

The Interactive Minority Game

INTERACTIVE MINORITY GAME

web-based investigation of human market interactions

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SCORE

13

13.00

per turn

agents (94)
comparison:

best:	13
avg.:	-6.5
worst:	-13

1 turns

**STOP
GAME**

You must play 200+ turns to challenge for the hiscore.

(that means you buy)



down

up



(that means you sell)

An empirical approach to economic complexity

- Much of the economic literature has been characterised by ‘pure theory’ that (often deliberately) ignores the realities of human behaviour
- If we want to get a handle on economic complexity we need empirical data—on both small and large scales
- ... and since economic systems are complex, we need experiments that attempt to recreate these complex situations

Overview

- The Minority Game: agent-based market modelling
 - A recap of the game
 - Some of the key observed results
- Mixing simulation and experiment: the *Interactive Minority Game*
 - Experimental setup
 - Observed behavioural patterns
 - What information do human players make use of and why?
- The Interactive Minority Game version 2

The Minority Game

- At each time step, t , N players have to choose independently between two actions, +1 (buy) and -1 (sell)
- When everyone has decided, agents gain or lose according to the formula,

$$g_i(t) = -a_i(t)A(t)$$

where $A(t) = \sum a_i(t)$ is the aggregate market action

- Agents use simple strategies to map market histories to actions

D. Challet & Y.-C. Zhang (1997), *Physica A* **246**, 407-418

D. Challet & M. Marsili & Y.-C. Zhang (2005), *Minority Games* (Oxford UP)

A. C. C. Coolen (2005), *The Mathematical Theory of Minority Games* (Oxford UP)

The Minority Game (II): Agent strategies

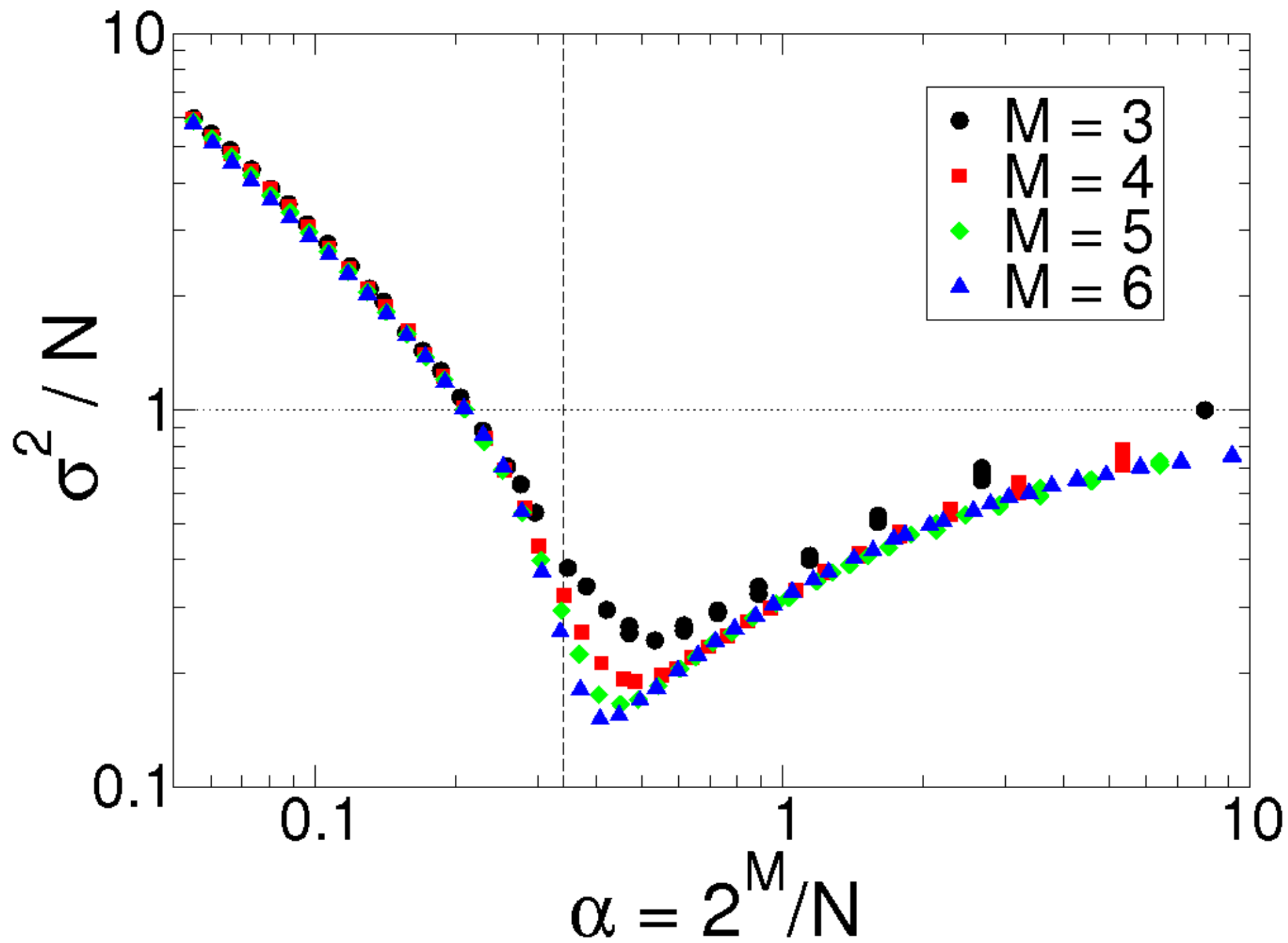
- Agents look at the last M price turns and map the sequence of aggregate outcomes (+ or -) to a suggested action. e.g. for $M = 3$:

