

## **Information Markets: A Tool for Effective Decision Making**

Society's economic, corporate, and public policy decisions are often times influenced by the advice and discretion of experts. The decisions making process involves making predictions about the underlying uncertainty that surrounds the social issue at hand. Differences in research methods, facts, beliefs, and values bring about the variety and differences in opinion amongst a group of experts or decision makers. For the non-expert who is often times presented with a plethora of expert opinion, deciding who to believe or weighing all the opinion may not be an easy process. Economists believe that financial markets do a good job in aggregating information in part because they provide the participants with strong incentives to form good predictions. Prices of oil futures predict spot prices well because traders have the incentive to make money. Speculative markets perform relatively well when compared with information institutions (academia, news media, experts, etc) in terms of their information aggregation and prediction accuracy when presented with the same situation or environment. Some examples may include Florida Orange juice commodity futures which have improved on government weather forecasts (Roll, 1984), betting markets that have beaten major national opinion polls 451 out of 596 times in predicting U.S presidential election results (Forsythe, Nelson, Neumann, and Wright, 1992), and betting markets that beat out Hewlett Packard official forecasts 6 times out of 8 at predicting the computer corporation's printer sales (Chen & Plott, 1998; Plott, 2000). So why not incorporate such markets in areas of public choice in order to facilitate societal decision making? Markets may be able to aggregate expert opinion in ways that help people form beliefs of

the likely consequences of certain decisions. Economist Robin Hanson expresses the view that in a democracy, we can say what we want, but speculative markets tell us how to get what we want. “Information Markets or Prediction Markets”, which are gradually evolving into a new form of financial market, involve the trading of state contingent securities. Participants trade in contracts whose payoff depends on unknown future events. Until the outcome of the event becomes evident, the current price of the contract represents the trader’s aggregated consensus on the likelihood that the event occurs, which in turn is proportional to the probability that the actual event will occur. For an example of how an information market operates, we consider a simple market with a “winner takes all contract,” where the contract costs some amount  $\$p$  and pays off,  $\$1$ , if and only if a specific event ‘B’ occurs, i.e. Bush wins the 2004 elections. So it will pay off  $\$1$  if Bush wins the election and nothing otherwise. Since the expected value of “Pays  $\$1$  if B” is  $\$p(B)$ , then someone who buys this asset for  $\$0.70$ , can be interpreted as saying that the chance that Bush will win will be at least 70%. And a market price of  $\$0.70$  can be interpreted as a consensus that the probability that Bush will win the election is approximately 70%. Today, many electronic prediction markets (for profit and non profit) are set up to enable traders to test their knowledge and hunches by tying their investments to a wide range of uncertain events of the future. Events include academy award Oscar winners, box office returns, sporting game outcomes, stock prices, interest rates, political party presidential candidate nominees, and more. The possibilities seem endless and the application of prediction markets to support decision making in other arenas are currently being formed. Prediction Markets tend to perform better than group deliberations, opinion polls, and expert prognostications because they provide greater

incentives for traders to find ways to become more informed about an uncertain event through inciting a traders' motivational drive and involving a his or her monetary risk. Tied to this explanatory factor, is the market design in which the identity of traders are unknown amongst each other; such a quality promotes the kind of truthful revelations that contributes to the generation of accurate predictions. Furthermore, market makers among the trading population (those with the best information and who execute the most trades) eliminate the influence of unknowledgeable traders or traders who possess standard biases; the effect of these traders often taint the predictions made by a group. If the best kinds of decisions are made possible through the elimination of the uncertainty that surrounds the decision, then Information Markets should be utilized to support important societal decision making for this very reason. Nevertheless, certain limitations still undermine the viability of these markets in the real world while necessary and important market design issues should be considered in regards to the effectiveness of these markets. The paper will first address the connotations of the power of the market and price to reveal information. The issue of a market as a better organizer of information will be discussed and supplemented with an example in experimental economics of how a market can both aggregate and broadcast information. The paper will analyze the explanatory factors that contribute to the accuracy of these markets and illustrate an example of the application of the use of a prediction market in the corporate world. These results will be compared with the prediction accuracy of a group of experts where such factors are not present.

