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Information Markets: A Research Landscape

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Abstract:

Information markets are mechanisms that allow a group of geographically dispersed participants to reach and continuously reevaluate consensus by discovering the value of alternative outcomes. Evidence suggests that these markets can produce better quality decisions than a small subset of selected decision makers: a finding in direct opposition to the trust we place on expertise. In challenging and uncertain decision-making arenas, information markets offer an interesting, and somewhat counter-intuitive approach. In practice, information markets may be used in combination with other decision-making methods, but these market-based mechanisms offer many advantages. This paper presents an information market typology and explores some of the challenges raised by different market applications. Market types include event and estimation-based prediction markets, decision markets, and idea markets. An integrated research landscape model and research propositions are presented to help guide continuing research in this area.

Keywords: information markets, decision making

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I. INTRODUCTION

The overall message of information markets is that a large group of market participants can produce better quality decisions than a small subset of selected decision makers. This is in direct opposition to our inherent trust in expertise. Significant specialization and training, along with deep domain knowledge, are highly valued in society. The expert physician or diagnostician immediately leaps to mind. However, there are many areas in which the track record of experts does not merit such high levels of trust. In these challenging and uncertain decision-making arenas, information markets offer an interesting, and somewhat counter-intuitive approach. In practice, information markets may be used in combination with other decision-making methods, but these market-based mechanisms offer many advantages such as feedback and signalling, participant anonyminity, and incentivised prediction accuracy.

Information markets are mechanisms that allow a group of geographically dispersed participants to reach and continuously reevaluate consensus by discovering the value of alternative outcomes. The technology behind information markets can support a large number of participants, engaging many people in the decision-making process. The process itself is very democratic, with all participants enjoying equal access to buy and sell their favored outcomes, typically in an anonymous market. Information markets are less expensive mechanisms than face-to-face meetings or facilitated group consensus methodologies. In addition, markets are able to operate continuously, thereby allowing participants to immediately respond to unfolding events. Re-pricing based on newly available information makes markets excellent feedback mechanisms that can be integrated into more complex and dynamic business processes.

There are many different types of information markets that accomodate a variety of decision-making tasks. Some markets are aimed at predicting the outcome of a specific event, while other markets are used for idea generation. Market designers have a rich pallette of options to choose from when adapting a market to a specific decision making context.

This paper will first organize markets into a typology and define the various types. We will then provide a research landscape model to guide future exploration of this topic area. The landscape model defines and describes the relevant high level constructs. Finally, exemplar research propositions are presented to further explain how the typology and research landscape model can be used in information market research.

II. INFORMATION MARKETS

Berg et al. [2003, pg. 79] define information markets “as those run for the purpose of using the information content in market values to make predictions about specific future events.” The overall goal of all information markets is to harness the collective wisdom of the crowds. This notion is the topic of a recent book by Surowiecki [2004]. Information markets effectively aggregate the opinions of participants with vastly different backgrounds, holding localized knowledge, who may be geographically dispersed [Sikora and Shaw 1998; Plott 2000]. There is a large body of evidence that information markets are effective at estimating the probability of future industrial or political events, such as shifts in monetary policy, predicting the next Supreme Court Justice to leave the bench, and assessing various forms of geopolitical risk [Berg and Rietz 2003; Brüggelambert 2004; Gruca 2000; Herron et al. 1999; Oliven and Rietz 2004; Wolfers and Zitzewitz 2004]. The Iowa Electronic Market (www.biz.uiowa.edu/iem), perhaps the most well-known example, has compiled an impressive record of predicting presidential elections [Berg et al. 2001; Berg and Rietz 1996; Forsythe et al. 1992]. Several informal explanations for the success of these markets are presented in the prediction market literature. Most notably, this literature identifies financial incentives for accurate predictions, better-informed traders self-selecting to participate, their ability to aggregate information, and the feedback provided by market price as critical success factors [Plott et al. 2002]. The initial popularity of these markets to forecast election outcomes [Berg and Rietz. 2003] has spread, and their use has expanded to many decision-making environments. Many companies have been using proprietary internal information markets for managing demand risk (Intel, Google), determining product ship dates (Microsoft), forecasting market capitalization prior to an IPO (Google), identifying breakthrough technologies (GE), and estimating effort for project management (USF Milestone Market) among other tasks. Best Buy, Motorola, Qualcomm, Edmunds, and Misys Banking Systems have used Consensus Point, a commercial information market company, for a variety of prediction activities. Some other information markets are Economic Derivatives, News Futures, Foresight Exchange, and the

Hollywood Stock Exchange. Predictify supports specialized and general trading on political, financial, current events, sports, and entertainment questions.[1]

This expansion in use has spawned a variety of information markets designed to elicit the changing types of information required to reduce uncertainty. Figure 1 presents a market typology that organizes markets by the type of decision making task. Each of these market types is aimed at a different type of task, which often leads to different designs. There are three main categories of information markets differentiated by the type of information sought: prediction markets, decision markets, and idea markets.