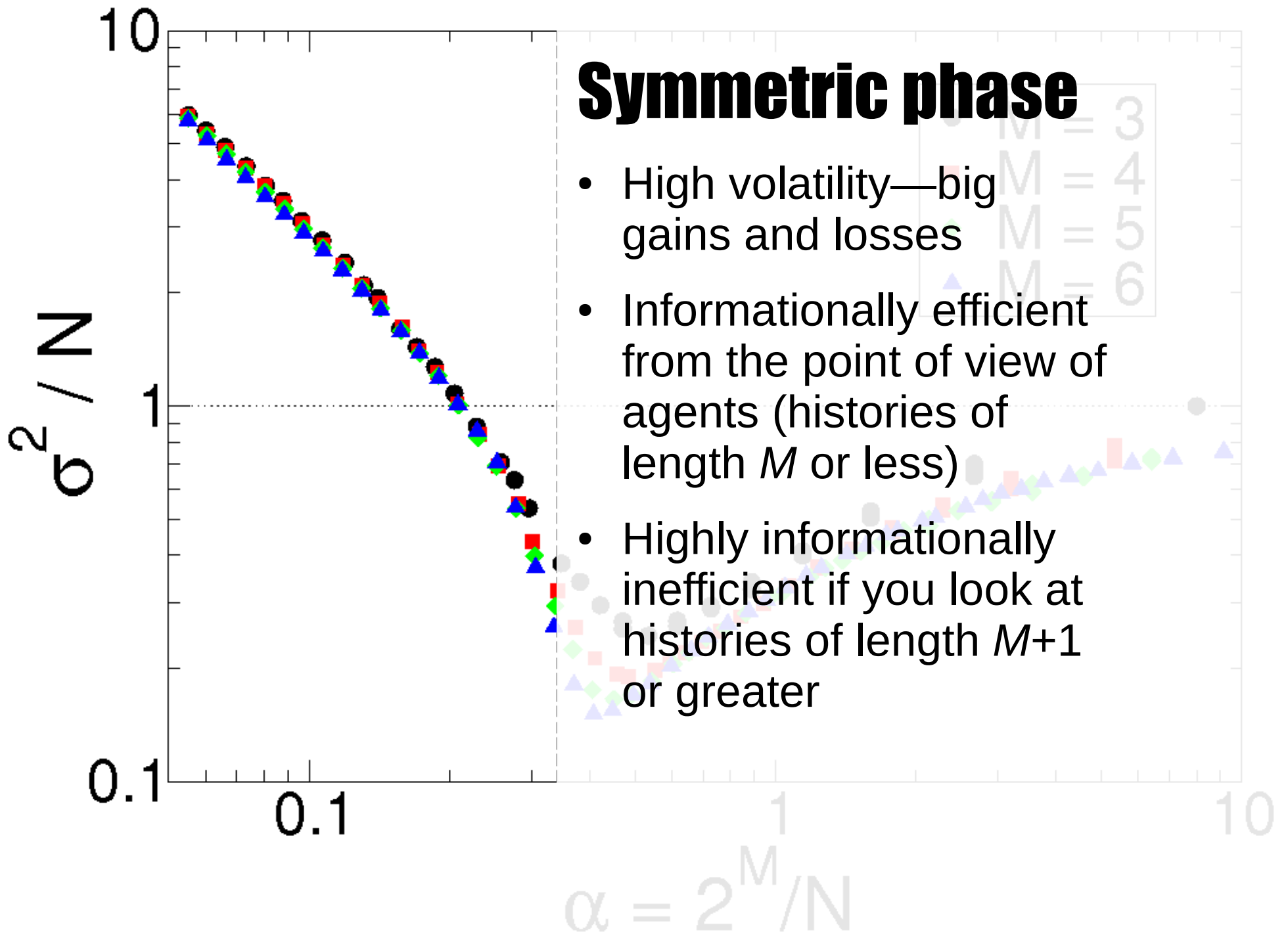
Market history	Action	Market history	Action
---	-	---	+
--+	+	--+	-
-+-	+	-+-	-
-++	+	-++	-
+--	-	+--	+
+ - +	-	+ - +	+
++-	+	++-	+
+++	-	+++	-

- Agents have S (usually 2) such strategies and keep score for them according to the success of their predictions—and use at any given time the highest-scoring strategy.