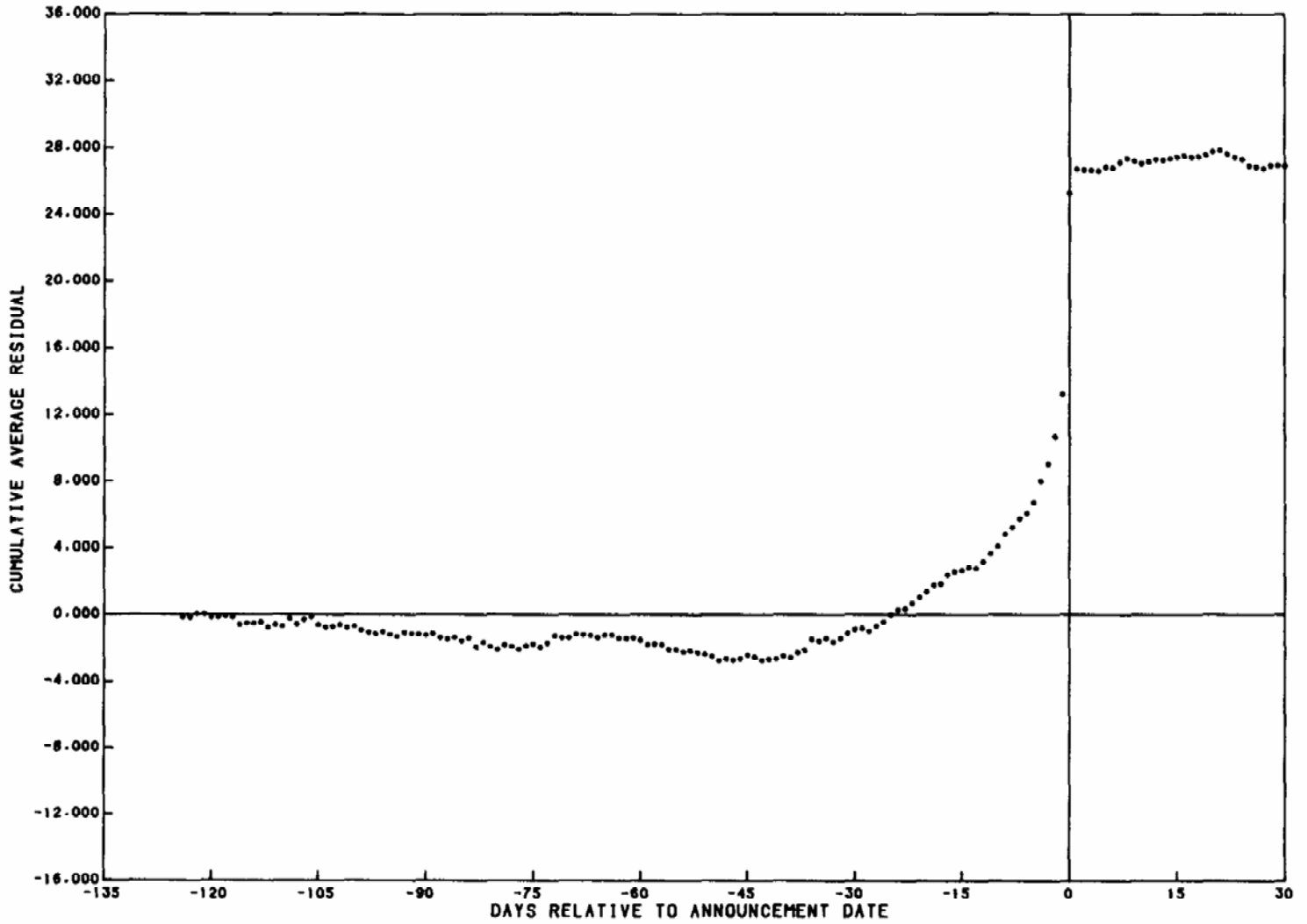
The idea behind the prediction market is based on the notion that a marketplace is a better organizer of insight and predictor of the future than individuals are. The efficient

market hypothesis supports the concept that market prices incorporate all the available information about the security. When markets attract a large amount of participants, prices can reflect the total collective disparate information of the masses. Even non participating members can stand to benefit from observing market signals reflected in the price. Economists have long held onto the belief, in theory, that in a properly designed market, the prices reflect the collective information possessed by all the traders about unknown future events. In regards to stocks, any public available information that might be used to predict stock performance, including information on the macro economy, the firm's industry, and its operations, plans, and management, should already be reflected in the stock prices. As soon as there is any information indicating the stock is under-priced and offers a profit opportunity, investors flock to buy the stock and immediately bid up its price to a fair level, where ordinarily rates commensurate with the risk of the stock can be expected again. But if prices are bid immediately to fair levels, given all available information, it must be the case that the new information causes the up and down movements of the price. Based on the theory, new information must be unpredictable for if information were predictable, then that prediction would be part of the available information impounded into the price of the security. Arthur Keown and John Pinkerton studied the impact of takeover attempts on the stock prices of 194 firms. Keown and Pinkerton plotted the cumulative abnormal return percentage to the days relative to the announcement date of the takeover. The results show that the prices jump dramatically on the day the news becomes public. However, there is no further drift in prices, after the announcement date, suggesting that prices reflect the new information, including the

likely magnitude of the takeover premium, by the end of the trading day (Keown and Pinkerton 1981). [See graph 1]

The theory of rational expectations equilibrium accounts for the strong-form of the Efficient Market Hypothesis where security prices reflect all information relevant to the public as well as information known to insiders. The rational expectation theory posits that prices are not only coherent, but also reflect the sum total of all information available to all market participants. Even when some agents have exclusive access to inside information, prices equilibrate exactly as if everyone had access to all information. The procedural explanation is that prices reveal to the ignorant agents any initially private information; that is, agents learn by observing prices. Several authors show that, if agents begin with identical priors and disparate evidence, repeated observation of some aggregate statistic (e.g., price) will converge to a consensus on posteriors, for various sufficient statistics. A possible methodology for the prediction of future outcomes is the construction of markets where the asset is information rather than a physical good.

Graph 1



Source: Keown, AJ and Pinkerton, JM, "Merger announcements and insider trading activity: an empirical investigation," *Journal of Finance*, 36(3):855-869. (1981)

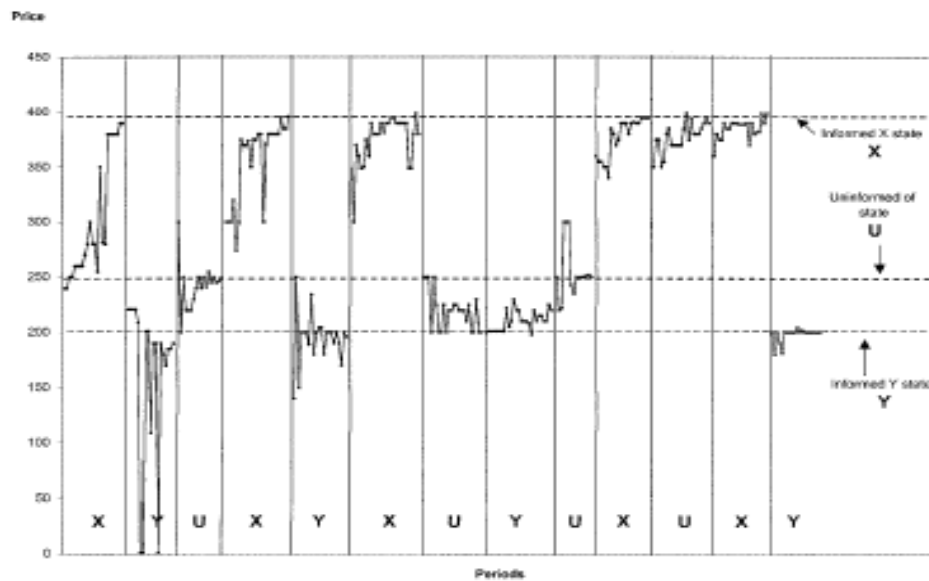
*Markets Broadcast and Aggregate Information*

