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# Prediction Markets for Defense Acquisition: The Devil is in the Details

Coughlan, Pete; Myung, Noah; Arkes, Jeremy; Gates, Bill

Monterey, California. Naval Postgraduate School

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Acquisition Research Program:  
Creating Synergy for Informed Change

## **Prediction Markets for Defense Acquisition: The Devil is in the Details**

Bill Gates, Pete Coughlan, Noah Myung, Jeremy Arkes  
Professors of Economics  
Naval Postgraduate School

# Navy Student Theses

- **Lt. Josh Dishmon**
  - Review acquisition-relevant applications of prediction markets
- **Lt. Michael A. Chinn & Lt. Leslie A. Huffman:**
  - Prediction Markets for Navy Manpower Outcomes
  - Did a pilot set of prediction markets for manpower outcomes (and fun topics)



# Promise and Pitfalls of Prediction Markets

- Potentially VERY powerful tool

BUT ...

- The “devil is in the details”
  - Small changes in market design can have big impacts
  - #1 rule of carpentry: “Measure twice, cut once”
- A little econ knowledge can be a dangerous thing
  - A basic understanding of the principles is not sufficient to design and implement an effective market
  - Within DoD, several examples where a good economic idea has been implemented in a sub-optimal fashion
  - Pattern: From “too slow” to “too fast” with good ideas



# Popular (but Applicable?) Prediction Markets

| Market  | Focus   |
|---|---|
| <b>Iowa Electronic Markets</b><br>< <a href="http://www.biz.iowa.edu/iem">www.biz.iowa.edu/iem</a> ><br>Run by University of Iowa                         | Small-scale election markets.   |
| <b>Centrebet</b><br>< <a href="http://www.centrebet.com">www.centrebet.com</a> ><br>For profit company  | Northern Territory bookmaker, offering odds on election outcomes, current events, sports, and entertainment.            |
| <b>intrade</b><br>< <a href="http://www.intrade.com/">www.intrade.com/</a> ><br>For profit company  | Trades in political futures, financial contracts, current events, entertainment, etc.                                   |
| <b>Economic Derivatives</b><br>< <a href="http://www.economicderivatives.com">www.economicderivatives.com</a> ><br>Run by Goldman Sachs and Deutsche Bank | Large-scale financial market trading in the likely outcome of future economic data releases.                            |
| <b>Newsfutures</b><br>< <a href="http://www.newsfutures.com">www.newsfutures.com</a> ><br>For profit company  | Political, finance, current events and sports markets. Also technology and pharmaceutical futures for specific clients. |
| <b>Foresight Exchange</b><br>< <a href="http://www.ideosphere.com">www.ideosphere.com</a> ><br>Non-profit research group                                  | Political, finance, current events, science and technology events suggested by clients.                                 |
| <b>Hollywood Stock Exchange</b><br>< <a href="http://www.hsx.com">www.hsx.com</a> ><br>Owned by Cantor Fitzgerald   | Success of movies, movie stars, and awards. Data used for market research.  |



# Applications Relevant for Acquisition

| Application         | Firm            | Description  |
|---------------------|-----------------|--|
| Sales Forecasting   | Hewlett-Packard | Hewlett-Packard used an internal market system to forecast printer sales. HP's official forecast erred by 13%, while the market erred by 6%; the market performance exceeded the accuracy of official forecasts 75% of the time. |
| Product Development | Eli Lilly       | Eli Lilly applied internal markets to predict which of six potential new drugs would have the greatest success in passing product development hurdles.   |
| General Forecasting | Google          | Google uses internal markets to forecast new product launch dates and new office openings, predicting the likelihood that an event will occur and on a specific date.  |
| Product Development | Siemens         | An internal market predicts whether the firm will deliver software projects on time  |
| Product Development | Microsoft       | Uses internal markets to predict whether projects will meet milestones articulated in their project plans  |

Sources: Chen and Plott (2002), Corporate Executive Board 2006), Kiviat( 2004), Malone (2004), Ortner (1998)



# Asset Value & Market Prices as Predictors

- Two dimensions of value for any asset/contract :
  - **Arbitrage value:** Potential financial benefit from reselling asset/contract at a higher price at a later date
  - **Intrinsic value:** Expected financial benefit of holding the asset/contract indefinitely (or until market closes)
- Many people think about the value of stocks in the stock market only in terms of the *arbitrage value*
- Prediction markets provide reasonable predictions only when prices reflect estimate of *intrinsic value*
- Thus, assets and markets must be designed to direct focus toward intrinsic value



# Measuring Prediction Market Performance

- Prediction markets make predictions by aggregating knowledge among traders
- Thus, prediction market performance can only be measured by degree of information aggregation
- Prediction market performance can not best be measured by prediction accuracy
  - Predicting a coin flip
  - Better weatherman: Las Vegas or Seattle?
- At best, prediction market performance can be measured by relative accuracy
  - But alternative predictions often don't exist