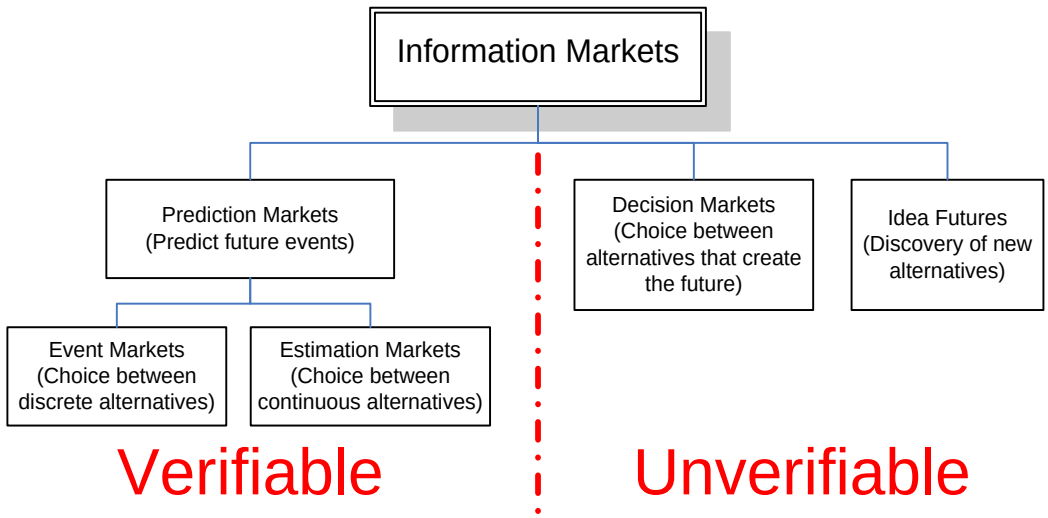

Figure 1. Information Market Typology

As indicated in Figure 1, information markets can be divided into two distinct groups based on their outcomes and whether these outcomes are verifiable or unverifiable. Because prediction markets, by their definition, attempt to predict the state of a specific event at some future time, the results can be verified against an actual outcome. The outcomes of decision-and-idea markets reflect the participant's choice among alternatives or breakthrough solutions that will not have comparable events with which the results can be verified. A more detailed description of the various types of markets follows.

Prediction Markets

Prediction markets are concerned with forecasting the future. Because these predictions will ultimately come to pass, the truth of the predictions can be verified. Prediction markets are an increasingly common type of market that can be used in a wide variety of decision-making contexts. Most markets are event markets with binary, discrete and mutually exclusive contracts, such as bidding on the winner of a presidential election. Recently, the choices and contracts have become more complex, allowing the bidder to select from any number of possible outcomes or outcomes that represent a continuous range of choices. Prediction markets can be further decomposed according to the type of events being predicted.

Event Markets

Typically, event markets operate with a well-defined set of outcomes provided a priori to market traders. Through implicit evaluation and explicit trades, the alternative outcomes are priced at varying levels, conveying the voice of the market. In event markets, the outcomes are discrete outcomes. Which candidate will win an election? Which team will win a game? Which of three delivery dates are most likely? The truth of these questions are ultimately revealed as the actual events occur, changing from predictions to historical facts. The election markets conducted by the Iowa Electronic Markets (IEM) and the Hollywood Stock Exchanges markets for expected box office returns

[1]Information market Web sites include: Consensus Point [consensuspoint.com], Predictify [predictify.com], Hollywood Stock Exchange [hsx.com]. Economic Derivatives [economicderivatives.com], News Futures [us.newsfutures.com], Foresight Exchange [iedosphere.com].

are classic examples of this type of information market. Other examples of this prevalent format are supported by a variety of platforms such as Economic Derivatives (economicderivatives.com), Newsfutures (newsfutures.com), and the Foresight Exchange (ideosphere.com).

Estimation Markets

Estimation markets differ from event markets in that the outcomes are points along a range. An estimation market can be approximated by an event market by selecting a set of discrete points as a priori alternatives. While this may be a straightforward method of handling quantitative outcomes, there is a risk of losing some useful precision and precluding traders from selecting the truly desirable alternatives. There are many interesting situations in which a quantitative estimation market seems like a natural fit. For example, project management revolves around time and cost estimates that are certainly quantitative in nature. The Milestone Market (www.MilestoneMarket.org) is a prototype market built at the University of South Florida and is being deployed for project estimation tasks. Forecasting sales or any of a myriad of financial indicators, such as interest rates, that can affect the business environment provide other examples of estimation markets. Plott and Chen [2002] successfully applied information markets in a more business-oriented experiment to forecast sales volume and the level of profit sharing at Hewlett-Packard Laboratories. Their market results outperformed official internal sales forecasts 75 percent of the time [Ostrover 2005]. Although in this particular market, the choices were discrete due to the functionality of the market mechanism, the type of choices exemplify the potential of estimation markets to allow for continuous alternatives.

Decision Markets

Decision markets seek to support decision making in more uncertain environments. Typically, their goal is to decide between alternative choices where there is not necessarily a clearly correct choice. In decision markets, traders explicitly state their preferences for different outcomes through purchases of desired outcomes and sales of less desirable outcomes (at particular price points). These markets help create the future because the results (the most preferred alternative) may determine an organization's course of action. Prediction markets state the decision tasks in certain terms that can be verified once the actual event takes place. This requirement is relaxed somewhat in decision markets, which can present alternatives that may not be evaluated in black and white. For example, Intel and Google's demand forecast markets, and Starwood's markets to develop and select marketing campaigns represent variants of such decision markets. A decision market for selecting marketing campaigns would involve describing in some detail fairly complex options and then proposing evaluation criteria that could be used to determine which campaign was actually the winner. Given a limited marketing budget, it might be difficult to thoroughly investigate the performance of each alternative so that market accuracy can be assessed. In fact, it may be impossible to reach high levels of certainty in many decision making contexts. Yet, such decision markets can still be very useful in determining courses of action or selecting amongst a set of alternative outcomes in less structured domains. All that is necessary are clear descriptions of the outcomes and an evaluation method that is perceived as fair by the participants, as well as capturing the actual usefulness of the outcomes in a practical sense. The limitation is the uncertainty in the final assessment since in many situations the actual merit of every alternative outcome may be unverifiable. Ultimately decision markets are only as good as the quality of the decisions in practice.

Idea Markets

Idea markets or futures operate in even less-structured domains. The intent of idea markets is information discovery similar to brainstorming. General Electric has recently implemented what they call an "Imagination Market" to identify breakthrough technology research areas to pursue. It is likely that many of the alternative outcomes are never truly verified. Again, successful idea markets require good descriptions of the possible outcomes and a fair evaluation method at the close of the market. However, the challenges involved in representing alternatives and evaluating those alternatives in the future are more extreme. In a brainstorming environment, there must be a fairly easy mechanism for proposing (and possibly removing) alternative ideas. For example, the GE Imagination Markets have resulted in between 60 to 150 proposed ideas, but only around 50 ideas are actually realized [LaComb et al. 2007]. In addition, each unique idea must be accompanied by some method of evaluation. Any market-based solution must empower all, or at least many, traders to offer alternatives. In such unstructured environments, market management becomes critical as the tumultuous process of both idea generation and trading is combined. At the close of the market, the evaluation of all the potentially diverse ideas presents an equally difficult set of challenges. In the GE Imagination Market, more ideas were generated, ideas were easily visible to all who participated, and there was more participation than traditional idea-generation techniques, but the ranking of ideas using volume-weighted average price was no better than the rating and ranking of ideas by members of a leadership team [LaComb et al. 2007]. Customer facing markets have emerged such as Dell's IdeaStorm [ideastorm.com] and Starbuck's, My Starbucks Idea [mystarbucksidea.force.com] which allow participants to post, review, and vote on product and service suggestions.