Since people tend to interpret market behavior as having anticipated future events, certain movements in the stock market can serve as an indication about the likelihood that the Federal Reserve Board will change interest rates, a company will have a good earnings report, the government will approve of a new product to market, or a company will undergo a merger or buyout as among other unpredictable events. These examples are derived from theories of market equilibrium which includes the rational expectations theory of information propagation where participants maximize their respective expected utilities in terms of consumables or monetary equivalents. For instance in the stock market, the individuals who hold bits of important information, or the “insiders” tend to signal their register their particular beliefs through their security trading activity in the market. The market as a whole collects and aggregates all the privately held and otherwise highly decentralized information. The design of processes that would enhance the properties of this concept is what economist Charles L. Plott calls an Information Aggregation Mechanism (IAM). Laboratory experiments have been set up to verify whether a market based mechanism can aggregate decentralized information so as to produce accurate forecasts on uncertain events. Plott conducted an experiment that shows how markets can potentially collect and broadcast information. Plott considered two states of the world X and Y in which a single asset pays according to which two states of the world occurred. All market participants were endowed with units in each period as the economy proceeds in a series of days or “periods.” Information about the state may be distributed and trading takes place until the true state of the world is announced. As soon as the trading session ends in each period, dividends are paid and the

securities are then discarded. 200 units were designated to be the dividend if the true state turned out to be Y and 400 units if the true state turned out to be X. The probabilities associated with these two states were 0.75 and 0.25 respectively. Before each trading session begins, insider information was distributed and each participant received a piece of paper that was either blank or had the true state of the world written on it. A 50-50 random event determined the case as to whether insider information existed or not. So if it happened to be the case that a random event determined that there was no insider information, all participants would receive a blank piece of paper and each individual would not know whether such insider information existed or not. If it was the case that a random event designated that there was insider information, then a certain number of the participants would be given that private information. In this case, the participants who received the insider information would know that insider information existed and would also have knowledge of the true state of the economy.

Theoretically, if the true state of the world was X and everyone knew this, then the price of the security would be 400. Similarly with the public knowledge of the true state being Y, the price of the security would then be 200. If there were no insiders and everyone knew that insider information did not exist, then the price of the security would be the expected value of 250. It turns out that out of the eleven periods, the prices quickly adjusted to the equilibrium price as if everyone knew that insiders existed and everyone knew the true state of the economy. However, in the last period, the price adjusted to the high dividend price and suggested that the true state of the economy was X when in actuality, there were no insiders and no one knew that there were no insiders. In period eleven of this experiment, the market made a wrong prediction. [See Graph 2].

Graph 2



Source: Plott, Charles, "Markets as Information Gathering Tools," *Southern Economic Journal* 67(1):1 – 15, (2000)

This experiment demonstrates that markets do have the capacity to publish and broadcast the important information in which only a select few of the traders possess. Uninformed traders do not necessarily negatively affect the predictive accuracy of the overall group because such traders sense the price signals that are a result of the informed trader's trading activity and base their own trading activity accordingly. However, this experiment also demonstrates that markets are not perfect and can also make mistakes as in the case of the last period of the experiment. Carmerer and Weigelt (1991) show that even in situations without insider information, trading patterns sometimes are similar to the patterns perceived in the case where such information existed because some traders believed that others had private information. So it is not a necessary condition for the existence of insiders to move asset prices. In another similar experiment conducted by Shyam Sunder, Sunder finds that with just the convergence of the prices of three traders

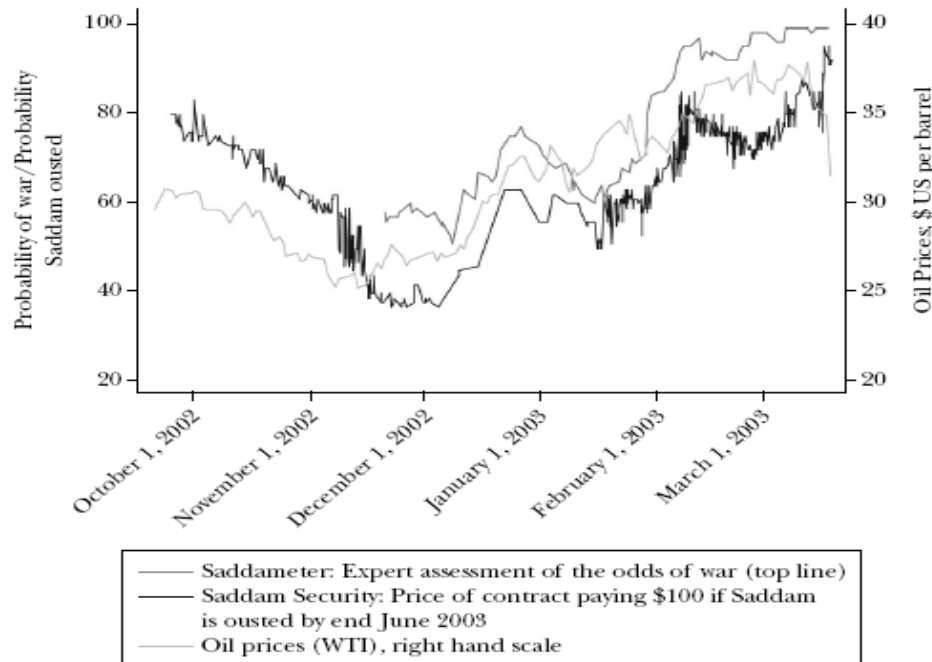
to the wrong price, the market ended up making a wrong revelation about the true state of the world being X instead of Y. These cases have important implications for market manipulation and issues of market design, which will be addressed later in the paper.

