

Mini-Conference on
INFORMATION AND PREDICTION MARKETS

Individual Behavior and Beliefs in Parimutuel Betting Markets

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Aim of the paper

Study experimentally individual and market level behavior in a parimutuel betting market with asymmetric information

- Is the market an efficient **information aggregation** device?
- Are **herd behavior** driven by informational externalities / **contrarian behavior** driven by negative payoff externalities important forces?
- Do **belief elicitation** procedures affect bettors' behavior and the market informational efficiency?

Motivation

- Bettors in a parimutuel betting market face a decision problem with the essential features of the one confronting investors in a financial market
Is it better to be a net buyer or a net seller given:
 - The current market price
 - One's private information
 - Beliefs about the rationality of other market participants
 - The history of trading activity
- Parimutuel betting markets provide a tractable setting to study how individuals use the types of information given above

- The “rules of the game” are unambiguously defined
- There is a well-defined **termination point** at which the value of each bet becomes certain

Ⓐ Markets outcomes are clearly and repetitively observable

Contributions of the paper

- **(i) Model evaluation:** Apply an Adaptive Model, that predicts behavior in our betting market, and test how well it performs
 - Consider whether statistical generalizations of the model can explain observed deviations
- **(ii) Impact of beliefs:** Explore whether elicitation of beliefs affects/improves betting decisions, the market's capacity to **aggregate information**, and consistency with the Adaptive Model
 - Does the placing of bets affect/improve belief statements?
 - Does being observed by others who submit belief statements affect betting decisions?

Related experimental work (incomplete)

- Anderson and Holt (1997, AER), Hung and Plott (2001, AER), Kübler and Weizsäcker (2004, RES)
- Plott, Witt and Yang (2003, ET), Drehmann, Oechssler and Roider (2005, AER), Cipriani and Guarino (2005, AER)

Parimutuel betting markets

- The origin of parimutuel markets lies in **horse-race betting**
- Individuals directly place bets on horses
- If the horse chosen by an individual wins, then his investment yields returns that are decreasing with the proportion of bettors who bet on the same horse (**negative payoff externalities**)
- The proportion of the money that is bet on any given horse is interpreted as the **subjective probability** that this horse will win the race

A sequential betting game

- Horse race of **two horses**: A and B
- **8 bettors** who **sequentially** choose (in a predetermined order, with **perfect monitoring**) between “betting one unit of money on horse A ” and “betting one unit of money on horse B ”. Bettor i chooses s_i in $\{A, B\}$
- Bettors have a **common flat prior belief** over the set of states {“horse A wins”, “horse B wins”}
- The winning horse is revealed only after all individuals have submitted their bets

Each bettor i gets a **private signal** q_i that is correlated to the true state of Nature

$$\Pr(q_i = a \mid A) = \Pr(q_i = b \mid B) = 3/4$$

$$\Pr(q_i = a \mid B) = \Pr(q_i = b \mid A) = 1/4$$

\Rightarrow Signal **a** is in favor of horse **A** whereas
Signal **b** is in favor of horse **B**

Conditional on the state of nature, signals are independent

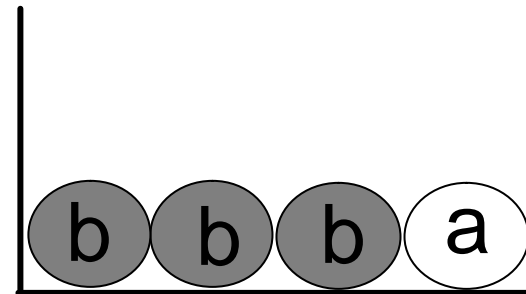
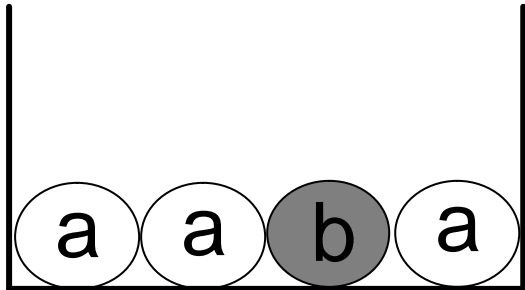
Nature