The market typology presented in Figure 1 serves to organize the different types of markets by the type of decision-making task to be implemented. These market types, from event or estimation-based prediction markets to the less-structured decision and idea markets, offer many different areas for research. However, these markets also share some common core characteristics. Many of these core market characteristics include aspects of market participants, general market structure, and mechanisms for rewarding traders and understanding the market outputs. In the next section of this paper, as we consider the research landscape for information markets, we model the relationships between seven high level constructs: trader characteristics, organization characteristics, market environment, external information, trader behavior, market design and market outcomes. All will be relevant factors as we study specific information markets. For example, there has already been research on how trader characteristics impact trader behavior [e.g., Forsythe et al. 1998]. However, the typology of information markets will require quite different conceptualizations and measures for market outcomes, which include how the voice of the market, activities, and performance are measured. These differences for market outcomes by market type are detailed in Table 1.

Table 1. Differences in Conceptualization and Measurement of Market Outcomes, by Market Type

Market Type	Market Outcomes		
	Voice of the Market	Activity	Market Performance
Prediction			
Event	Discrete Choice Price	# of Trades	Accuracy of Prediction
Estimation	Point Estimate on Continuous Curve	# of Trades	Accuracy of Prediction
Decision	Price of Alternative Choices	# of Trades	Subjective Evaluation of Decision
Idea	Price Ranking of Ideas	# of Ideas	Subjective Evaluation of Realized Ideas

III. INFORMATION MARKET RESEARCH LANDSCAPE

Research into the use of information markets to assist with business decisions is rich with opportunities. This paper presents a few of the potential research areas as they apply to a variety of information market applications. Figure 2 presents the research landscape model depicted as a model that was developed from existing information market literature, as well as new areas for exploration outlined in this conceptual paper. The high level constructs and their relations in the topology represent an organization of ideas from information market research. Information market research has investigated the relationships between individual trader characteristics, market environment, organizational characteristics, external information, market design, trader behavior, and market outcomes. Table 2 presents some examples of influential and key findings from this literature for each of the high-level constructs that make up our research landscape model. In Figure 2 and the following text we identify instances of these high-level constructs that have already been studied and/or appear to be highly relevant to information market research. However, these instances are in no way intended to provide an exhaustive list. The goal of mapping the research landscape at this stage in information market research is to help structure research efforts on information markets by organizing the results of past studies, as well as detecting those areas that need additional work. Within the market topology, research and development issues are separated into individual trader characteristics, organizational characteristics, market environment, external information, trader behavior, market design, and market outcomes. Individual trader characteristics represent individual differences along a host of dimensions that include socio-demographic items, cultural differences, risk profiles, work roles, and levels of relevant expertise. Market environments consider the collective aspects of the traders, such as diversity and independence, as well as the type of market, the number of participants, and the length of time the market is open. Organizational characteristics relate to the organizational and political environment surrounding the market application. External Information relates to the amount, availability, and accessibility of relevant information, search costs, and even insider trading knowledge. Market design factors include the trading interface and functionality choices to accommodate the various market types, the level of anonymity provided traders, aggregation and feedback mechanisms, as well as decisions regarding the payoff mechanisms proposed to reward participants. All of these market constructs directly affect trading behavior. Trader behavior is characterized by the participant's bidding strategy, level of participation or engagement with the market, and how accurately they trade. Trading accuracy is measured against the ultimate market outcome that can be assessed objectively or subjectively contingent on the market type. Additionally, market design choices will moderate the effects of individual trader characteristics, organizational characteristics, and market environment on trader behavior. Finally, how a trader behaves will impact the outcome of the market. Market outcomes include the actual performance or results of the market, the volume of activity, and various other measures that result in the market conveying the combined wisdom of the participants or the voice of the market. The market outcomes will result in a feedback loop to the traders possibly altering their behavior. These issues are all interesting areas of research and will to some extent determine how widely information markets can be applied.

Table 2. Key Supporting Literature		
High Level Constructs	**Information Markets Research**	**Summary of Findings**
Individual Trader Characteristics	Forsythe et al. 1998	Some traders exhibit judgment biases in their market choices
Organizational Characteristics	LaComb et al. 2007	Type of incentive for participation affected trader behavior
Market Environment	Plott & Chen 2002 Surowiecki 2004	Small numbers of participants can result in acceptable performance, but may lack diversity (variation in ideas is needed)
External Information	Forsythe et al. 1999	In election markets, candidate debates changed trader behavior
Market Design	Hanson 2005	Anonymity minimizes traders' fears about expressing or valuing ideas that conflict with status quo
Trader Behavior	Bottazzi et al. 2005	Trading patterns of trend followers and noise traders
Market Outcomes	Pennock et al. 2001	Identified determination of the voice of the market as the most difficult challenges to information markets