### *Market Makers*

The previous experiment demonstrates the ability of prices to signal the trading activity of informed traders. One factor that contributes to the explanation of why prediction markets are relatively accurate in their predictions is because the most informed traders are often the ones who drive the market and send out the price signals to the other traders. Many information markets are based around topics that are widely discussed and debated in society. Typically, since human sources of prediction place a lot of weight on the opinions of experts relative to ordinary people, one may assume that betting markets in turn, place too much weight on ordinary people relative to experts. However, this is hardly the case; if anything, the judgments of individual participants in betting markets are highly influenced by expert and public opinion. In fact, a tendency to place too much weight on the advice of experts, both public and private, is often a characteristic associated with Speculative markets (Lichtenstein, Kaufmann, and Bhagat, 1999). The Saddam Security once offered on Tradesports illustrates this concept. The contract paid off \$100 if Saddam Hussein was ousted from power by the end of June 2003 and nothing otherwise. The figure below shows that the price of this particular contract co-moved with two other measures, that of expert opinion (represented by an expert journalist's estimate of the probability of United States going to war with Iraq) and oil prices.

Graph 3

**The Saddam Security**



Source: Wolfers, Justin and Zitzewitz, Eric, "Prediction Markets," *Journal of Economic Perspectives*, 18(2), Spring (2004)

The inconsistency gap thus expands and we are further led to consider how speculative markets perform relatively better than information institutions when they are both influenced by the same fallible human sources. Certain standard biases exist that affect traders' decision making are commonly associated with events such as the expectation of a favorite sports team or political candidate winning a championship or election respectively, as seeing that team's dominant appearance in the news media or that particular candidate winning debates. However, the influence of such traders may in fact be negligible when we consider those other traders labeled as "Market Makers" who invested twice as much, traded more, earned higher returns, and made one sixth as many

errors, and were also found to be unbiased on average. Market Makers were the ones who made offers that others accepted instead of accepting the offers made by others. As a group, they tend to be more highly educated and experienced at trading (Forsythe et al., 1992; Forsythe, Rietz, & Ross, 1999). If Market Makers exert such an influence and prediction markets are relatively accurate, it must be the case that accurate predictions can emerge even in circumstances where a small percentage of traders have good information. This can be demonstrated through the Iowa Prediction Markets. It turns out that 85% of traders who participate on the exchange do not seem to possess good judgment. These traders tend to hold onto their shares for a long time and simply accept someone else's offering price. The actual predictions of the markets however, are actually driven by the 15% of the group who are the so called market makers. Market makers know that they possess better and more accurate information and are thus more willing to bet on it. Betting markets tend to beat opinion polls and other competing institutions due to the disproportionate influence that these highly, rational, and experienced traders have on these markets. Hence, information markets do not require a majority of its traders to possess good information in order to make accurate forecasts. In this context, information markets have an advantage over group deliberations.

### *Incentives*

Another advantage that information markets possess is that they are more likely to provide a sufficient level of motivation to align the trader's incentives to the goal of the information market, which is to make the most accurate prediction. A common understanding in the literature of Prediction Markets of why these markets work so well

is because they enable the participants to “put their money where their mouth is” (Hanson 1999). The implication is that when a participant bets on an uncertain event in a prediction market, he or she takes on some form of monetary risk which eventually leads this individual to make a better forecast than someone else who faces no such financial risk. The underlying assumption is that the participant, who willingly takes on the financial risk, has more of an incentive to conduct research and maximize his or her ability to become informed about the event. Information Markets provide incentives for people to be all the most truthful in their revelations, generate incentives toward in depth research and information discovery, and provide an algorithm for polling opinions. For an individual to participate in a real money prediction market, this individual most likely has good confidence in his or her knowledge and intuition and executes his trades according to his rational judgments. In the experimental economics community, there is a prevalent belief that monetary risk is required in order to obtain valid conclusions about economic behavior.

*Implications for non-monetary rewards*

Economists Servan-Schreiber, Wolfers, Pennock, and Galebach (2004) delve deeper into the topic comparing the accuracy of real money prediction markets and play money prediction markets. They point to the fact that in real money prediction markets, the weights given to a person’s opinion is directly related to how much the individual is willing to bet, which in turn may be correlated with the individual’s wealth. Individuals are also believed to bet on uncertain events that they are more confident about. These two factors may potentially lead to inefficient opinion weighting. The economists compare

the accuracy of two online sports trading prediction markets, one a real money prediction market and the other a play money prediction market. They observe the predictions made on Tradesport.com, a real money sports gambling market and Newsfutures.com, a play money prediction market where registration is free and a small amount of play money is allocated to traders that fall under a certain net worth. Servan-Schreiber, Wolfers, Pennock, and Galebach pose the question of how much accuracy is lost when utilizing a play money prediction market as opposed to one that that operates with real money when making predictions about uncertain events. It should be noted that whereas players face no financial risk when partaking in play money prediction markets, players are provided with incentives in the form of prizes, cash, psychological satisfaction, bragging rights, and etc. Also, with most of these for play money prediction markets, players build their wealth through their reputation of accuracy. For example, the players with the highest play money net wealth are invited to bid on a few real prizes worth a few hundred dollars, offered through auctions at the end of each month. To compare the forecasting abilities of the two markets with individual humans, the economists also participated and entered the trading prices of the two prediction markets into a popular internet prediction contest where contests were structured around predicting the probabilities of certain team winning their games. The economists found that both types of markets had nearly the same predictive ability in accuracy (they compared the respective average percent of the exchange's favorite games won with the average pre-game prices for each of the exchange's favorites and found the numbers to be quite similar). Neither market performed systematically better than the other market across 208 experiments.