# Measuring Prediction Market Performance

- “There’s a common ‘weatherman’ misunderstanding about prediction markets, especially in the press. Perhaps counterintuitively, a weatherman is not wrong if the sun comes out after a 90 percent forecast for rain because there was still a 10 percent chance of sunshine. Instead, the weatherman is a good predictor if it rains 90 percent of the time when he gives a 90 percent chance of rain—any more or less would be poor predictions. Prediction markets work the same way.”
- -Todd Proebsting, Microsoft



# Prediction Markets as a Decision Tool

## PROBLEM:

- Consider asset measuring project performance
- Market price drops (negative reflection on project)
  - ⇒ DoD or agency takes corrective action
  - ⇒ Market price goes up ... or does it?
- Market price should already incorporate expectations about any corrective action
  - ⇒ Market price may not reflect what you think

## SOLUTIONS:

- Measure variables unaffected by DoD decisions
- Conditional assets/contracts: If \_\_\_\_\_, then \_\_\_\_\_



# Using Conditional Assets/Contracts

## DESCRIPTION:

- Conditional assets ask:
  - “If \_\_\_\_\_, then what is the probability that \_\_\_\_\_?”
  - “If \_\_\_\_\_, then what will be the measure of \_\_\_\_\_?”

## PROBLEM:

- How do assets “payoff” if condition doesn’t occur?
- If zero value, distorts price as a predictor

## SOLUTION:

- Closing price termination rule
- If an asset is “delisted,” each share of asset pays amount equal to average price over final X days
  - Delisting fear should not distort prediction value of price



# Incentive Issues with “Play Money”

- Private corporations use real money
- Resistance to using real money in government
- With play money, traders go for the home runs:
  - Buy low-probability events
  - Avoid high-probability events
  - Leads to inaccurate probabilities of events
- Research suggests real money gives more accurate predictions



# Incentive Issues with “Play Money”

- Competition and bragging rights as an incentive?
  - Requires degree of non-anonymity (not good)
  - How do traders know if they are “winning?”
  - Intrinsic values not realized until after close of market
- Portfolio value as measure of performance?
  - Does not recognize good predictors of outcomes
  - Rewards traders for being a good predictor of other trader’s predictions (of other trader’s predictions ...)
- Beware of research suggesting play money works
  - Settings often involve intrinsic motivation



# Market Maker Concerns

- Thin market  $\Rightarrow$  asynchronous trades  $\Rightarrow$  market maker
- BUT how is price adjusted in response to trades?
  - Critical for price to be a reasonable predictor
  - Without knowledge of underlying supply and demand, price adjustment is educated “guesswork”
- Current price may not reflect aggregate belief
  - Contributes to price volatility
- Alternative approach: Proxy bid/ask thresholds
  - If price rises above \$\_\_\_\_, then sell \_\_\_\_ units
  - If price falls below \$\_\_\_\_, then buy \_\_\_\_ units
  - PLUS: Gives off-equilibrium supply and demand info



# Asset/Contract Types

- “Winner-take-all” assets/contracts
  - Pays fixed amount if outcome occurs, zero otherwise
  - Price reflects market expectation of probability of event
- “Index” assets/contracts
  - Pays variable amount tied to a specific future measure
  - Price reflects expectation of mean value of measure
- “Spread” assets/contracts
  - Pays fixed amount if & only if measure is above/below threshold (adjusted to balance two sides of market)
  - Price reflects expectation of median value of measure



# Asset/Contract Types

- Winner-take-all markets are easiest to implement
  - Allow use of market-maker algorithm for thin market
  - Widely available mechanisms for doing so

BUT ...

- Index markets may reveal more valuable info
  - Specific date on which an event is expected to occur
  - Specific degree of cost-growth that is expected to occur





# Asset/Contract Design Issues

- To be valuable, a prediction market asset must measure something that is:
  - Valuable
  - Quantifiable
  - Clearly defined
  - Ex-post measurable
  - Exogenously determined



# Thesis Student Pilot Study

- Participants:
  - N1 personnel
  - Recruiting command personnel
  - Researchers at NPS, CNA, other research org's
- Questions:
  - Manpower outcomes
  - Generally economic outcomes (unemployment, stock market)
  - Fun questions (NFL opener, Emmy's, MLB play-offs)



# Thesis Student Pilot Study

- Participation was very low and tailed off, despite encouragement from N1
  - 11 of 35 non-NPS potentials made trades
- Adding “fun” questions didn’t seem to increase participation in manpower outcomes
- Top reasons for lack of participation:
  - Lack of time
  - No incentive