50 %

50 %

Horse *A* wins

Horse *B* wins



- Vector of bets $\mathbf{s} = (s_1, s_2, \dots, s_8)$
- $h(s)$ = number of individuals who bet on horse H
- **Odds against horse A:** $O_A(s) = b(s) / a(s)$
- **Odds against horse B:** $O_B(s) = a(s) / b(s)$
- If bettor i bets on the winning horse H then his payoff is :

$$1 + O_H(s) = 8 / h(s)$$

- If bettor i bets on losing horse, his payoff equals 0

Main Features of the Market Game

Strategy of bettor i depends on his signal (private information) and on the history of bets (public information)

- **Information Externalities:** Bets of previous bettors can reveal their private information to subsequent bettors
 - ⇒ More bets on horse A should indicate more private signals favoring horse A
 - ⇒ Can generate **herd behavior** \hat{U} The bettor bets on the favorite even if his private signal is in favor of the longshot
- **Negative payoff externalities:** Bets on a given horse **decreases** the return of this horse
 - ⇒ Can generate **contrarian behavior** \hat{U} The bettor bets **against** the favorite even if his private signal favors the favorite

Experimental Setup

- 8 sessions conducted at Louis Pasteur University in Strasbourg (France), using 176 students (computerized experiment)
- 20 rounds, of 8 periods (*partners design*)
A period refers to the betting decision of one individual
- The same profiles of private signals were used in all sessions, though the profiles differed between rounds within a session

3 Treatments

- T1: Standard betting environment.

Each of the 16 participants is randomly assigned to two independent groups of eight people to play 20 rounds of the betting game

- T2: Betting vs. predicting.

One group of eight participants make bets by knowing that another group observe their decisions

The other eight participants are asked, in each period of each round, to key in a probability vector which represents their **beliefs** about the likelihood that horse *A* or horse *B* wins the race

Subjects' assessments in the second group are rewarded on the basis of a **quadratic scoring rule**

- T3: Betting plus predicting.

Each of the 16 participants is randomly assigned to two independent groups of eight people to play 20 rounds of the betting game

Each participant is **additionally** asked to state his **beliefs** about the likelihood that horse *A* or horse *B* wins the race

Subjects' assessments are also rewarded on the basis of a **quadratic scoring rule**

Null Hypothesis: The Adaptive Model (Koessler and Ziegelmeyer, 2004)

- Each bettor uses the sequence of bets to infer bettors' private signals whenever possible
 - This requires players to distinguish between informative and uninformative bets
- The inferred signals and own private information are used to construct a probability estimate of each horse winning
- Bettor bets on horse with the higher expected payoff given this probability estimate and the current odds
- Bettor takes into account the effect of his own bet on the odds but ignores the impact of his action on later bettors' decisions and how they affect the odds (limited foresight)
- Unique prediction at each decision node (? Nash, sequential equilibrium)

- An alternative decision rule: **Private Information plus Odds heuristic**, under which bettors use only the odds and their private information

Main results

1. Greater information aggregation in T3
 - Less frequent failure to herd when appropriate
 - Less contrarian behavior
 - ⇒ much smaller FLB
2. The Adaptive Model (AM) describes behavior very well in T3, and a statistical generalisation (QRAM) provides a good fit to the data from all three treatments

3. Belief statements are both more accurate and more consistent with market activity when agents stating beliefs are also placing bets

4. Public knowledge that beliefs are being elicited is insufficient to improve decision making. Bettors must be stating their own beliefs to induce an improvement of their betting decisions

Market behavior: Prices and information aggregation

- **Subjective prob.** of A :

$$P_A(s) = a(s) / (a(s)+b(s))$$

- **Objective prob.** of A :

$$\Pr(A \mid q_1, q_2, \dots)$$

- **Observable signals subjective prob.** of A :

$P^{\text{OS}}_A(s)$ = subjective probability in a hypothetical market with public observation of previous signals