However, it should be noted that both markets' predictions performed remarkably well when compared to individual predictive abilities ranking 6<sup>th</sup> and 8<sup>th</sup> in a competition with 1,947 participants covering more than 200 NFL football games. Also, the predictions easily outperformed the average assessment of the "experts." The economists argue that knowledge and motivation are the primary factors that are responsible for the accuracy of prediction markets, and the use of real money is just one of the different ways to provide knowledgeable individuals to trade and find ways to become more informed.

### *Anonymity*

In private and public institutions, group deliberation is the means of aggregating information. An increase in accuracy serves as the underlying justification for the use of groups instead of individuals to make forecasts and decisions. However, groups often times excel as good estimators and judges under limited circumstances. This may be due to the fact that groups performing tasks that are not easily demonstrable tend to perform at the level of their average members (Sunstein, 2004). The statements and actions of some group members convey relevant information and that information leads other people to not disclose what they know. Social pressures may be imbedded into the psychological mindset and hence actions of a groups' individual members. Some group members may feel the need to silence themselves when their own ideas and findings are inconsistent with that of the group's members who are imposing such pressures. Group deliberation often times leads to unfortunate consequences such as the propagation of errors, group polarization, and cascade effects. Information Markets are less susceptible

to the pressures that make deliberating groups err because they are more effective at pooling information. A central advantage in information markets is that they impose the proper incentives for people to disclose the information that they hold and in turn the individual's private information becomes incorporated in the pricing signals of any particular contract. The anonymity aspect imbedded in the design of information markets prevents detailed trades and individual investments from being disclosed. Traders do not feel the informational pressures imposed by others when they buy contracts for a specific political candidate to win or when betting on the sales of a certain product. For instance, employees within the company's sales team may have incentives to outwardly predict a lower than expected sales target to enable them to increase the probability of beating their expected forecasts in the future when bonuses and performance based pay are implemented within the company's pay structure. Company meetings and employee surveys can thus serve as an inefficient approach in regards to forecasting due to problems associated with incentives, proper methodologies for aggregating disperse information, and insignificant amounts of information in one location.

### *Application and Evidence*

Prediction Markets became highly publicized in the public policy arena during July 2003 when the Defense Advanced Research Projects Agency (DARPA), a research tank within the department of Defense proposed a project that would set up a Public Policy Analysis Market that would allow traders to bet on specific future outcomes of economic health, military disposition, international relations, and etc. The idea behind this concept was to analyze how effective trading on such political contracts would help

predict future events. The project caused uproar when the agency proposed the concept of trading on the likelihood of terrorist acts. Not only did people and politicians alike feel the subject area morbid, the market may have not been able to work since the an idea was raised that the prices may have the potential to inform the terrorists of government security plans while terrorists themselves could profit off of their own insider information by manipulating the market. Yet still, a number of successes surrounding prediction markets have generated interests in its use in less controversial political and private sector areas. In the entertainment/corporate context, Pennock, Lawrence, Giles, and Nielson (2001) found that the security prices of Oscar, Emmy, and Grammy awards on the Hollywood Stock Exchange (play-money information market) correlated well with actual award outcome frequencies. The economists demonstrate that the predictions made by the Hollywood Stock Exchange regarding Oscar winners were as accurate as a panel of expert forecasters.

The idea of markets operating within companies has started to seep out into some of the nation's largest corporations. Companies from Microsoft to Hewlett Packard and Eli Lilly have developed information markets with workers trading futures on commodities such as revenue, product demand and success, supplier behavior, and etc. Important corporate strategic decisions such as potential mergers, the introduction of new products, company expansions, and the removal of top level management can be delegated to the workers of the company not necessarily in the upper levels of the corporate hierarchical ladder for the betterment of the company. News Futures.com a U.S consulting firm that focuses on implementing and formatting information markets for companies specifies the procedure in creating these markets: First define the outcomes

for which the firm would like reliable estimates. Then the company invites people with relevant knowledge to trade "virtual" stock based on their confidence in each outcome. The result is a trading price that tracks the *consensus* opinion (in contrast with the *average* opinion that a poll yields). Because the market is online, it involves any number of participants, from anywhere, at any time. These markets help companies maintain their competitiveness and make better informed decisions.

Many businesses lack, especially in areas of supply chain management, business forecasting, new product introduction, and supply uncertainties, a systematic information aggregation method, that can collect all the information sets and subjective beliefs of its key players closest to the activity to facilitate decision making. In most cases, individuals who are the closest to a particular business activity possess information along with their personal intuition within their respective field of business. Such information is considerably limited compared to the substantial information set that a whole group of individuals associated with the same business activity possess altogether. Since we live in a world of limited time and resources, it may be an extremely difficult task if not impossible to individually survey all the key players that have relevant insight about a forecasting problem. Within a company setting and specifically when employees are surveyed about their future perspectives of the profitability of the business, it may also be difficult for the employees as a group to combine subjective information such as knowledge of a competitor's move with objective information such as previous company historical data. The key employee's location dispersal, personal incentives, and insignificant amounts of information make the process of group deliberations inefficient. Employees may also have incentives to not be honest in their revelations regarding

quotas and budget settings because such misrepresentation may ultimately serve to offer than more benefit than would revealing to the public their real personal opinions.