The Minority Game (III): Key analytical results

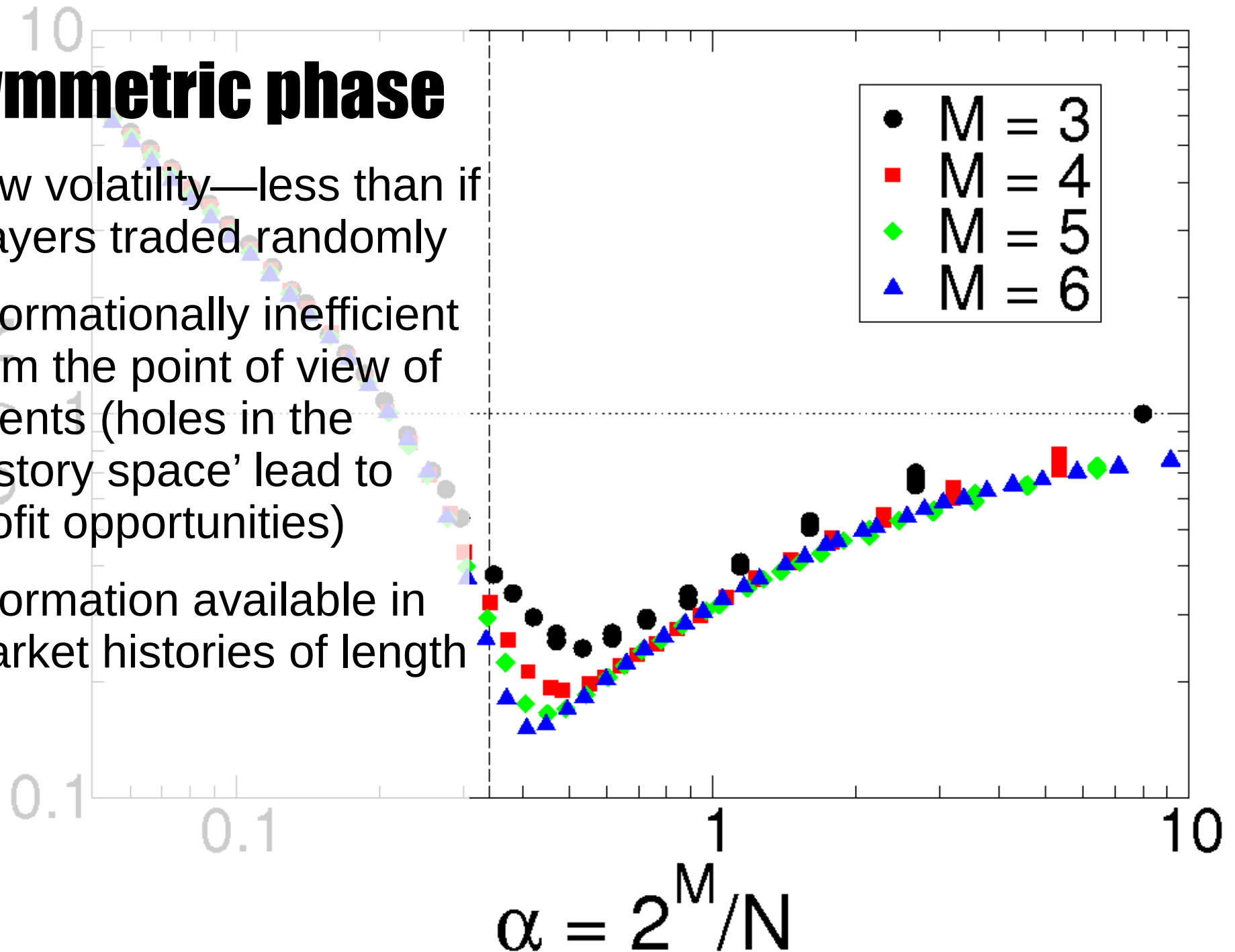
- The Minority Game is very well understood on the basis of both computer simulation and extensive analytical results
- The key result we need to be aware of here is a transition between two distinct market phases, that depends on the ratio $\alpha = 2^M/N$
- We can see this transition by looking at the variance (volatility) of the market movements, $\sigma^2/N = \langle A^2 \rangle/N$





Asymmetric phase

- Low volatility—less than if players traded randomly
- Informationally inefficient from the point of view of agents (holes in the ‘history space’ lead to profit opportunities)
- Information available in market histories of length M



The *Interactive* Minority Game: Mixing simulation and experiment

- The idea: use the complex (but understood) dynamics of the simulated Minority Game to provide a trading environment for a human player
- We can translate the history of the game into a 'price series' by the formula $P(t+1) = P(t) + A(t)$
- Using a Flash interface we were able to make the game widely accessible on the world wide web