- Information aggregation measured by:

$$IA = (V_{max} - V) / V_{max}$$

where

$$V = \sum_{q^8 \in Q_E^8} \frac{1}{20} | P_A^{OS}(q^8) - P_A(q^8) |$$

$$V_{max} = \sum_{q^8 \in Q_E^8} \frac{1}{20} | P_A^{OS}(q^8) - 1/2 |$$

Result 1. Elicitation of beliefs improves information aggregation

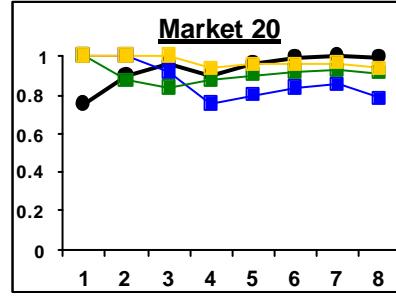
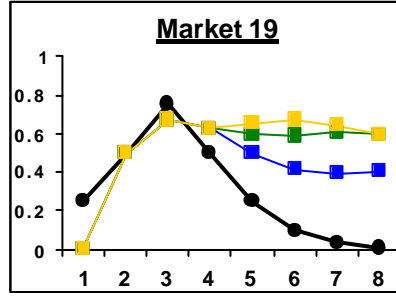
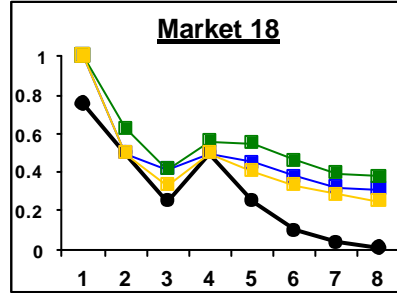
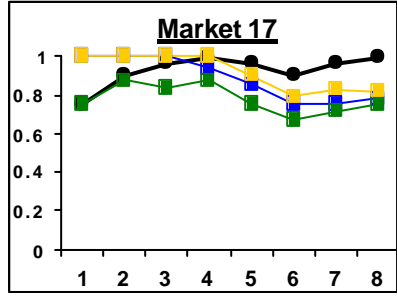
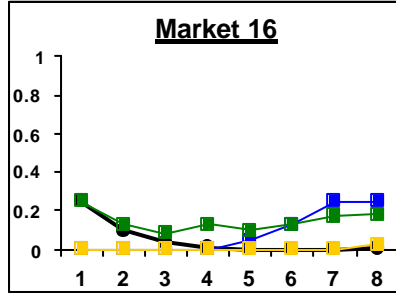
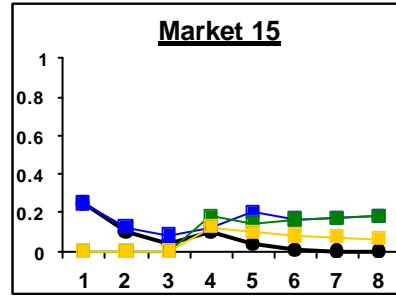
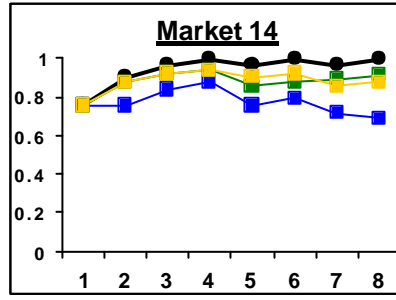
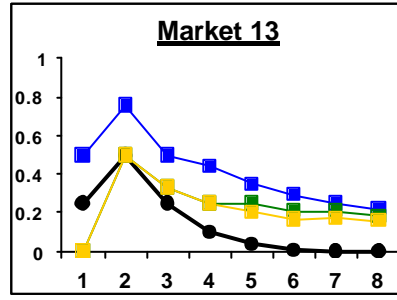
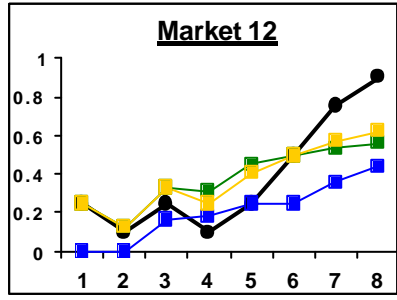
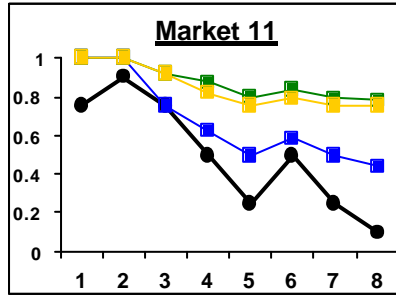