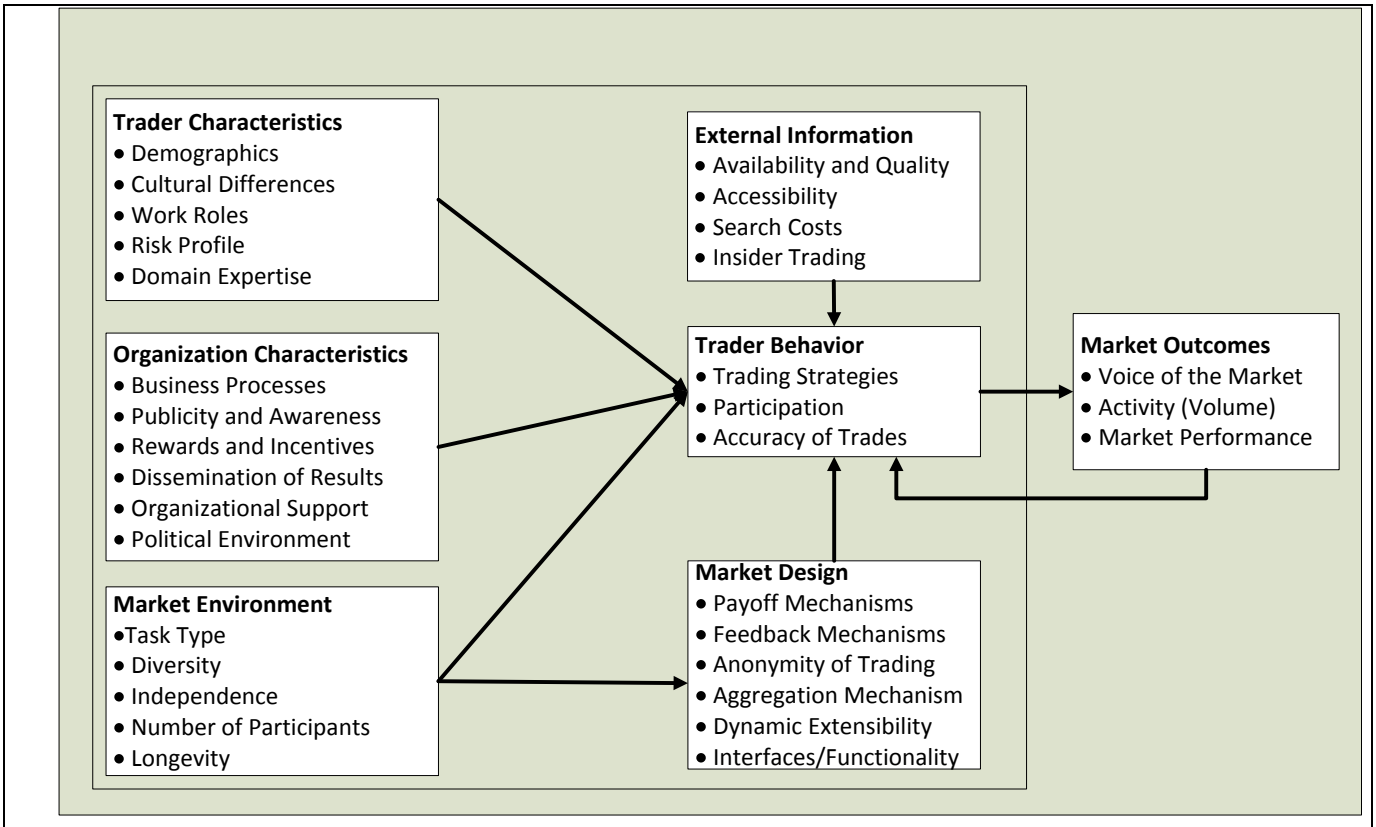

Figure 2. Research Landscape Model

Trader Characteristics

All traders are not created equal. Trader age, individual expertise, work roles, tolerance for risk, or even experience with online financial services may all affect participation in an information market. For example, there is a well-known difference between cultures in power distance: the extent to which individuals expect and accept the unequal distribution of power, and tolerate differences in a hierarchy [Hofstede 1991, 2001]. Market participants from cultures high in power distance may be reluctant to trade, or in non-anonymous markets, may follow the trades of individuals who have higher positions, rather than participate based on their own beliefs. Some educational

backgrounds or work roles might result in more experience or even domain expertise. Is this more relevant experience associated with more sophisticated estimation market trading strategies? Individuals also vary in their tolerance for risk, which would certainly affect trading. In short, individual trader characteristics are fundamental factors in understanding how markets might operate with a given set of traders.

Organization Characteristics

Markets do not exist in a vacuum. Markets operate in organizational and political environments that will affect everything from market acceptance to individual trader activity. For example, a decision has to be made about how to incorporate markets into business processes such as project management, marketing strategy decisions, or innovation development. The structured outcomes of prediction markets may be more easily integrated into business processes (e.g., use the market to estimate completion times at the beginning of the project and at set intervals throughout the project) than the more complex outputs of decision or idea markets (which may be used in conjunction with existing processes, such as forecasting or brainstorming processes). How is a trader's market performance perceived within the larger context of teams and management structures? The methods used to publicize information market applications and recognize strong performance (or to keep less inspired performance private) are factors outside of the market itself that will cause participants to alter behaviors. Organizational support and how the results of market applications are disseminated and used all signal the value of information market technology to participants. Finally, the outputs of markets are used to change or enlighten existing business processes. The nature and importance of the processes and integration efforts are also central factors.

The type and level of incentives can vary within an organization. At GE, multiple incentives are used, including small prizes for the best idea, best portfolio of ideas, and amount of participation, as well as funding to prototype the best idea submitted by a participant [LaComb 2007]. At Best Buy, the top trader in their prediction market for new product sales received a $200 gift certificate [Dvorak 2008]. What is an adequate level and type of incentive to facilitate trading, and participation? For example, the effort required to study a problem, and make an informed decision may not be trivial. What level of incentive is necessary to prompt participants to expend the effort required to form predictions? Are there any incentives that would cause some market participants to trade in ways that influence the outcome in inappropriate ways? Also, what impact do various incentive structures have on trading strategies and ultimately on the outcome of the market?

Market Environment

Applying information markets to new and interesting problems brings into play a variety of task types. The degree of task complexity of the problem being predicted can vary significantly. Unlike a simple event market predicting the outcome of a political campaign, where there is one correct choice among two choices, there are other markets that involve multiple contracts that may change over time, or even participant-generated contracts. The market typology captures much of this task complexity from well-defined prediction tasks to idea markets that are used for brainstorming. For instance, care must be taken in the choice and description of the alternatives in estimation markets with many contracts, or decision markets with several complex alternatives. Additionally, the market developer must decide on the granularity of the contract ranges, what, if any, reference points to provide, and whether or not to allow the contracts to be modified as the market progresses. Task complexity can vary within the various market types, as well as across market types. For example, an estimation market can be used to select alternatives from a few possible contracts or to perform more fine grained predictions using a continuous range of alternatives.