P. Laureti, P. Ruch, J. Wakeling & Y.-C. Zhang (2004), *Physica A* **331**, 651-659



INTERACTIVE MINORITY GAME

'Are playing... please not disturb'

[BACK](#)



SCORE

13

13.00

per turn

agents (94)
comparison:

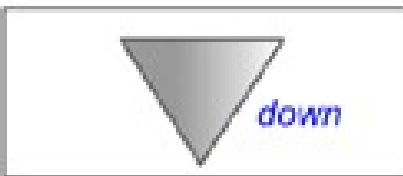
best:	17
avg.:	-6.5
worst:	-13

1 turns

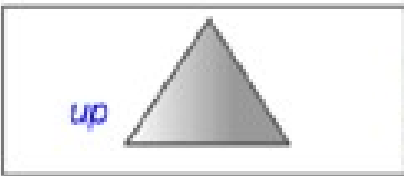
STOP GAME

You must play 200+ turns to challenge for the hi-score.

(that means you buy)



Bet on next price move



(that means you sell)

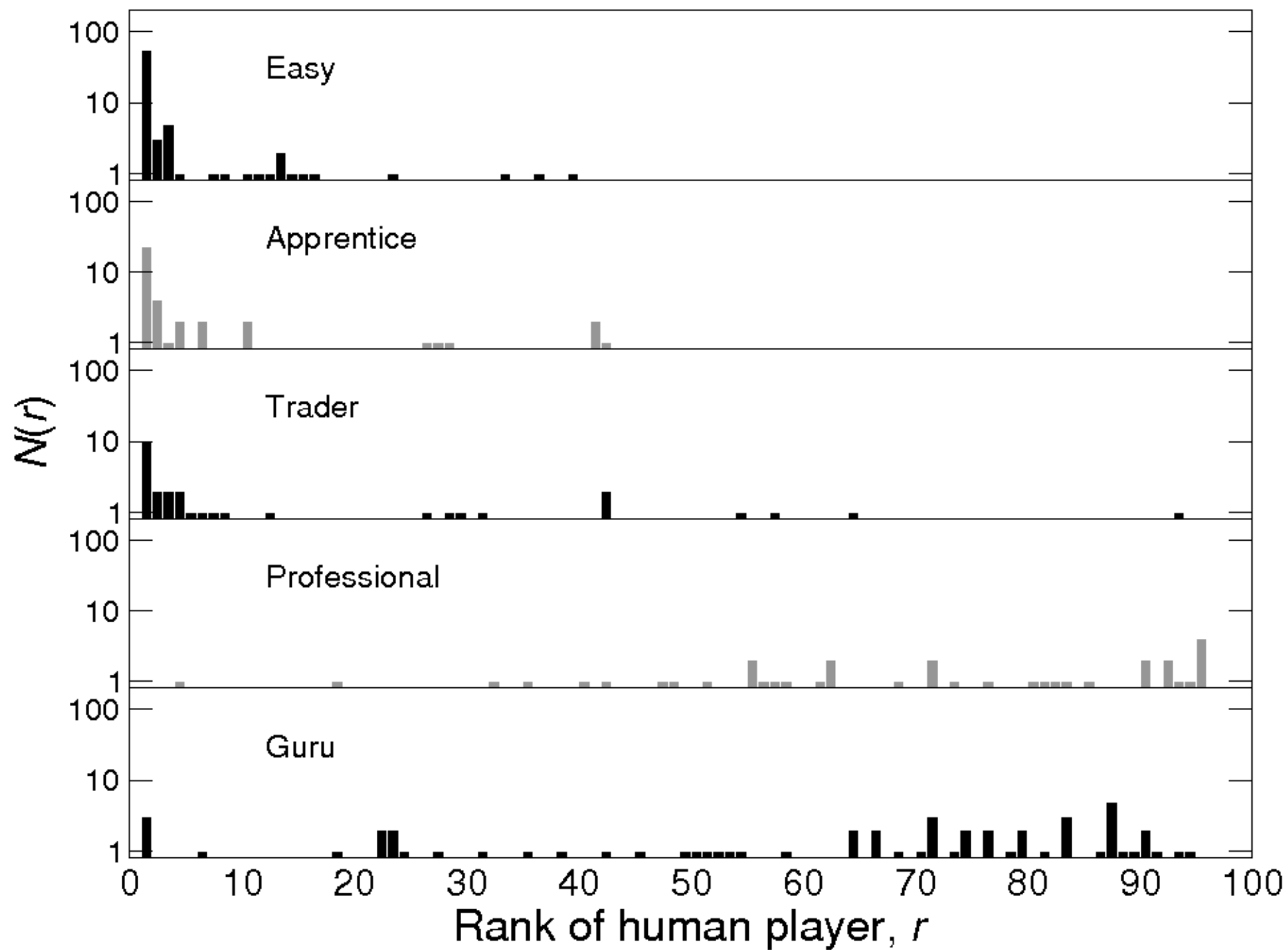
The Interactive Minority Game: Results (I)