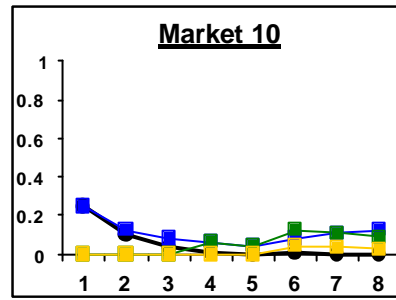
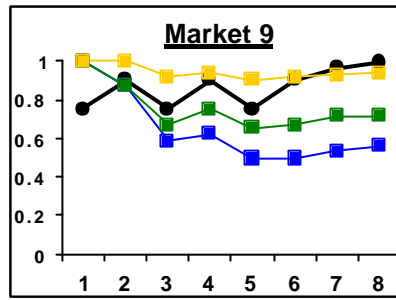
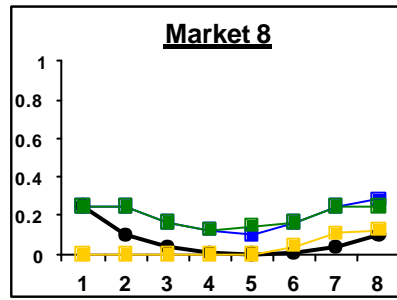
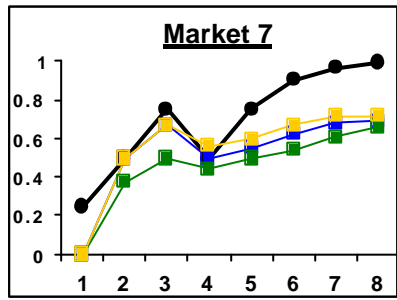
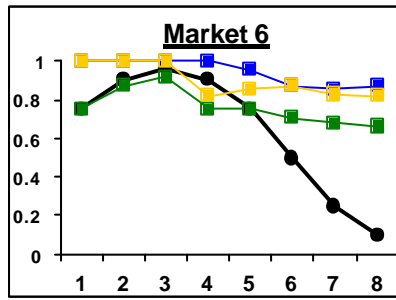
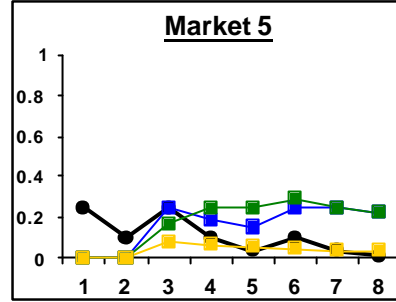
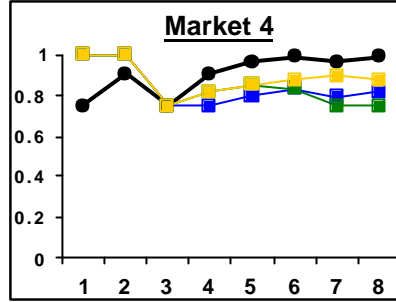
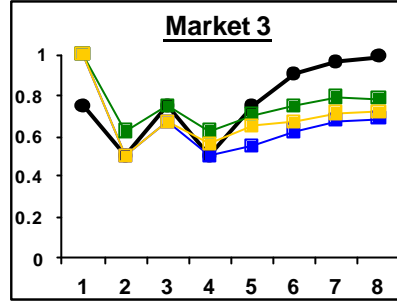
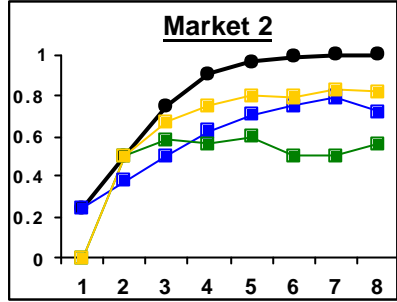
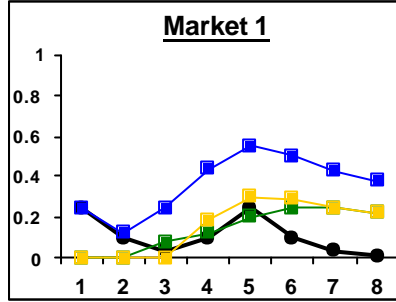
(IA = 50% in T1, 53% in T2, 68% in T3)

Deviations are consistent with a favorite-longshot bias. The bias is sharply reduced when bettors' beliefs are elicited

The level of information aggregation is lower than under the AM (IA = 87% in AM)

A's Objective vs. Subjective Prob.

