application of idea markets is not limited to generating new product ideas but can be applied for all processes of idea generation by involving members from inside as well as outside the organization.

5.4. Expert identification

Besides encouraging participation (cf. Section 4.3), user rankings can be used to identify highly knowledgeable participants, for the process of new product development, Spann et al. [72] show how prediction markets may be used to identify so-called lead users. Lead users are those who have high expertise in a respective product field and realize needs of customers earlier than the rest of the market. Therefore, they have the capability to innovate. Two separate mechanisms allow markets to identify lead users. Firstly, a sort of "self-selection" effect occurs since the incentive mechanism ensures that only well-informed individuals with a high interest in the particular contract will participate. Secondly, a "performance-effect" arises "because well-performing participants [...] show a better understanding of the market than their (already self-selected) fellow participants" [72]. Thus, the most knowledgeable participants are likely to be ranked as the best performers in the market. It is clear that using prediction markets to identify such highly sophisticated members within an organization is beneficial for organizational foresight. The best-performing and thus most forward thinking participants may be asked to participate as experts in other foresight activities on a smaller scale such as brainstorming, Delphi, or scenario development.

6. Conclusion

We described remaining challenges that may prevent a wider implementation of foresight in organizations. In particular, the needs to deal with the future, anticipate change, increase participation, and reduce costs and complexity of foresight call for new methods to improve current foresight activities. We introduced prediction markets to the field of foresight to address this deficit. Prediction markets are a judgmental forecasting method that gained increasing attention in the business domain. We discussed particular advantages of prediction markets in overcoming the described challenges of foresight, particularly continuous and real-time information aggregation, motivating participation and information revelation as well

as cost-efficiency and scalability. Moreover, in contrast to traditional forecasting approaches, which mostly feed on historical data, prediction markets trick participants into continuous, active, and evolutionary future thinking. Yet, we do not consider prediction markets to be solely a forecasting tool but rather think of them as a *toolkit* for foresight. In particular, we suggest four fields of application for prediction markets to improve foresight: continuous forecasting and environmental scanning, combination with deliberative approaches, continuous idea generation, and expert identification. We provided examples of specific studies that demonstrated how prediction markets have been implemented for such purposes. However, we are not aware of any implementation that harnesses the power of prediction markets simultaneously for all four proposed fields of application and therefore emphasize the need for further empirical studies. We conclude by considering prediction markets as a nascent and highly promising approach for foresight and advocate for further research.

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