# Pilot Experiment

| PROJECT          |      |    |    | Attribute 1 | Attribute 2 | Attribute 3 |
|------------------|------|----|----|-------------|-------------|-------------|
| <i>Alpha</i> –   | Fail | .. | .. | F           | P           | F           |
| <i>Beta</i> –    | Fail | .. | .. | P           | F           | P           |
| <i>Gamma</i> –   | Pass | .. | .. | P           | P           | P           |
| <i>Delta</i> -   | Fail | .. | .. | F           | P           | P           |
| <i>Epsilon</i> – | Pass | .. | .. | P           | P           | P           |
| <i>Zeta</i> -    | Pass | .. | .. | P           | P           | P           |

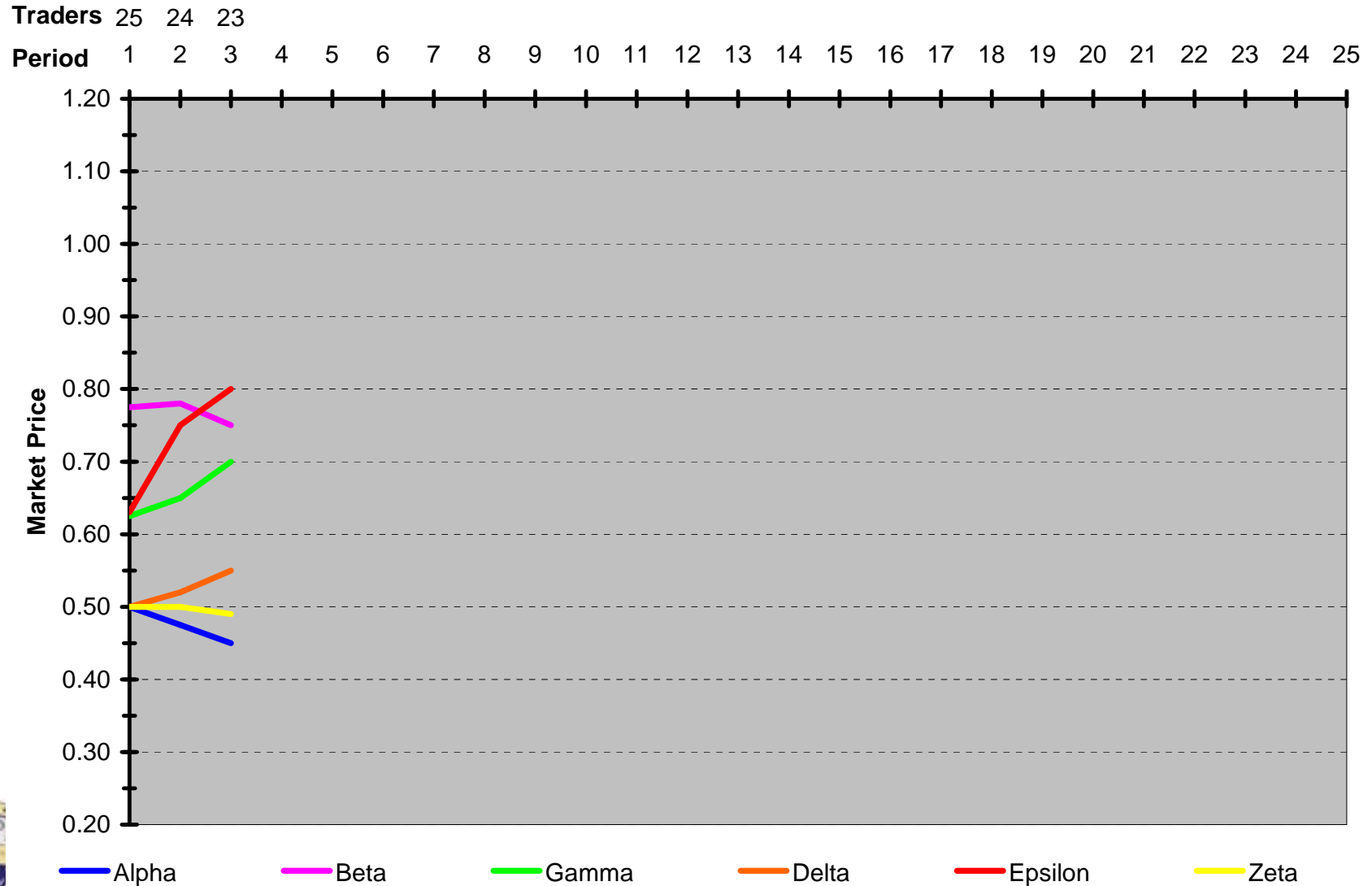


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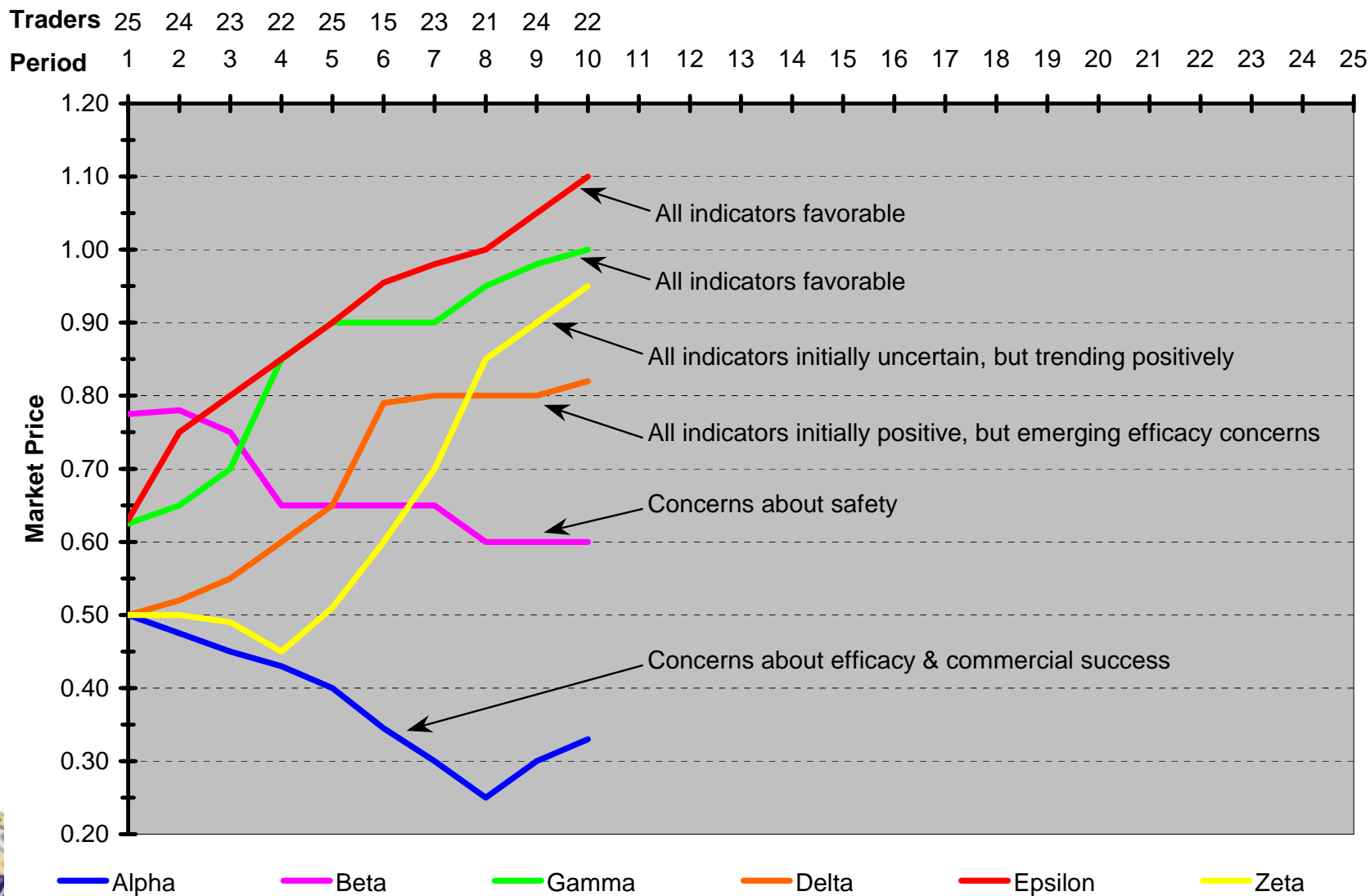
# Pilot Experiment Results