T1 T2 T3



Individual behavior: Bets placed

Result 2. Individual bets in all treatments provide strong support for the Adaptive Model

The formulation of both bets and belief statements improves the predictive performance of the AM

In all treatments, the AM correctly predicts more individual betting decisions than the private information plus odds heuristic

Adequacy with predictions (hit rates)

	Treatment 1	Treatment 2	Treatment 3
Adaptive Model	81 %	81 %	87 %
Private information heuristic	75 %	68 %	66 %

Result 3. Elicitation of beliefs almost completely eliminates contrarian betting and reduces the incidence of the failure to herd

However, it does not reduce the incidence of incorrect herding

Observed deviations from the AM

	Treat. 1	Treat. 2	Treat. 3
Contrarian behavior	10.5 %	11.5 %	3.1 %
Incorrect herding	22.1 %	29.5 %	34.4 %
Failure to herd	58.5 %	41.8 %	38.6 %

- Statistical model: **Quantal Response AM**
(McKelvey and Palfrey, GEB 1995, EE 1998)

$$e^{IU_i(H|s^{i-1};q_i)}$$

$$\Pr(i \text{ bets on } H) = \frac{e^{IU_i(H|s^{i-1};q_i)}}{e^{IU_i(A|s^{i-1};q_i)} + e^{IU_i(B|s^{i-1};q_i)}}$$

	T1	T2	T3
Response precision parameter λ	2.890 (0.193)	2.837 (0.257)	7.184 (0.590)
- Log Likelihood	277.3	301.7	188.0

Simulated deviations from the AM

	QRAM's precision parameter		
	3	5	7
Contrarian behavior	11 %	4 %	1 %
Incorrect herding	32 %	33 %	34 %
Failure to herd	51 %	40 %	36 %

Remainder : Observed deviations from the AM

	Treat. 1	Treat. 2	Treat. 3
Contrarian behavior	10 %	11 %	3 %
Incorrect herding	22 %	29 %	34 %
Failure to herd	58 %	42 %	39 %

Result 4. Contrary to Noisy AM, QRAM captures the pattern of deviations from the AM observed across the three treatments

QRAM outperforms step-k-QRAM in predictive power: assuming limited depth of reasoning does not improve predictions

The belief elicitation procedure reduces the estimated incidence of commonly known errors as measured by the parameter λ

Individual behavior: Belief statements

Result 5. When the same individuals both place bets and state beliefs, there is greater **consistency between bets and belief** statements than when different individuals place bets and state beliefs