Participant selection is a critical factor in any market, especially if the market is small or the knowledge is specialized. Participant traits that support an effective information market include decentralization, diversity, independence, and the number of interconnections among participants in the market [Holland 1998; Johnson 1999; Knight 1921]. Information markets are excellent mechanisms for bringing together many decentralized "experts" or team members and subsequently sharing the group consensus through market prices. By harnessing the power of information markets to aggregate diverse knowledge and expertise, the limitations of single-expert decision making can be avoided. Diversity in market trader characteristics will have a direct impact on trader behavior. This is a market characteristic, because diversity is measured in relation to other traders, and therefore, informs the selection of traders for a specific market. Diversity of backgrounds and opinions is viewed as positive for information markets, because differing ideas and beliefs will drive trading [Surowiecki 2004]. If everyone had the same idea or belief, there would be no trading. All traders would desire to buy and sell the same items, therefore no trades would occur. To facilitate a market, participants must have differing expectations regarding the value of a stock. The old adage, "One man's trash is another man's treasure," exemplifies this notion. Without trader diversity, everyone would have the same belief and thus value their trash and treasure the same. Also the "no-trade" theory suggests that adverse selection will prevent rational uninformed agents from trading if they believe their counterparts are all informed

agents [Milgrom and Stockey 1982]. A very diverse set of participants may interact differently from those with more in common.

Factors such as domain expertise and trading experience may influence market behavior. Therefore, it is important to incorporate individual traits, evolving trading experience, and other factors specific to the particular context or market type. However, involving the ideal set of market participants is not as critical as one may expect. Including somewhat less informed, or even completely uninformed, traders in a market adds liquidity as they may buy and sell contracts at prices that more informed participants would hold [Plott and Chen 2002]. In fact, the attraction of markets is that they display high levels of efficiency even though individual traders may have biases and make mistakes [Forsythe et al. 1992; Oliven and Rietz 2004; Forsythe et al. 1999]. Participants must be free to act independently and express their personal opinions through trading behaviors. Participants need to be free from group pressures when forming their valuations. Independent value formation reduces the influence of dominant opinions, one of the important advantages of information markets. While independence is necessary to foster a unique perspective, it is also desirable to have interconnections between market participants to foster the exchange of individual information. Although a diverse mix of traders may maximize the independence of market participants, it may reduce the interconnectedness of those participants, which could minimize the exchange of individual information. The impact of these influences on trading strategies, level of participation and trading accuracy needs to be teased out.

The level of competition or the number of participants in the market, should also have an effect on trader behavior. Berg and Rietz [1996] found that larger, more active markets with fewer contracts are more accurate. However, reasonable performance has been demonstrated with small (i.e., thin) markets or markets with as few as 8 to 30 participants [Plott and Chen 2002; Ortner 1998]. For instance, Chen et al. [2001] successfully ran laboratory experiments using information markets with fewer than 15 participants. However, small markets do present some unique market design challenges. A small market is more susceptible to intentional market manipulation or the subtle dominance of shared beliefs. Additionally, market liquidity may suffer due to a limited number of trades offered because of the small number of participants involved. Participants must be engaged and actively trading to generate enough data for informed estimates. Future research needs to discover if there is an effect on trading strategies, participation and accuracy of trades with differing numbers of participants. In other contexts, idea markets could be used as a brainstorming tool with relatively few participants or a much more widely deployed solution to capture “out-of-the-box” thinking by employees at all levels. Again, the number and type of participants will certainly affect such markets.

The long-term nature of many information markets can be particularly troublesome. Capturing the reaction to the changing environment is a benefit of using information markets over time, but it also poses challenges related to task descriptions. Accommodating changes to the outcomes being traded becomes even more difficult to manage depending on market longevity. How varying levels of complexity over time will impact trader behavior is a very interesting and as yet unexplored question.

Many of the market environment factors noted above will directly affect market design choices, since the market technology requirements are different for the different types of markets, or may be used to support a market environment characteristic (e.g., anonymity of trading to maximize independence).

External Information

As the problems tackled with information markets become more complex the impact of external information that traders possess may be influential. The knowledge a trader can use to inform market activity can be affected by existing expertise, individual bias in how that information is processed, the ability of the trader to adequately research and obtain publicly available information, and/or the participants’ access to insider information. High search costs or low information quality can force a trader to make uninformed decisions. Of course, low quality information might even be supplied intentionally by competing traders. The notion of insider trading is particularly significant with small markets that can fall victim to intentional manipulation by a few influential traders. Also, some participants may have more domain knowledge regarding specific tasks. For example, in software projects a database developer may have insight about an upcoming change to the database management system that will affect the completion of the project that is not known by the rest of the development team. Such unique knowledge or insights can be reflected in trading behavior that captures new or additional information quickly and the results may influence the market outcomes.

Trader Behavior

Trading behavior can be characterized by the strategies bidders choose, their level of engagement or participation, and how truthfully they trade. Trading truthfully implies that the bids posted reflect the bidder’s true beliefs. Trader

characteristics, market characteristics, access to external information, and market design all play a direct or indirect role in influencing the behavior of market participants. Additionally, traders also react to market outcomes and market outcomes are in turn influenced by trading behaviors. In any market, traders react to current valuations of contracts, especially in comparison with their own valuations, in order to decide whether a buying or selling opportunity exists.

Future studies can attempt to identify the various trading strategies adopted by participants and what effect they have on market outcomes. Likewise, we need to discover what engages traders to actively participate in the market and the result of differing levels of participation on individual successes and overall market accuracy. Trades should represent the participant's true beliefs. We need to investigate if bidders are behaving rationally when trading in effort estimates or other outcomes. Does the level of trading translate directly into accurate market forecasts? To what degree do individual errors influence the voice of the market? Are trader values more elastic when predicting outcomes of future events as compared to purchasing a material good or service? How are changes in task scope and variability in the environment captured by the market?