## *Price Patterns & Performance Indicators*



# Pilot Experiment Results

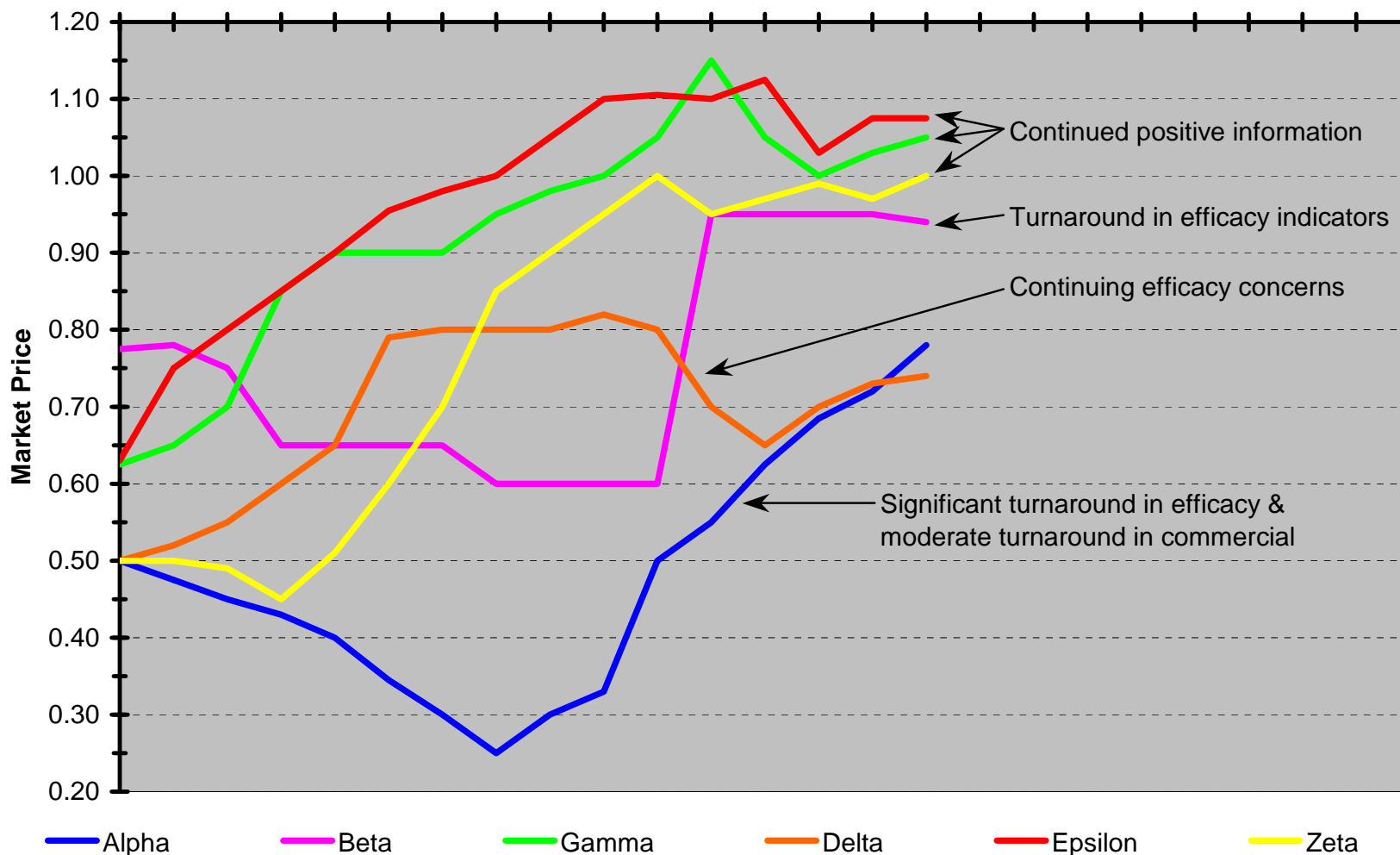
## Price Patterns & Performance Indicators