- Hundreds of individuals played tens of thousands of game turns
- Players could choose from 5 different difficulty levels with different game properties:

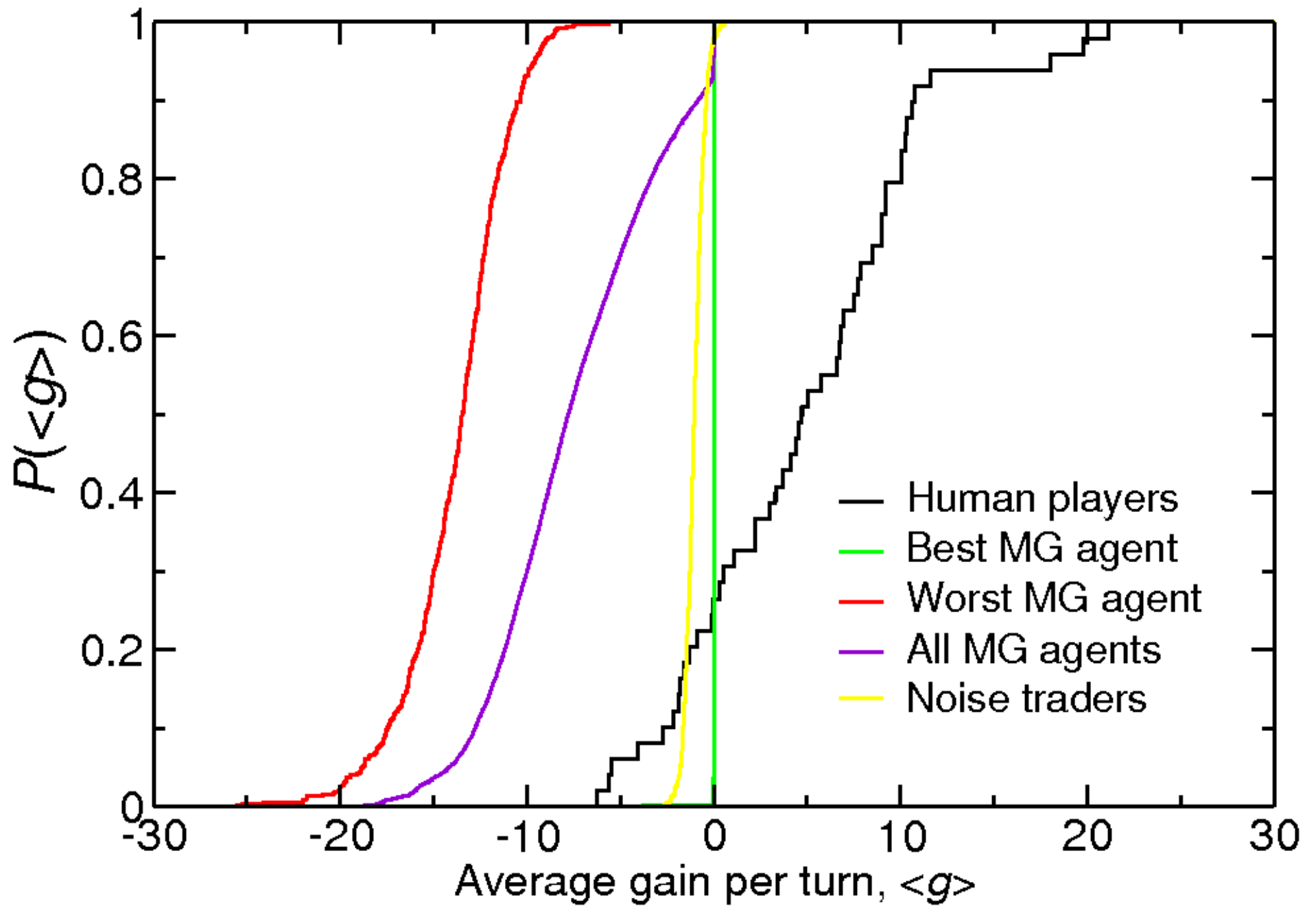
Level	Agents' memory, M	α	Market phase	Volatility ^a σ^2/N	No. of game turns played by humans ^b
Easy	2	0.04	Symmetric	7.58	15,400
Apprentice	3	0.08	Symmetric	3.71	11,000
Trader	4	0.17	Symmetric	1.46	9,400
Professional	6	0.67	Asymmetric	0.25	9,800
Guru	Mixed values	—	Asymmetric	0.24	16,000

^aData from simulations. $\sigma^2/N = 1$ means that fluctuations are the same as if agents were playing randomly.