The operation of an information market may be appropriate and attractive in the area of corporate governance. For instance, suppose a board of directors is trying to decide who to elect as the Chief Executive Officer of a corporation. The board has the fiduciary responsibility to hire the candidate who will most likely maximize shareholder value. Economist Robin Hanson proposes utilizing a financial market to get at a decision that will enable the board obtain its goal. Such a market will be comprised of a derivative security whose value depends on who will become the Chief Executive Officer. If there are two candidates, the board will create a market with two securities (stock options), one that will deliver one share of stock if candidate A gets the job or one share of stock if candidate B obtains the job. So the securities are tied to who will win the job and a two money options are also created that will reward one dollar if candidate A wins and one dollar if candidate B wins. Candidate A's money option should sell for the price that is roughly proportional to the probability that candidate A will win the job in a well functioning speculative market. Candidate A's stock option on the other hand should sell for the value of one share of the stock multiplied by the probability that Candidate A will get the job. The ratio of the stock option to the money option will give the value of the company's stock if candidate A is chosen for the position.

*Hewlett Packard Case Study*

A prediction market was setup for experimental purposes at the major computer company, Hewlett Packard. The idea was to predict printer sales at Hewlett Packard and observe the comparative accuracy (relative to the tradition approach of surveying the sales and finance personnel) of such markets to make sales forecasts. Key factors such as the pay-off structure, anonymity, and market design influenced the incentives of the traders to make accurate predictions that beat out official predictions. Charles R. Plott, an economist at Caltech along with Kay-Yut Chen of Hewlett Packard Laboratories took the methodologies of experimental economics a step further to design an information aggregation mechanism (information market) to help Hewlett Packard predict the sales of its products in the next quarter. The objective of the study was to also test whether the capacity of a competitive process can be harnessed into an information aggregation tool with market power as its underlying driving force for decision making and ultimately business management.

The Hewlett Packard experiment ran prediction markets that revolved around predictions for monthly sales for a month three months into the future. In all of the cases, the information was gathered in a week with the markets being opened during the lunch time and in the evenings. A relatively small number of 10-15 participants were chosen for the experiment. The experiment was conducted with three different HP divisions and business participation was limited to the marketing and financing organizations; the employees from the different divisions were thought to have had different patterns of information about the targeted event. The employees were selected because they were the ones who possessed the most relevant patterns of information, including market

intelligence, specific information about big clients, and pricing strategies, which were in need of aggregation. Laboratory experiments have suggested that a small number of uninformed participants provide both market liquidity and a function of adding “consistency” to the market through a process of “reading” and “interpreting” the actions of others. So, five subjects were recruited from HP Labs (with little or no information) in each experiment. The subjects were geographically dispersed in California and the markets were typically open for a week and trading was conducted through a web server located in CalTech. No public summaries of information available to the participants during the operation of the prediction market. The official forecasts were not known until after the prediction market closed. Each participant was given a portfolio of shares in markets and cash. A 15-20 minute instruction session explained the structure of incentives, the market mechanism, and the web interface. In addition, the participants were told the goals of the experiment and were told that their participation was important for HP business. Participants in the experiment remained anonymous yet each was assigned an ID number. When each participant made a transaction, such information was made public through their ID numbers only. The experimenters also took into consideration business constraints such as the opportunity cost of the participants who were involved. To appease such potential problems, each participant was provided with a small amount of cash in the beginning of market sessions. Perhaps in conjunction with the potential to earn money from the experiment, such incentives were believed to be sufficient to ensure that each employee had motivation to actively engage in trading.

The primary choice of the instrument to be traded was a single compound security, which paid a dividend in proportion to the level of sales, if sales are the item to be predicted, in multiply state contingent contracts. The space for possible outcomes was partitioned into a finite set of possible outcomes. When the real outcome became realized, the security tied to the winning outcome would pay off a fixed amount. All the other securities paid out nothing. Each subset was part of an interval that lay within a positive interval line. For example, the interval 0-100 would be associated with a security named 0-100 that traded in a market named 0-100. If the market fell within that interval, the corresponding security would pay off a fixed amount, say one dollar for each security a participant owned. By examining the prices of all 10 shares, HP could assign a probability to any combination of outcomes - a more nuanced analysis than that available from a questionnaire. They could determine, for example, the probability of sales falling anywhere below 10,000 units or anywhere above 25,000 units. HP subsidized participation in the information market, so the traders could not lose money. But the traders could keep any money that they made, giving them substantial incentive to trade carefully. HP compared the implicit forecasts made by the prediction market with its own official forecasts and with actual sales figures. The pattern of results indicate that the IAM prediction was more accurate in its predictions than the HP official forecasts. Table 1 lists the description of all twelve events in which these markets were setup. IAM forecasts in comparison to the official forecasts are shown in the table 2 for all twelve forecasts. The actual outcome, HP official forecasts, and their absolute percentage errors are listed in the table. We observe that in 6 out of the 8 events in which HP official forecasts were available, the IAM forecasts were closer than the HP official forecasts to

the outcome. Encouraged by these results, HP created its own experimental economics laboratory.

From this experiment, the researchers noted that the sell offers tended to exceed the buy offers in the duration of the experiment. The intuitive interpretation of this observation is that in the early stage of the experiment, little information is revealed and prices equilibrate around the same levels in all possible outcomes. However, as the market progressed and aggregated more information, prices associated with most outcomes started to decrease. The observation of more sell offers than buy offers suggest that as more information was acquired and then aggregated by the participants, people began to get a better idea of the outcomes that were not likely to occur and thus attempted to try to sell their contracts tied those particular outcomes. The anonymity aspect embedded in the methodology of such markets tends to eliminate or greatly limit incentives to hide valuable information, misrepresent information, or simply ignore request for information. The potential rewards to be earned in participating in this market provided the participants with incentives to acquire information about future events and use this information wisely when executing their market trades.