# Pilot Experiment Results

## Price Patterns & Performance Indicators

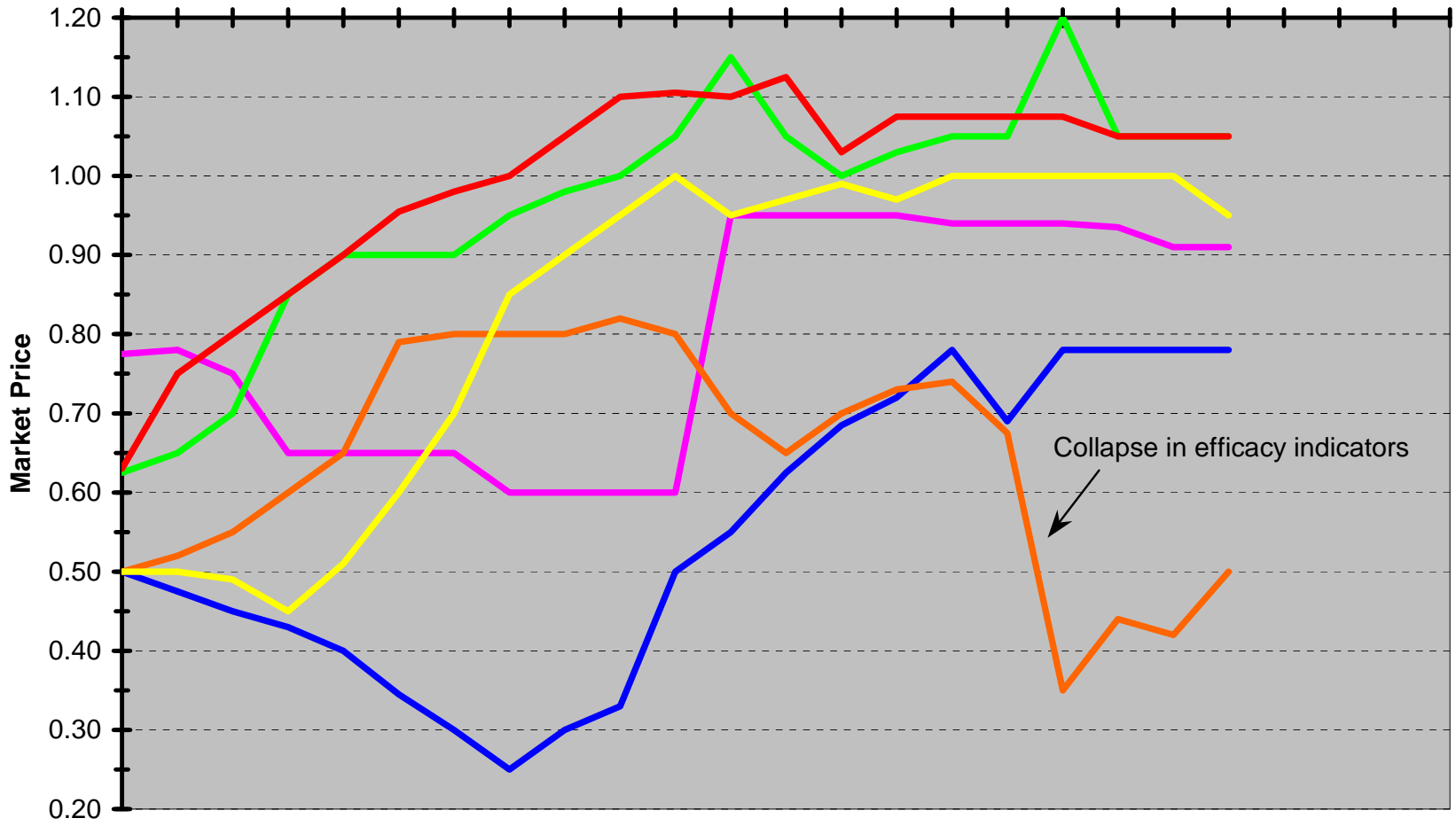
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|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Traders | 25 | 24 | 23 | 22 | 25 | 15 | 23 | 21 | 24 | 22 | 18 | 13 | 17 | 12 | 14 | 15 |
| Period  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 |



# Pilot Experiment Results

## Price Patterns & Performance Indicators

|         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Traders | 25 | 24 | 23 | 22 | 25 | 15 | 23 | 21 | 24 | 22 | 18 | 13 | 17 | 12 | 14 | 15 | 11 | 10 | 11 | 12 | 10 |    |    |    |    |
| Period  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |



Alpha      Beta      Gamma      Delta      Epsilon      Zeta

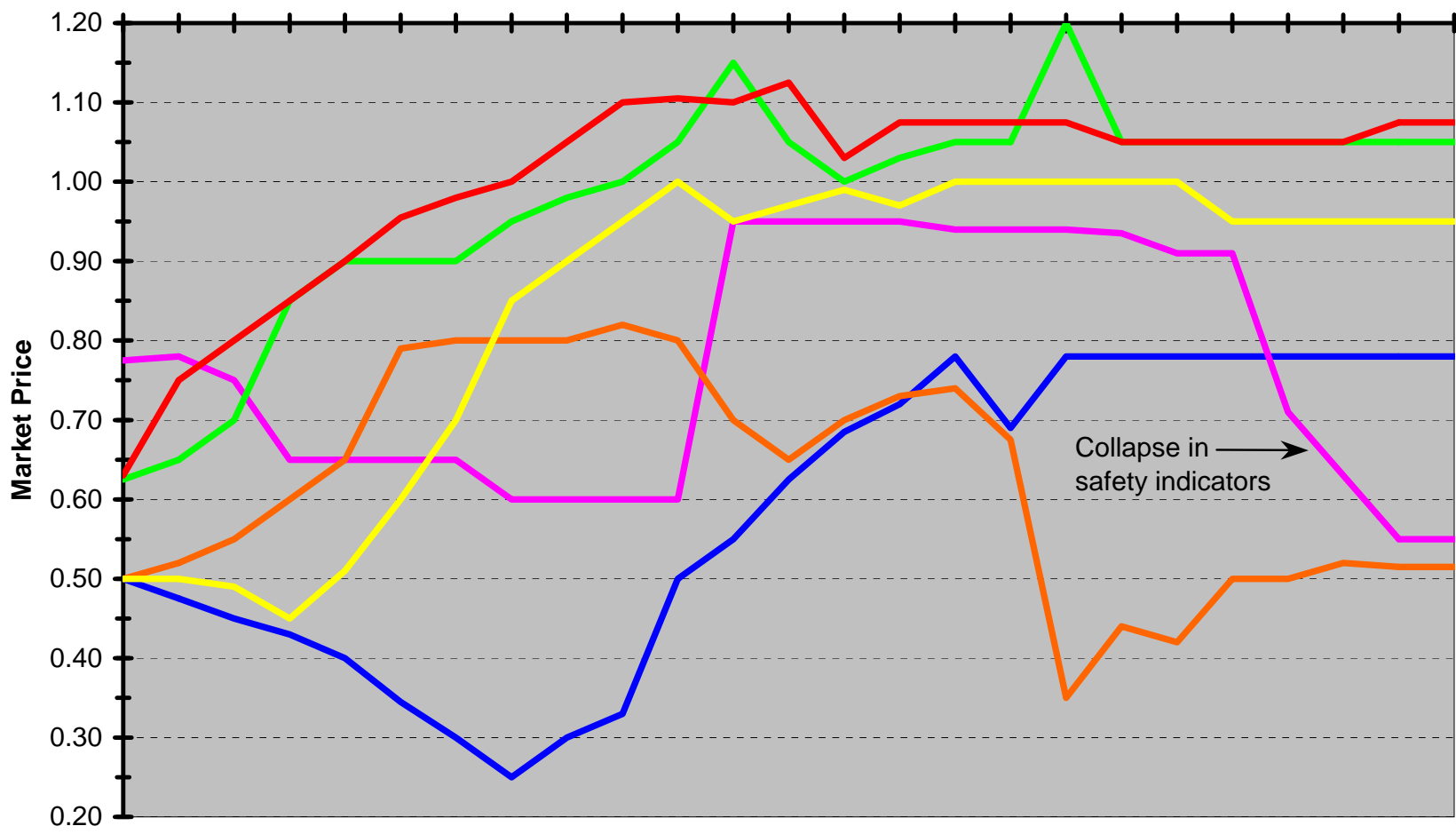




# Pilot Experiment Results

## Price Patterns & Performance Indicators

|         |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Traders | 25 | 24 | 23 | 22 | 25 | 15 | 23 | 21 | 24 | 22 | 18 | 13 | 17 | 12 | 14 | 15 | 11 | 10 | 11 | 12 | 10 | 10 | 11 | 9  | 3  |
| Period  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |



Alpha      Beta      Gamma      Delta      Epsilon      Zeta