Market Design

The role played by information market design features is another important research area. Choices made by market developers during the design of the market mechanism may have a direct effect on trader behavior as well as moderate the effects of individual trader characteristics, market environment, and organization characteristics. We have identified six design considerations: 1) payoff mechanisms; 2) feedback instruments and notification frequency; 3) methods to aggregate the trading activity; 4) the level of anonymity afforded to traders; 5) the determination of market closings; and 6) the basic features, functionality and appearance of the market.

For information markets to be successful contracts must be clear, easily understood, and easily adjudicated. As participants buy and sell contracts in a market, the price of the individual contracts forecasts the probability of each event occurring [Berg et al. 2001; Malinvaud 1974]. This equilibrium property of information markets acts as an opinion-aggregation mechanism, with supply and demand principles illuminating the group consensus. The feedback provided by the prevailing market prices of the contracts allows bidders to learn from the actions of other traders and possibly modify their initial estimates. This concept is well defined in the literature on common value auctions [Kagel and Levin 1999; Rothkopf and Harstad 1994, Dyer and Kagel 1996]. Wolfers and Zitzewitz [2004 pg. 125] suggest that prediction markets "provide three important roles: 1) incentives to seek information; 2) incentives for truthful information revelation; and 3) an algorithm for aggregating diverse opinions."

A market must provide some motivation to induce truthful trading behavior. Market participants must have the proper incentives to fully engage in the market, as well as to trade in a forthright manner. That motivation is normally in the form of a monetary payoff. Payoffs can be real money or virtual currency. The "real-money" markets follow the principle that forecasts will be better if traders risk their own money. However, due to regulatory issues mainly surrounding state prohibitions on gambling, many commercial information markets have adopted the concept of virtual currency in which participants are awarded prizes or other intrinsic rewards rather than legal tender. Servan-Schreiber et al. [2004] compared the accuracy of information markets with real-money and virtual currency payoffs and found no difference. Their conclusion is that real money is only one of many possible motivators such as the thrill of competition, reputation and community bragging rights, or prizes for the best forecasters. There are a number of potential payoff functions that can be applied to the market. For example, participants can be rewarded for holding the most winning contracts. Other payoff methods can be based on the amount of credits (or monetary units) a participant has accumulated (the participant's bank). One such method, referred to as the winner-take-all method, specifies that the payoff for owning a share of the winning contract at the close of a market is always a dollar ($1.00). By using this strategy, we can interpret the prices of contracts as the probabilities that it will be the most likely outcome at market close [Jørgenson 2004]. Thus, a participant's payoff is depicted in Equation 1:

$$\sum_{b=1}^{B} (\$1 - p_{v^*}^{b}) S_b \qquad (1)$$

if a participant owns any contracts in v* at market close and 0 otherwise. Where:

B is the set of contracts bought in outcome *v**;

$p_{v^*}^{b}$ and S_b are the price and number of shares in any contract purchase of *v**.

A participant will incur a loss equal to the amount they paid for shares in non-winning contracts.

$$\sum_{b=1}^{B} (p_{v^*}^{b}) S_b \quad . \qquad (2)$$

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The participant's bank is adjusted by Equation 2 and participants are either rewarded for having the largest bank or given a monetary reward that is some fractional percentage of their bank.

Payoff functions are designed in conjunction with incentives to participate in order to reward traders, both intrinsically and extrinsically. Research needs to be conducted to test the difference between real and play money rewards in the new business problem domain [Servan-Schreiber et al. 2004].

We expect that feedback mechanisms, such as email alerts of changing market conditions, may have a significant impact on trader behavior. Additionally, creating innovative new feedback artifacts may prove to be a fruitful area to investigate. Similarly, the design of algorithms that summarize and transform trading activity into information that can be provided as feedback to both traders and sponsors has limitless potential (and is represented explicitly in Figure 2). The prevalent data generated by the market can show trends, the degree of consensus among participants, and much more.

The influence of the level of anonymity afforded to traders must also be explored. This is especially important in markets within small business units in which traders may be influenced by their close association with other traders. It may be difficult to maintain independence in the market and/or minimize impacts on trading if there are influential cultural factors like power distance that arise if participants are known to one another.

Market designers must choose how to accommodate unique aspects of the different tasks being predicted in the various market types. Estimation markets present new challenges with regard to trading interfaces and other issues such as extensibility. If there are no discrete outcome options available for trading, the market interaction becomes more of a selection of points along a continuum. The issues to be researched include the development of engaging human-computer interfaces that support these types of actions, how to handle potentially infinite points along the continuum, and how to allow the trading range to be expanded or reduced while the market is active. Should there be more general long-term estimates with closing dates well in advance of the projected contract or should the close be dynamic? How do you account for scope creep in the choice of contracts? Should additional contracts be added to the market if it appears that the original contracts are no longer valid or as early estimate dates expire? In most cases the alternatives are known at the start of the market. However, one interesting challenge is to provide mechanisms for adding alternatives while the market is active. It is quite natural for critical information to change during the course of a market. For instance, injuries to key players may dramatically affect the prospects of a team winning a specific game. At times it is not information about an existing outcome, rather a completely new alternative that must be evaluated. What happens if a new candidate enters an election? The new outcome may be simple or complex, but some method of adding the alternative to the market in a fair and equitable manner must be provided. In other words, markets may be designed to be extensible. The challenge is to decide who can add new alternatives, how should traders be notified, and when should trading be opened?

Idea markets also require unique design considerations. One challenge is ensuring the adequate description of each alternative. How is the quality of the representation to be judged prior to an offering in the market and how should modifications be handled once trading has commenced? How are new offerings entered into the market, traders notified, and trading started or suspended in an equitable manner? How are shareholders compensated if an idea is withdrawn? Another potential problem is determining if two ideas are the same. Market participants may use very different approaches to describe similar ideas. How should these potential conflicts be detected and resolved? How should the voice of the market be interpreted if two similar ideas are valued very differently? Again, there are many human-computer interface issues and market administrative policies that would be fruitful areas for research.