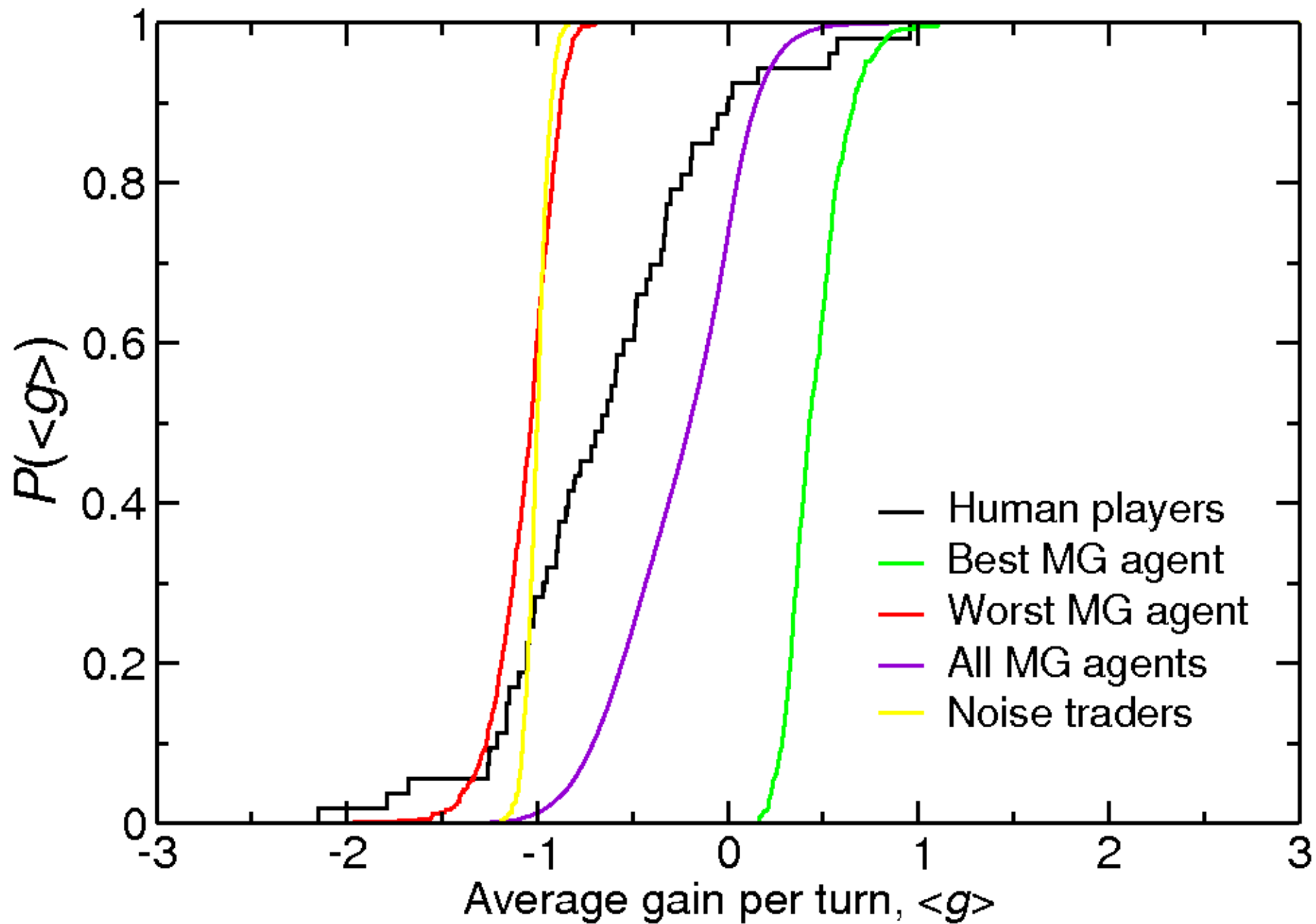
^bData taken up until 05/2003. Note that this statistic only includes games of more than 100 turns in length.