# Information Aggregation (Kalovcova 2007)

- Six equally likely possible states
  - A, B, ..., F
  - True state: A
- Five individuals have private signal of true state
  - Represented by balls in an urn
    - A represented by five balls; B – F by two each
- Draws: 

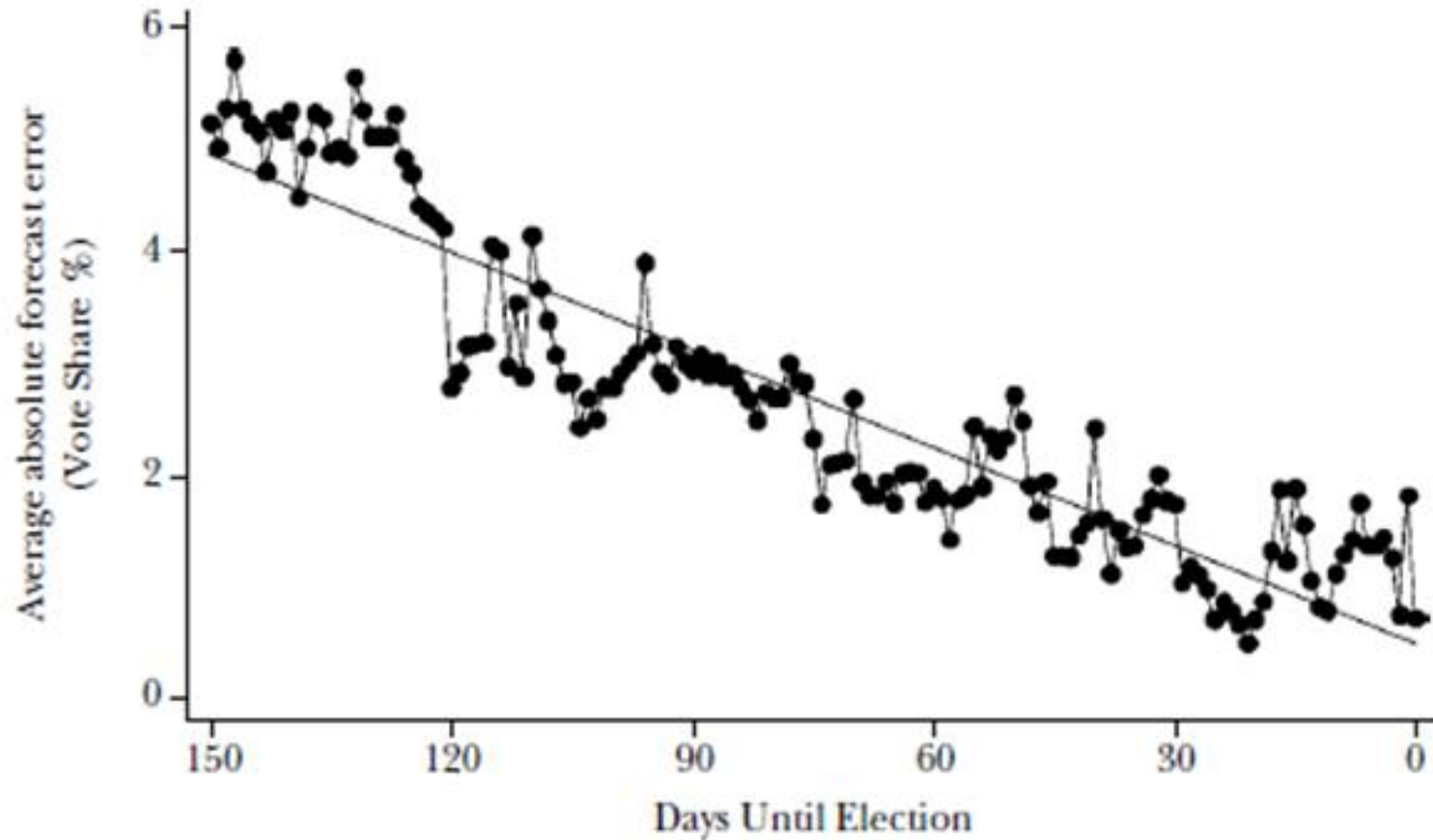
|     |     |     |     |     |
|-----|-----|-----|-----|-----|
| AAB | AEE | ABF | ACD | CDF |
| ↓   | ↓   | ↓   | ↓   | ↓   |
| A   | E   | ?   | ?   | ?   |
- Aggregate Information: AAAA, BB, CC, DD, EE, FF