Finally, the design of the trading interfaces is critical and can draw on the many ways of organizing markets, such as auctions, private exchanges, or more complex arrangements, such as the various financial exchanges. Whatever the market organization, the appropriateness of the trading interface will directly affect participation. Interface issues can be even more important in the information market arena, because participants are casual traders, not professionals whose livelihood is linked to market use. The type of information market also places different demands on the interface, from the ease with which someone can execute a trade to the analysis of current market conditions. In addition, any markets that require dynamic changes to the choices will require much more involved administrative capabilities.

Market Outcomes

The ultimate goal of using a market is to gain knowledge regarding the consensus of the participants. This consensus is what Surowiecki [2004] refers to as the "wisdom of the crowds." The voice of the crowd, or market, is the price of the representative contracts. Ideally, these prices should predict the true outcomes. One of the most difficult challenges in using information markets is determining exactly what the market is saying, because there are

many ways to aggregate the trading behaviors and prices [Pennock et al. 2001]. Plott and Chen [2002], used a volume-weighted price average (VWPA) to determine the most valuable contract and a single estimate: the voice of the market. The volume-weighted price average was calculated for each contract (c_i) in a market with a set of contracts (C). Let q_j be the quantity of contracts purchased and let p_j be the price (the number of credits paid for each contract) in a single trade (t_j). The total cost of any trade is then $p_j q_j$. Finally, the VWPA (v_i) for each contract is found by summing the cost of all trades in a contract over the sum of the share quantities (as shown below).

$$v_{c_i \in C} = \frac{\sum_{t_j \in T_i} p_j q_j}{\sum_{t_j \in T_i} q_i}$$

C – set of contracts in the market
c_i – the i^{th} contract in C
v_i – the volume weighted price average for contract c_i
T – set of trades in the market
T_i – set of trades involving contract c_i $(T_i \subseteq T)$
t_j – the j^{th} trade in T
p_j – price per share in trade t_j
q_j – quantity of shares in trade t_j

As noted earlier in the market design section, additional data can be collected and manipulated to provide insights into participants' beliefs such as the volume, velocity, and bid ask spread of trades. Each of these variables can be viewed at intervals or as they trend over time. The activity or volume of trades may indicate the popularity of an estimate. Looking at the spread between pending bids and asks could be interpreted as the level of (dis)agreement between participants' expectations. A longitudinal review of the trade/bid/ask history can display the belief trends. The interpretation of the data provided by an electronic information market is unlimited. For prediction markets that are verifiable, market performance can be measured by accuracy: how closely the voice of the market matches the actual result of the event or estimate. For the unverifiable markets (decision and idea markets), the determination of the voice of the market, and what constitutes activity and market performance will be somewhat different from the verifiable markets. For the decision markets, the voice of the market will be the price of alternative choices, similar to that for the event market, to identify the single desired choice. For the idea markets, these prices will be rank ordered to distinguish the more valued set of ideas from those that are less valued. Activity in idea markets is measured by the number of ideas generated, not solely by the number of trades, which is enabled by a market design that allows dynamic extensibility. Finally, the market performance of both decision and idea markets are measured via subjective assessment, since no actual real world outcome is available for comparison. In fact, in the decision market, the purpose is to create the real world outcome (i.e., decide what to do).

IV. RESEARCH PROPOSITIONS

As discussed earlier, the information market research landscape is rich and varied, and there are many areas that need investigation. In the following section, we present an example of research propositions related to each of the constructs in our model. See Table 2 for a summary of the key constructs. The propositions demonstrate how specific research projects can continue to contribute to our understanding of information markets.

Table 3. Summary of Propositions

High Level Constructs	Proposition
Trader Characteristics	Proposition 1: The economic culture of individual traders will impact their trader behavior
Organizational Characteristics	Proposition 2: Organizational incentives to participate will impact the amount and quality of trader participation in the information market.
Market Environment	Proposition 3: In idea futures-type information markets, market diversity and number of participants will impact market performance (number and quality of ideas generated).
External Information	Proposition 4: When new, external information is available to all market traders, those traders will differ in how that new external information impacts their trading behavior.
Market Design	Proposition 5: Idea markets designed for anonymous trading will generate more ideas and greater participation than non-anonymous idea markets.
Market Outcomes	Proposition 6: The best method for determining the voice of the market will vary by type of market.
Market Outcomes	Proposition 7: Software cost estimation using information markets will be more accurate than existing methods of cost estimation.

Proposition 1: The economic culture of individual traders will impact their trader behavior.

Baumol at al. (2007) and others recognize that although most of the world's nations have now implemented capitalism as their economic system, there are dramatic differences between types of capitalism. Given that information markets are built on an information corollary to financial markets, it is unlikely that individual traders who have only experienced their nation's particular form of capitalism will view the market in the same way, and participate in the same way. For example, if individuals have only experienced the kind of state-guided or oligarchic capitalism described by Baumol et al. (2007), then those individuals may view markets as less free and expect market results to be dominated by established powers. This will certainly affect global markets, such as international software development teams and the advantage of geographically dispersed participants.

Proposition 2: Organizational incentives to participate will impact the amount and quality of trader participation in the information market.

As discussed earlier, organizations vary in how they use incentives to participate in information markets. However, it is currently unknown how these incentives operate, both initially and over time. Research in this area can leverage the large body of research on incentives from organizational behavior, and in particular, cognitive evaluation theory, which has found that tangible rewards that are contingent on performance can undermine an individual's existing intrinsic work motivation [Deci et al. 1999], as well as reduce cognitive flexibility in problem solving [McGraw and McCullers 1979] and performance on complex tasks with difficult goals [Erez et al. 1990]. In some settings, it may be better to allow individual's intrinsic motivation to foster market participation.

Proposition 3: In idea futures-type information markets, market diversity and number of participants will impact market performance (number and quality of ideas generated).