### *Market Design and Implementation*

Careful market and contract design have important implications for an effective prediction market. In the case of the information market setup at Hewlett Packard, participants were provided with sufficient cash at the onset of the experiment to offset what they may potentially feel as an opportunity cost of participating in the study. Potential reward payoffs also helped generate active participation on the part of the

employees. It is important in regards to the viability of the information market that issue in which any contract revolves around will attract a significant number of traders to want to participate. Even a well designed market will fail unless people have incentives to want to participate in it. Information markets that involve securities of widely discussed events are more likely to succeed than contracts that involve obscure statistics or ones that involve a lot of esoteric information. This is so because trading on such issues will thus have a greater entertainment value and more information on which interpretations traders can disagree upon. Uncertain events, whose information is to the extreme privately held, are more likely to fail due to the tendency of insiders to drive out uninformed traders and hence unravel the market. Other important necessary conditions for the success of information markets are that the contracts must be clear, easily understood, and enforceable. Without such guarantees, it is obvious that no rational trader would have the incentives to participate in such a market.

#### *Market Manipulation and Arbitrate Opportunities*

It was once feared that the DARPA project had the potential to bring about horrendous consequences due to the profit motive presented to potential terrorists who could manipulate the market in their favor. However, such fears may be unfounded due to the fact that such a contract most likely would not have been offered on an actual market. Opportunities for huge profit gains would also have been very unlikely in light of the small scale size of these markets. Clearly, the likelihood of market manipulation depends on how thin the markets really are. Also, since existing thick financial markets already exist and respond to terrorist attacks; it seems unreasonably that terrorists would find

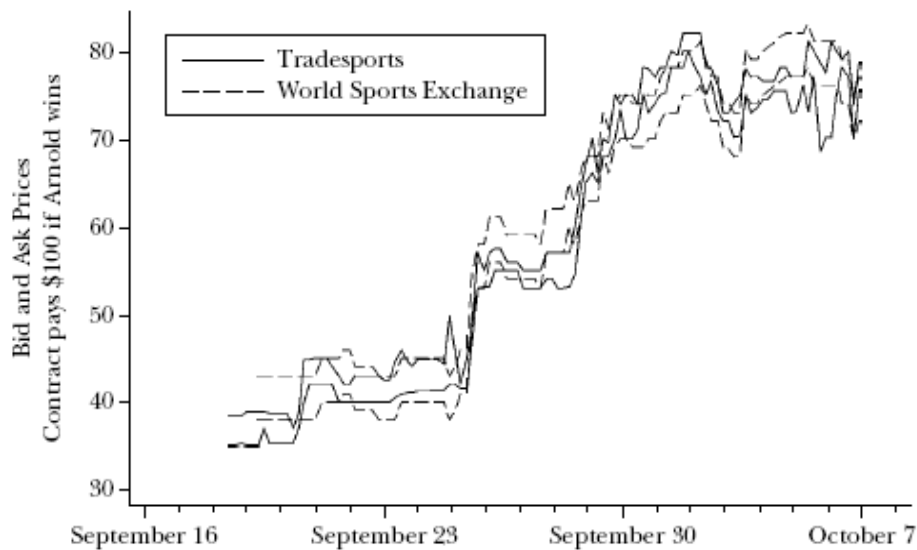
incentives to participate in information markets. Furthermore, the cost of orchestrating such acts of terror is more likely to exceed the potential profit gains. On the other hand, there have been several known attempts at market manipulation. Wolfers and Leigh (2002) find evidence of candidates betting on themselves to create a buzz. The typical thinness of information markets can also make it cheap for traders with bad motives to mislead the market with their trades. However, Hanson (2004) suggests that these so called “noise traders” may in fact help improve the accuracy of market predictions. The logic holds because when there are informed traders with a lot of money to invest relative to the volume of noise trading, increases in noise trading does not directly affect accuracy. By inducing more traders to become more informed, noise traders may even indirectly improve the accuracy of market prices. If market manipulators in their actions provide other traders with inclinations towards information discovery, then market manipulation should be less of a problem than many people fear it should be.

While Prediction markets tend to present small opportunities for arbitrage. Opportunities for arbitrage may include predictive patterns in the movement of prices, whether prices of similar contracts can be arbitrated across different securities (when the bid price on one exchange is higher than the ask price on another exchange), and whether arbitrageurs might be able to exploit predictable deviations from rationality. Wolfers and Zitzewitz (2004) studied and found that the pricing of families of similar securities tends to be internally consistent. They studied the movement of prices of several securities that traded on tradesport.com and found that their corresponding moved closely together in a way that suggests that both exchanges absorbed similar information at the same time. At

the same time, Wolfers and Zitzewitz found that the time series of prices in these markets do not appear to follow a particular path and simply strategies based on past prices did not lead to any opportunities for profit. The graph below illustrates the case where an event, the California Gubernatorial Election, was simultaneously run on two online prediction markets. The data which were the bid and ask prices on a contract that paid out \$100 if Schwarzenegger was elected Governor in 2003, were collected every four hours. We are able to observe that the movement of the price in the two markets moves closely together and opportunities for arbitrage are almost non-existent. [See Graph 4]

Graph4

**2003 California Gubernatorial Election**



Source: Wolfers, Justin and Zitzewitz, Eric, "Prediction Markets," *Journal of Economic Perspectives*, 18(2), Spring (2004)

Finally, the power of the prediction market is derived from that fact that it is able to generate the kind of incentives and motivational force that cause its participants to strive to become all the most knowledgeable about the uncertain event that the market is trying to predict. This in turn leads the market participants to become honest in their predictions. The paper suggests that anonymous markets are more likely to possess all the available information amongst the traders and reward and punish bettors in a straightforward fashion at the same that the market provides the kind of natural algorithm for information aggregation that group meetings and opinion polls lack. While prediction markets have obvious limitations, their use in supporting issues in public policy and in the private sector may bring about the realization of many intended goals and favorable outcomes. These markets can improve the quality in which governments and corporations can make decisions. The potential of such markets could in theory, perform even more, providing insights into the net benefits of many policy initiatives before they are even attempted. Information markets may even potentially be used as tools to hedge against public sector projects much like the futures markets are utilized to hedge against commodity price changes. Hahn and Tetlock (2005) provide an example that if a parent was worried and more confident than not that his or her child's education quality would decline after some policy initiative, that parent could bet against the policy's success on a prediction market so she would later have the money to send her child to a private school or invest in a private tutor. Hahn and Tetlock also consider what is referred to as the "Copenhagen Consensus," thought out and orchestrated by a Danish environmental policy entrepreneur as an attempt to gather a group of eight economists to set priorities for solving the world's biggest problems. The experts ranked 17 social investments in

