Prediction Markets are only Human: Subadditivity in Probability Judgments

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Abstract

Prediction markets establish the probability of future events occurring through the trading

of contracts that payoff according to certain outcomes, such as an Obama or McCain

presidency. The hope is that these markets efficiently aggregate information. The

present research finds that prediction markets fall prey to a decision error that plagues

individual humans. Markets, like resource-limited individuals, judge the probability of

the whole to be lower than the sum its constituent parts. Monte Carlo simulations of state

races (i.e., parts) demonstrate that the probability of an Obama presidency (i.e., the

whole) is underestimated by the market.

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Markets are forward looking in that they forecast value. Prediction markets aim to establish the probabilities associated with certain outcomes. These markets attempt to harness the wisdom of the crowds (1) to aggregate information. In prediction markets, buyers and sellers of contracts settle on a price that reflects the probability of an event occurring. For example, a futures contract on Intrade.com that stipulates that Barack Obama will be the next President of the United States of America might sell for 85.6, whereas a contract for John McCain might trade at 14.3. A contract is worth 100.0 if the projected event occurs and is worth 0.0 otherwise. Thus, the expected value of a contract is related to the probability that the event will occur.

These markets should be the best predictors of the future. To quote Wolfers and Zitzewitz (2), "In a truly efficient prediction market, the market price will be the best predictor of the event, and no combination of available polls or other information can be used to improve on the market-generated forecast." Prediction markets continue Wall Street's former tradition of betting on Presidential elections. In 15 elections between 1884-1940, the favorite in mid-October always won the election, the only exception being the hotly contested 1916 election in which the odds moved to even as voting ended (3). Betting odds roughly reflected the margins of victory, which is impressive given that many of these elections occurred before the advent of modern polling (3).

Despite the considerable enthusiasm for prediction markets, one key question is whether these markets fall prey to the same shortcomings that plague individual human

decision makers. The answer to this question likely speaks more broadly to the efficiency and rationality of the market mechanisms that are the foundation of capitalist economic systems. Determining the "rationality" of a market would seem to be an intractable proposition. Unlike human subjects, markets cannot easily be brought into the laboratory. However, the current Intrade market does provide a way to formally evaluate whether markets fall prey to one particular human reasoning error: subadditivity in probability judgments.

Subadditivity refers to the tendency of people to judge the probability of the whole to be lower than the sum of its constituent parts (4). For example, people judge the probability that someone will die of any natural cause to be lower than the sum of probabilities that someone will die of cancer, heart attack, or any other natural cause. "Unpacking" events results in more accurate judgments, likely reflecting our limited processing capacity. Indeed, subadditivity effects are larger for individuals with low working memory capacity and when people are put under time pressure (5). One key question is whether the Intrade markets transcend the cognitive limitations of human judgment by effectively aggregating information.

The Intrade market for the upcoming Presidential election contains a market for each candidate at the national (i.e., whole) and state (i.e., part) level. The key questions is whether the markets, like people, display subadditivity. At the national level, traders bet on whether Obama or McCain will carry the entire election. At the state level, traders wager on the outcome of each state's election (including the District of Columbia). The whole is a direct and transparent function of the parts. Each state has an associated number of electoral votes with the entire allotment assigned to the candidate who wins

that state's popular vote. A candidate wins the overall election when he achieves a majority of the electoral votes (270 out of 538 possible).

To evaluate whether the markets efficiently and rationally aggregate information, one million Monte Carlo simulations of the election were performed based on the state markets. Figure 1 displays the results and explains the methodology. In 98.2% of the simulations, Obama is the winner. In contrast, the national (whole) market predicts that Obama has a 84.3% chance of winning. Clearly, part and whole predictions cannot both be correct. Unfortunately, rationality appears not to be an emergent product of markets. One hypothesis is that markets, like people, cannot unpack events and properly integrate information. If markets display the same limitations as the people who invest in them, an Obama presidency is highly likely based on a proper unpacking of the state markets. This result also suggest that prediction markets should be designed in light of human capacity limitations.