In prediction-type information markets, it is known that even small numbers of participants can result in acceptable performance [Chen et al. 2001; Ortner 1998; Plott and Chen 2002]. Regardless of the number of participants, diversity in the market *is* needed, in order to get variation in ideas and beliefs [Surowiecki 2004]. It is unknown how these two market environment characteristics impact market outcomes, individually and as an interaction, in idea futures-type markets. This is particularly important because market participation does have a cost in terms of employees' time to consider the new ideas of others and create their own ideas. At GE, employees who did not participate as well as those who did not participate very often cited as the main reason "not enough time" (73 percent for non-participants, 82 percent for low-participants) [LaComb 2007]. Knowing how many participants and which participants are typically needed for good performance outcomes would be an important help in market design.

Proposition 4: When new, external information is available to all market traders, those traders will differ in how that new external information impacts their trading behavior.

It is known that individuals are biased in their processing of information [Tversky and Kahneman 1974]. For example, individuals may falsely believe that their preferences are widely held. A particular bias of interest to information markets that operate over time concerns how individuals process new information in light of the prior impressions and judgments. Currently, there is debate over the effects of assimilation (individuals are more influenced by and process more completely new information that is consistent with prior belief) and contrast (individuals are more influenced by and process more completely new information that is inconsistent with prior belief). Research in a variety of settings provides support for both effects (e.g., Foti and Hauenstein [1993] in the performance evaluation context); thus, the information market provides an ideal context in which to explore this issue.

Proposition 5: Idea markets designed for anonymous trading will generate more ideas and greater participation than non-anonymous idea markets.

The prime motivation behind idea markets is to support brainstorming by as many people as possible, so that all possible ideas, in particular those that represent "out of the box thinking," are raised. Anonymity as a design feature can minimize trader fear of retribution for expressing or valuing ideas that go against the status quo [Hanson 2006]. However, in groups with communication channels outside the market, identity information may be shared (as in the case of the GE Imagination Market [LaComb et al. 2007]). As mentioned earlier, this may be particularly important in settings in which traders are from high-power distance cultures, in which individuals are likely to be more deferential to those with higher rank in the organization [Hofstede 1991, 2001].

Proposition 6: The best method for determining the voice of the market will vary by type of market.

As noted earlier, the best way to determine the voice of the market is a key challenge for the use of information markets. There is considerable variety in the information markets currently in use in organizations. In a prediction market used at Best Buy, a common approach was taken: the price of shares were restricted to between $0 and $100 dollars, and the current stock price in a prediction was interpreted as an estimate of the probability of that prediction [Dvorak 2008]. In the idea market used at GE, another common technique, volume-weighted price was used to rank ideas, but those rankings were no better than leaders' expert ratings and rankings [LaComb et al. 2007]. In an event market in which there are established, discrete choices, as in the presidential election markets, the voice of the market is the percentage of total number of choices made.

Proposition 7: Software cost estimation using information markets will be more accurate than existing methods of cost estimation.

In this research area, there are also important research questions related to the use of information markets in the IS context. For example, Hastie [2001, p. 666] notes that the phenomenon of unrealistic optimism operates in only two contexts, and one of them is "judgments of cost and time to complete future multi-component projects." Effort estimation in software development may benefit from the predictive ability of information markets, with both event markets and estimation markets being reasonable tools. The software industry has a long history of inaccurate or inadequate estimation of the amount of effort required to complete projects. The Standish Group has tracked software projects for the last two decades and their findings are dismal. Their 2006 CHAOS report indicates that only 34 percent of software projects succeed, 51 percent came in late, over budget, or without the required functionality, and 15 percent failed – cancelled or finished but never used [Standish Group International 2006]. Similarly, the Meta Group estimates only a 28 percent success rate [McBride 2005].

Experiments using groups of experts have resulted in more accurate and less biased estimates than single-expert estimates [Jorgensen and Molokken 2004]. This same idea, harnessing the collective minds of many experts, is the driving force behind the Delphi method. Information markets provide a way to assemble the various opinions and judgments needed into a single estimation. The Milestone Market (www.MilestoneMarket.org) is a prototype project management market built at the University of South Florida. The market is being used to experiment with many of the research areas discussed in this paper, including the proposition that information markets are better than existing software cost estimation methods, especially over the life of a project.

One of the markets used at Best Buy in 2007 and 2008 illustrates the usefulness of a market over time in project estimation. In this interesting example, the likelihood of meeting the deadline began in December 2007 at 50 percent (share price at $50), but by late January, the share price fell as participants realized the difficulty in meeting the deadline. In response to the market value of the deadline-meeting contract, Best Buy revised its rollout plan, and by late February 2008, the share price of that contract had risen to $88.59, reflecting high confidence in meeting the project deadline [Dvorak 2008].

V. CONCLUSIONS

This paper focuses on the emerging area of information markets that can be used to support large groups of geographically dispersed decision makers. Information markets allow participants to buy and sell alternative outcomes in an effort to aggregate the diverse opinions of all participants. These market-based decision-making technologies have the potential of democratizing many decision-making activities, allowing highly diverse and widely dispersed participants. The idea that a potentially large collection of individuals can outperform a few specialized experts is still a somewhat radical proposition. However, there does seem to be many areas in which expertise has limits. In fact, information markets bring the "centralized planning" versus the "invisible hand" to the realm of decision making. While there are certainly areas that seem better suited to individual experts, information markets and the wide-ranging information gathering activities of participants can be applied in many situations.

The information market typology presented at the beginning of the paper (see Figure 1) organizes several different forms of market by the type of decision problem. Prediction markets, both discrete event-based markets and estimation markets, focus on forecasting events that can be verified once the actual event occurs. Decision markets are often used to choose among more complex alternatives and idea markets provide a market-based brainstorming environment. Each of these markets require different mechanisms and trading interfaces for successful application.

In addition to the market typology, the key constructs in the information market research topology (Figure 2.)—individual trader characteristics, organization characteristics, market environment, external information, market design, trader behavior, and market outcomes—are identified and discussed. These constructs and their relationships will vary depending on the information market context or application. A few research propositions are

presented that describe how the research landscape model can be used to guide work on information markets. These propositions include those directed at market technology design and applications in the MIS context, such as software cost estimation. Information markets promise to bring a new perspective to many decision-making tasks. A better understanding of trader characteristics, group dynamics in markets, and market design can help further information market applications.

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