- HP found results promising for using prediction markets to predict future sales com
- HP and Siemens found motivating employees to trade a major challenge
- Microsoft limits participation to informed traders; uninformed traders are less likely to participate (risks omitting informed trader)



# Iowa Electronic Markets Presidential Elections 1988 - 2000



Source: Wolfers and Zitzewitz 2004



# Anatomy of prediction markets:

## Most common trading mechanisms

- Continuous double auction:
  - Person-to-person selling
  - Needs to be a seller for a person who wants to buy
  - Examples: Intrade, Iowa Electronic Markets
- Market Scoring Rules Mechanism:
  - An algorithm determines prices based on demand for various outcomes
  - Needed when participation is low
  - Example: Inkling Markets



# Most common types of securities

- Winner take all for an event occurring:
  - Price represents probability of event occurring
  - Sarah Palin's price for being 2012 Republican nominee is between 24.4 (bid) and 25.0 (ask)
- Index
  - For continuous variables
    - What will Dow Jones be?
  - Intervals often used instead:
    - N1 Marketplace: What was the unemployment rate going to be for Sept. 2009?
      - Separate securities for:
        - » <9%, 9 – 9.3%, 9.4 – 9.7%, ...





# Limitations

- Participation will often be limited
  - Small # experts for most outcomes
  - Many potential traders don't understand the market
  - Traders will fear some people have huge advantage from insider info
    - E.g., Those who have authority to set SRBs
  - But, uninformed traders are needed for knowledgeable traders to make money and have incentive to play
  - Unlike with stock market, there can be long periods of time with no activity



# Limitations

- Thin markets (from low participation) cause:
  - Less accurate predictions
  - More volatility
  - Need for less ideal Market Scoring Mechanism
- Traders often don't understand short-selling
  - So difficult for people to bet against something



# Limitations

- Manpower outcomes can be self-defeating
  - Suppose there's a market for whether we meet endstrength goal
  - Trader 1 makes a correct assessment that Navy won't meet goal and sells shares
  - Price goes down
  - Navy sees low probability of meeting goal
  - Navy ups reenlistment bonuses
  - Now Trader 1 will lose money
  - (Are there similar potential problems for Acquisitions?)



# Lessons learned: need to phrase questions very clearly

- Inkling question: Did Juliet die on Lost? Question will close January 28, 2010 @ 09:34pm PST
  - Nope **\$26.51/ \$100.00 (closed)**
  - Yes....well as far as we know \$17.36/ \$0.00 (closed)
  - Sort of but reincarnated \$21.19/ \$0.00 (closed)
  - Who knows - Alternative reality \$34.94/ \$0.00 (closed)
- Our question, posed August 7, 2009:
  - Will the Dow Jones Industrial Average (INDU) close above 9,400 by COB on Friday, Aug. 14, 2009?
  - Dow closed at around 9395 on August 12