Easy



Guru

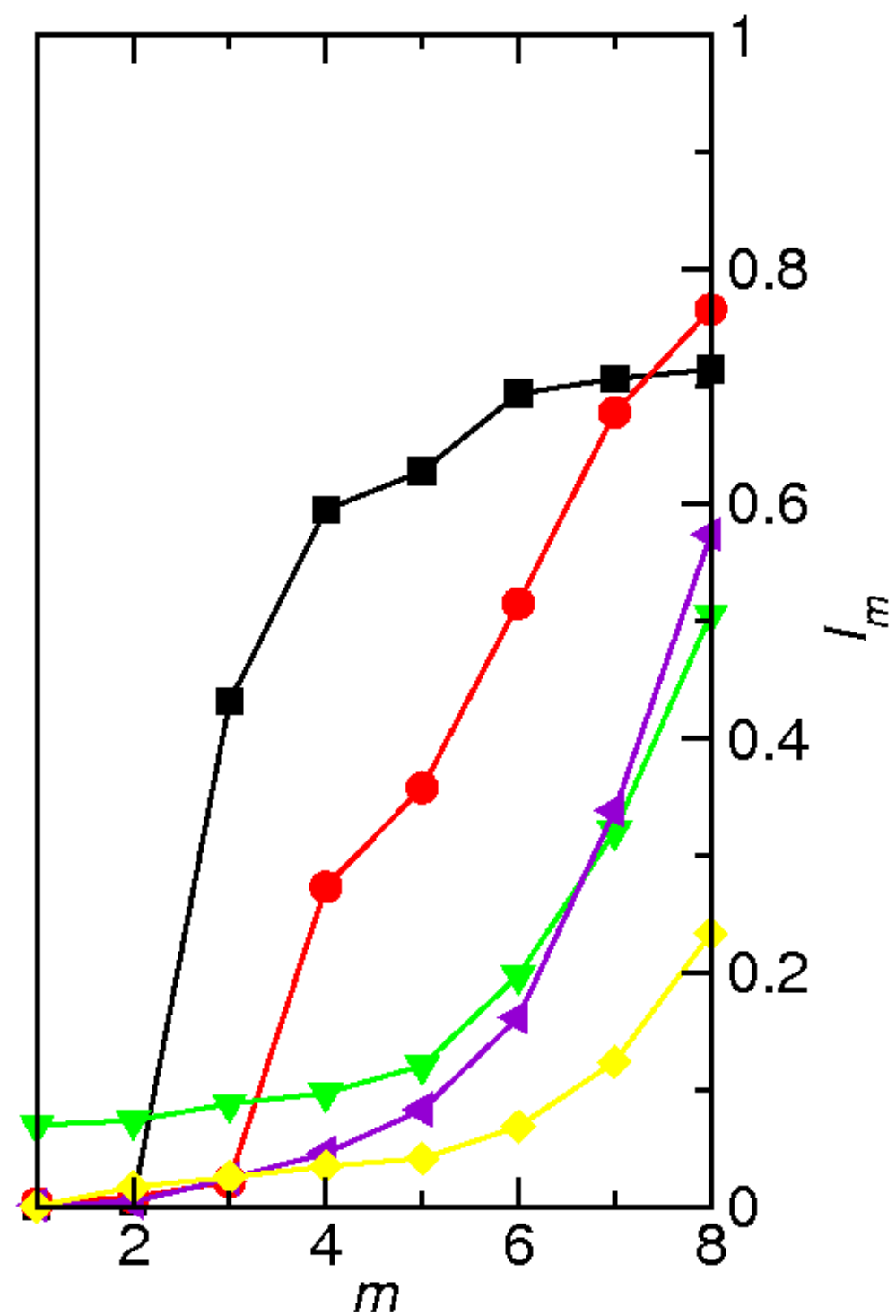
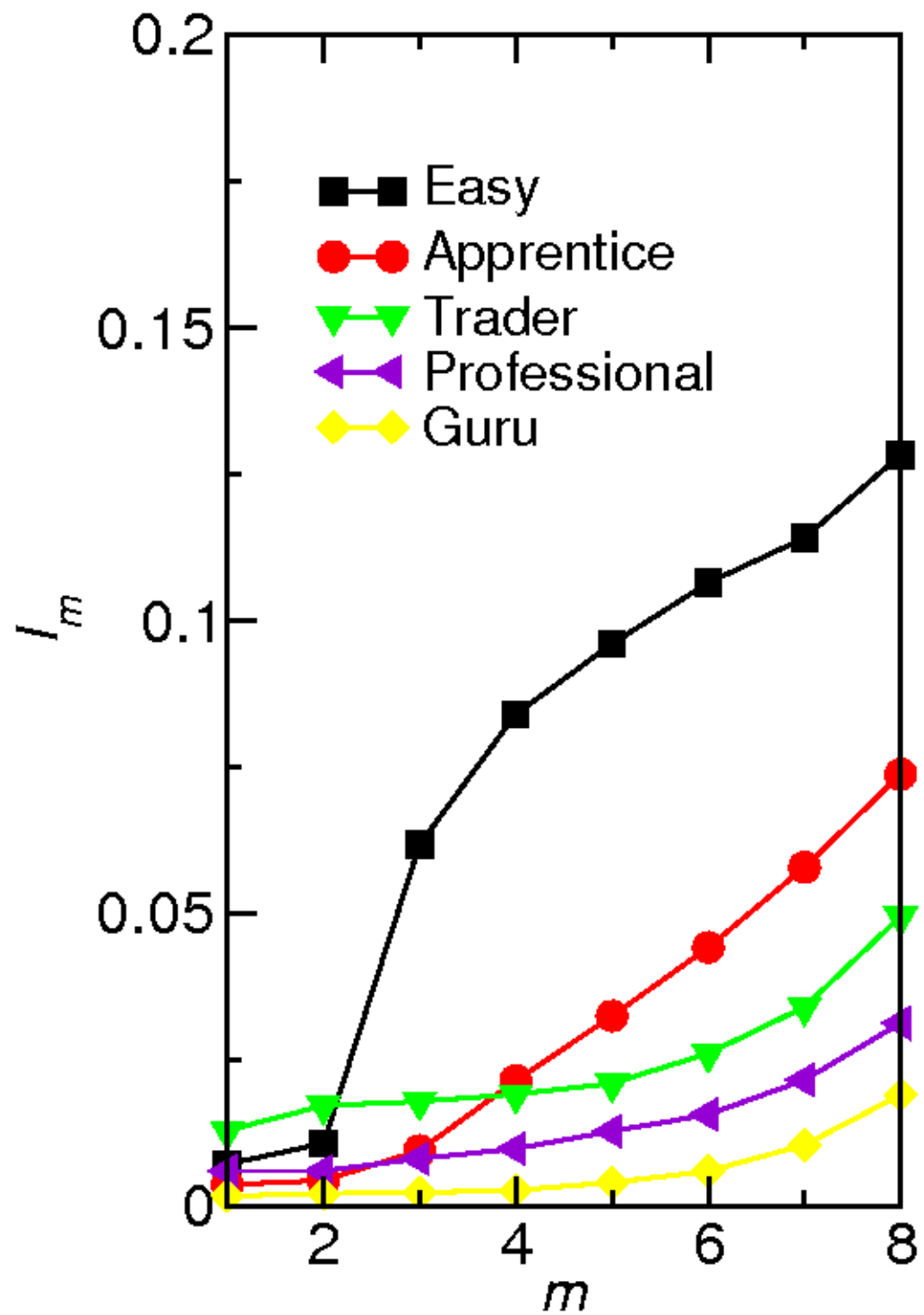