Caveats and Future Directions

This research is in its early stages and is vulnerable to a number of critiques. One possible critique is that the Monte Carlo simulations assume independence. For example, although voters in Rhode Island do not determine the outcome of the election in Massachusetts, common causal factors likely shape the outcome of both elections. The extent to which these common factors influence elections is not entirely clear. In the extreme, these effects can hold large sway. As a thought experiment, imagine a scenario in which all fifty states and the District of Columbia were governed by a common causal

factor that could manifest one of two values. Value 1, which has a 75% of occurring, leads to an Obama win in every state with certainty. Conversely, Value 2, which has a 25% of occurring, leads to a McCain win in every state with certainty. A Monte Carlo simulation would show Barack Obama to be the winner with near certainty, when in fact he would only have a 75% chance of winning based on the influence of the common factor. Of course, this thought experiment is not realistic -- no winner ever gains all the electoral votes. Likewise, there is no single hidden factor that determines the outcomes in all state races.

One important direction for future research is to establish the degree of non-independence and its form. One path to a solution is to analyze how markets jointly move. My intuition is that subadditivity will still be found after a correction. It seems far fetched that there could be many cases in which winning one state provides evidence for reduced odds (through a common factor) in another state. If most linkages are positive, subadditivity will likely be found after a reasonable correction.

Interestingly, as the election nears, the state markets (parts) have not moved much but the national (whole) market has moved decisively toward predicting an Obama victory. One interpretation of this result, in keeping with the hypothesis evaluated here, is that people have trouble unpacking all possibilities that can occur across states and though time. The simulations reported here focus on combining information from state markets, but another factor is imagining and unpacking all the events that can happen through time. As the election nears, this account correctly predicts that the differences between the predictions of state (part) and national (whole) markets should narrow as the range of possible events narrows.

References

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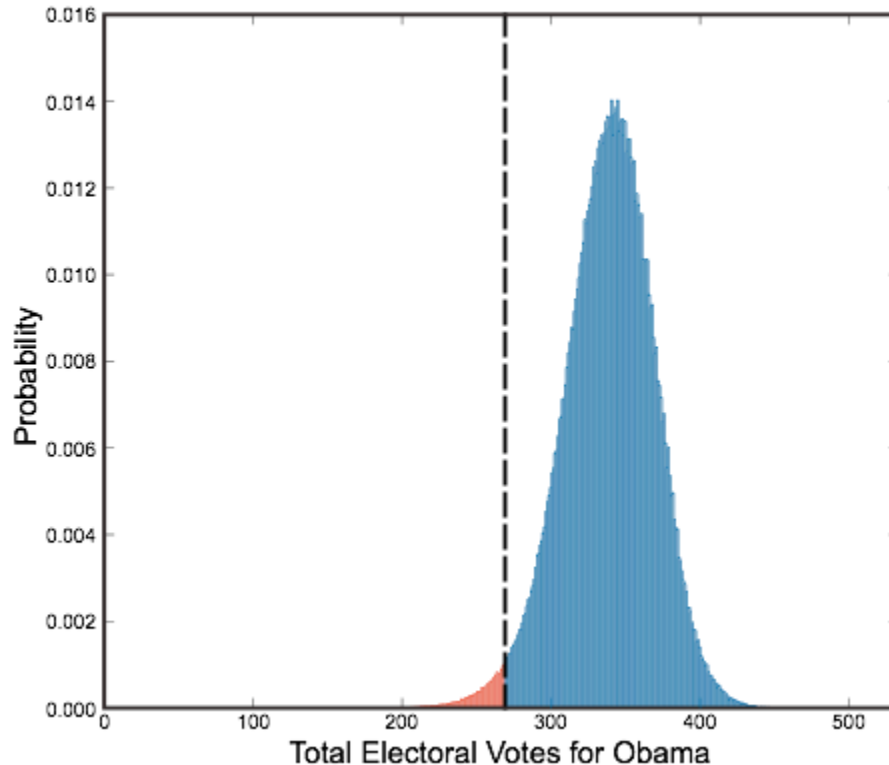5. M. R. P. Dougherty, J. Hunter, *Memory & Cognition*, **31**, 968-982 (2003).

Figure 1: The predictions from the state markets are properly aggregated to generate a prediction for the overall election. The results from one million election simulations are plotted. In each simulation, each state is assigned to Obama or McCain with the probability determined by the state's market. For simplicity, we used the Obama markets, but the complementary result occurs when the McCain markets are used -- the markets are efficient in the sense that the sum of probabilities for a state's Obama and McCain markets is usually close to 1. The vast majority of simulations lie to the right of dotted line that divides outcomes in blue that indicate an Obama victory from outcomes in red that indicate a McCain victory. The analysis is from market values from October 21st, but this result holds strongly over multiple days and times of day.