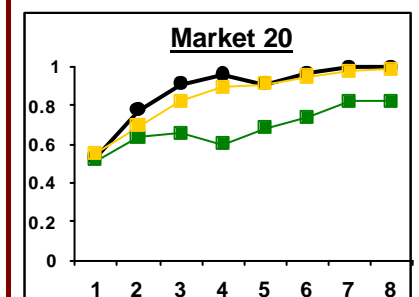
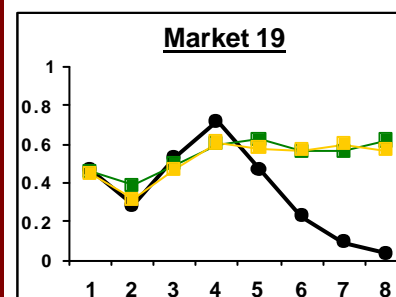
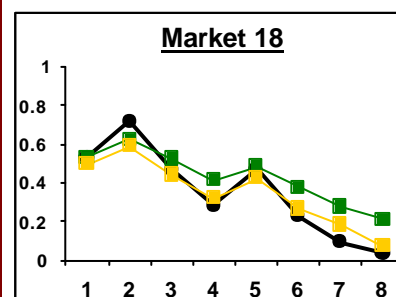
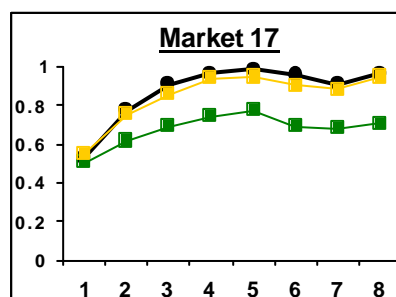
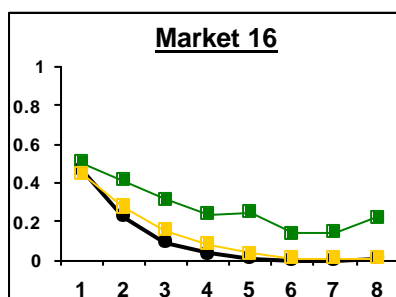
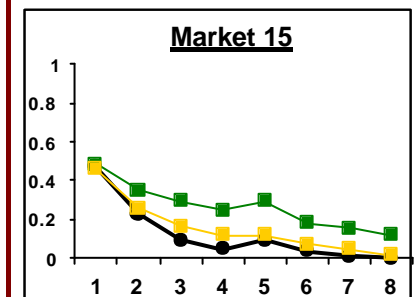
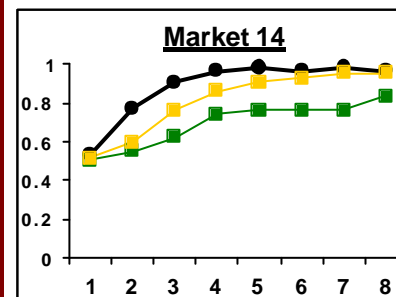
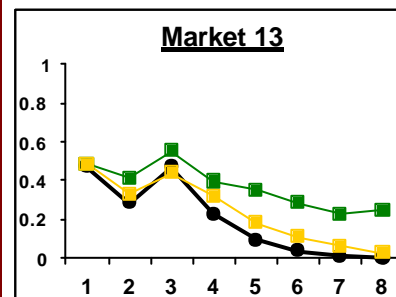
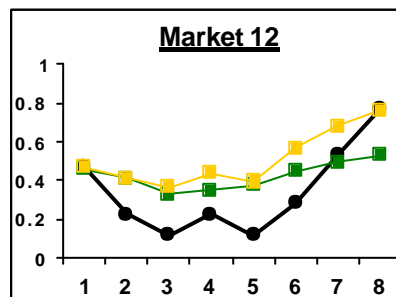
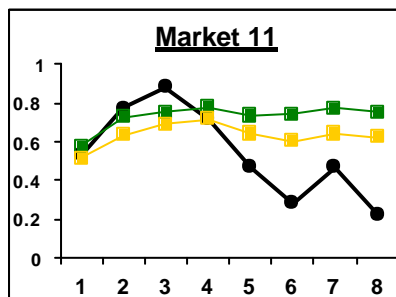
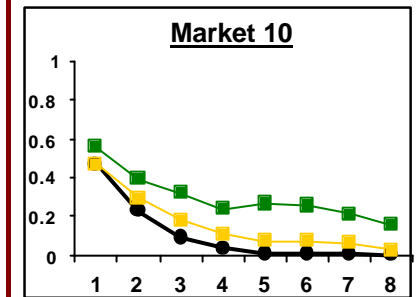
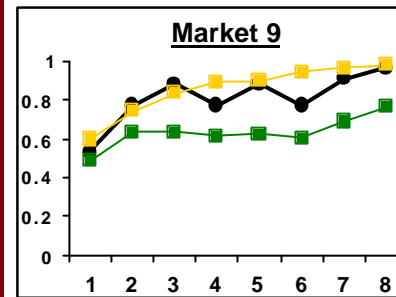
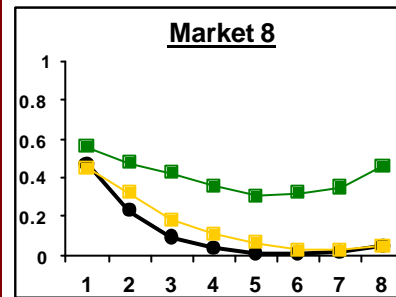
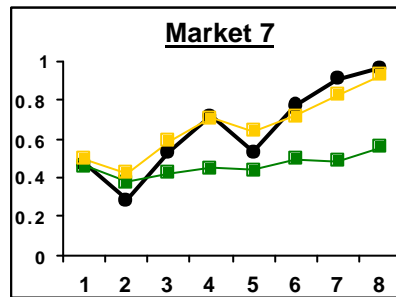
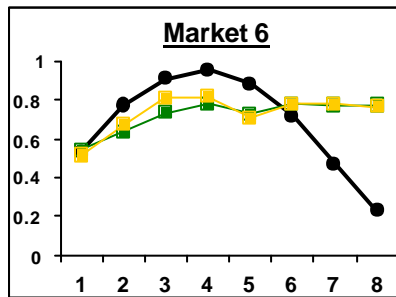
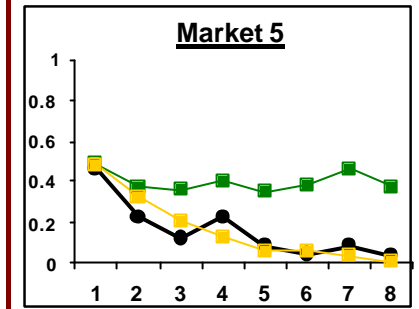
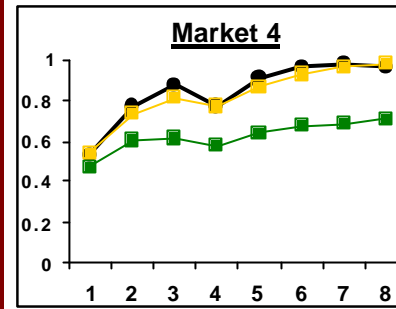
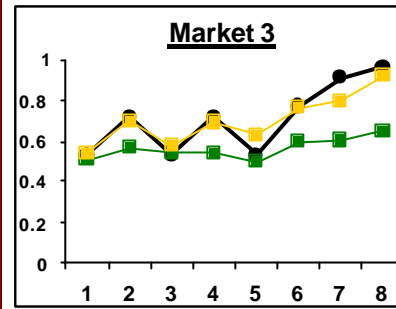
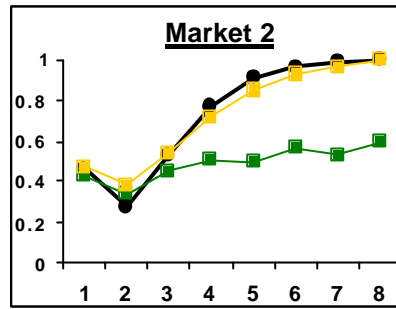
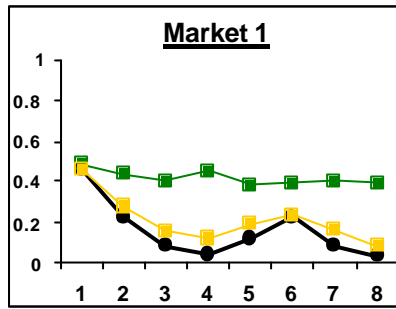
Support. The average absolute difference (i) between belief statements and subjective probabilities, or (ii) between belief statements and estimated QRAM's beliefs, is significantly larger in T2 than in T3

Result 6. Placing bets improves the accuracy of belief statements

Support 1: Subjects' stated beliefs in T3 lead to payoffs that are 15 % higher than in T2

A's Objective vs. Stated Prob.

T2 T3



Average Absolute Difference between Stated Beliefs and Objective Probabilities

	Treatment 2	Treatment 3
per period	0.202	0.088
in the last period	0.302	0.091

Conclusion

- Eliciting subjects' beliefs affects their betting behavior, improves the market informational efficiency, and corrects almost perfectly the contrarian behavior bias
- Playing the betting game improves the accuracy of belief statements
- The success / failure of information aggregation can well be understood with the AM and its statistical generalization QRAM