Analysing behaviour: the Information Gain Ratio

- Claude Shannon's information entropy can be used to define a measure of predictability of one set of events with respect to another:

$$I(Y|X) = 1 - \frac{H(Y|X)}{H(Y)}$$

- This takes values of 1 if Y is completely predictable with respect to X , 0 if it is not predictable at all
- Here we look at the predictability of human decisions with respect to market histories of length m .



Behavioural changes

- We observe a striking change in performance and behaviour between the three easier markets and the more difficult ones
- In the easier levels players outperform the computer agents and there is evidence that (at least the best) players are making concrete use of information we know is present in the market
- As the markets become more difficult players start ignoring the market history and engaging in very repetitive behaviour (at Professional and Guru level, players repeat previous action with probability ~ 0.8).
- The latter behaviour recalls what players do when groups of people play the Minority Game together.

Possible mechanisms

- Players' behaviour is not mindless—they consistently outperform random decision-making.
- There are a number of factors that could be responsible for the behavioural transitions observed:
 - Increasing agents' M may mean there are too many patterns to keep track of in working memory
 - As fluctuations become smaller, it becomes more difficult to act on information without changing the outcome
 - Differences in patterns generated in the symmetric and asymmetric phases

IMG version 2

- Our old server got axed, so we thought we'd take the opportunity to revamp the IMG before relaunching it
- Although it looks nice, a Flash interface has some disadvantages (proprietary, less flexible from a development/simulation point of view)
- Aim for Version 2: to have a system which can be freely developed and which you can plug into an arbitrary simulation (Minority Game, \$-game, a fixed price series, a group of other human players....)
- New version is being developed in Java (free[er], truly cross-platform)
- We aim to launch the new version before Christmas

IMG version 2 — longer-term goals

- We want to relaunch the Interactive Minority Game but also make it easier for it to be adapted to other, similar experiments (by us or others)
- Currently the simulation is part of the Java applet—we need to develop an effective client-server interaction (to allow for e.g. multiplayer games and to allow users to write their simulations in their preferred languages)
- There is a need for customisation features so you can adapt what the buttons do, or permit the user to buy/sell larger or smaller amounts or propose a price (as with limit orders), preferably WITHOUT having to delve into the code

Conclusions (I)

- The Minority Game provides a complex but comprehensible environment for experimentally investigating economic strategies and ability
- We observed a stark transition between exploitation of patterns in the market history (leading to victory over computer agents) and repetitive behaviour that ignores market history
- Players consistently outperform random decision-making
- Suggests a transition along the lines described by W. Brian Arthur: ‘beyond a certain level of complexity human logical capacity ceases to cope’—perhaps between *deductive* and *inductive* thinking

Conclusions (II)

- These experiments should be taken further—not only our own but with other, related games
- We want to build a tool to make this easier—an interface that can be used as a front-end to arbitrary simulations and other games
- If you're interested in working on this kind of thing or it would be useful for projects of your own, get in touch!

Thanks ...

- to my co-workers: Paolo Laureti, Peter Ruch, Yi-Cheng Zhang, Zike Zhang
- to Fribourg University's Chemistry department for hosting the original game
- to Fabio Mariotti, Maya Paczuski and Duncan J. Watts for lots of useful comments and advice
- to everyone who played the game
- ... and to all those who are being patient while we rebuild it after the chemistry department server was axed :-)
- Comments please to: joe@nbi.dk