four categories ranging from bad to very good. The very good category included investments in controlling HIV/AIDS and malaria, reducing malnutrition and promoting free trade. In reaching their decision, the experts relied on their collective wisdom as well as an abundance of research papers. Hahn and Tetlock (2005) suggest an alternative approach to tackling such a problem that involves the implementation of a prediction market. Hahn and Tetlock (2005) suggest that suppose a huge foundation was interested in containing the spread of the HIV virus in sub-Saharan Africa. It could use one market to predict the number of infections that would occur without intervention and another to predict the number of infections that would occur after the implementation of a specific policy initiative. Suppose the market suggested that one million HIV could be avoided if the foundation paid a \$1000 fee for every HIV infection below the baseline number. The foundation can then decide if it wants to go ahead with the project. The possibilities are thus endless and it seems like corporations and governments alike will continue to create innovative markets to gather the kind of information that will supplement or even eliminate the need for traditional means of information gathering.

Table 1

	Event to be predicted	Number of active participants	Date [time] of experiment	Experiment Duration	Number of Markets
1	Profit sharing percentage to be announced by upper management	16	10/96 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
2	Next month sales (in \$) of product A	26	11/96 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	9
3	Next month sales (in units) of Product B	20	01/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	9
4	Quarter ahead monthly sales (in units) of product C	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
5	Quarter ahead monthly sales (in units) of product D	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
6	Quarter ahead monthly sales (in units) of product B	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
7	Quarter ahead monthly sales (in units) of product C	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
8	Quarter ahead monthly sales (in units) of product D	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
9	Quarter ahead monthly sales (in units) of product E	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
10	Quarter ahead monthly sales (in units) of product F	12	04/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
11	Quarter ahead monthly sales (in units) of product G	12	04/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
12	Quarter ahead monthly sales (in units) of product H	7	05/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8

Source: Chen, Kay-Yut and Plott, Charles, "Information Aggregation Mechanisms: Concept, Design and Field Implementation for a Sales Forecasting Problem," (2002)

Table 2

Event				IAM Predictions			
				Last Trade	Average Last 60% Trade	Average Last 50% Trade	Average Last 40% Trade
1	Outcome	8.770	IAM Prediction	9.619	9.092	9.259	9.369
	HP Forecast	None	Tail Prob Truncated	0.040	0.038	0.043	0.041
	% error	None	% error	9.683	3.672	5.571	6.829
2	Outcome	220.000	IAM Prediction	234.065	230.136	230.059	230.294
	HP Forecast	249.000	Tail Prob Truncated	0.009	0.008	0.009	0.009
	% error	13.182	% error	6.393	4.607	4.572	4.679
3	Outcome	1152.000	IAM Prediction	1766.399	1814.155	1793.875	1781.017
	HP Forecast	1838.000	Tail Prob Truncated	0.010	0.008	0.008	0.008
	% error	59.549	% error	53.333	57.479	55.718	54.602
4	Outcome	1840.000	IAM Prediction	1612.891	1695.796	1690.102	1683.273
	HP Forecast	1681.000	Tail Prob Truncated	0.008	0.011	0.011	0.011
	% error	-8.641	% error	-12.343	-7.837	-8.147	-8.518
5	Outcome	2210.000	IAM Prediction	1429.839	1526.466	1512.397	1506.579
	HP Forecast	1501.000	Tail Prob Truncated	0.024	0.011	0.011	0.012
	% error	-32.081	% error	-35.301	-30.929	-31.566	-31.829
6	Outcome	128.000	IAM Prediction	91.801	96.985	96.592	95.619
	HP Forecast	90.000	Tail Prob Truncated	0.007	0.010	0.010	0.010
	% error	-29.688	% error	-28.280	-24.231	-24.538	-25.297
7	Outcome	2002.000	IAM Prediction	1828.000	1855.320	1861.382	1867.697
	HP Forecast	2084.000	Tail Prob Truncated	0.008	0.017	0.018	0.019
	% error	4.096	% error	-8.691	-7.327	-7.024	-6.708
8	Outcome	1788.000	IAM Prediction	1728.600	1752.300	1746.033	1755.340
	HP Forecast	1786.000	Tail Prob Truncated	0.008	0.026	0.028	0.021
	% error	-0.112	% error	-3.322	-1.997	-2.347	-1.827
9	Outcome	166.000	IAM Prediction	134.886	126.401	124.748	125.515
	HP Forecast	119.000	Tail Prob Truncated	0.027	0.061	0.073	0.076
	% error	-28.313	% error	-18.743	-23.855	-24.850	-24.389
10	Outcome	30.000	IAM Prediction	15.178	15.017	15.245	15.150
	HP Forecast	None	Tail Prob Truncated	0.148	0.092	0.073	0.072
	% error	None	% error	-49.407	-49.944	-49.184	-49.498
11	Outcome	10.000	IAM Prediction	15.158	15.170	15.308	15.337
	HP Forecast	None	Tail Prob Truncated	0.083	0.082	0.081	0.085
	% error	None	% error	51.583	51.705	53.082	53.368
12	Outcome	17.000	IAM Prediction	15.708	14.991	15.281	15.366
	HP Forecast	None	Tail Prob Truncated	0.085	0.054	0.061	0.064
	% error	None	% error	-7.602	-11.818	-10.112	-9.612

Source: Chen, Kay-Yut and Plott, Charles, "Information Aggregation Mechanisms: Concept, Design and Field Implementation for a Sales Forecasting Problem," (2002)

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