

Information aggregation in Arrow-Debreu markets

An experiment

Can market prices fully disclose the true state of the world when traders have identical or homogeneous partial private information? Lawrence Choo, a post-doctoral researcher at the University of Erlangen-Nuremberg and research fellow at the University of Haifa, Todd R Kaplan, Professor of Economics at the University of Exeter Business School and Associate Professor in the Department of Economics at the University of Haifa, and Ro'i Zultan, Associate Professor of Economics at Ben-Gurion University, are addressing this question in their research into the information aggregation properties of markets.

Prediction markets effectively bet and trade on the outcomes of future events. The market prices can indicate what the crowd thinks the probability of the event is. The use of prediction markets is becoming increasingly widespread within both governments and private corporations.

The notion that markets can combine information from various sources and translate it into prices underpins much thinking in economics and finance. Given a mix of fully and partially informed traders, prices will converge as a result of competitive bidding, reflecting the true state and revealing information to uninformed traders. When all traders are only partially informed about the true state, however, things become more complex. If the traders understand how their information affects behaviour, the price fluctuation will ultimately reveal the information that the other traders hold. Moreover, if the market is repeatedly conditioned by these traders, market prices should continue to move until the traders have learned all that they can from the prices.

Whether the equilibrium market price will fully reveal the true state depends on the information structure. One question still remains as to whether market prices can fully disclose the true state when traders initially

have identical beliefs but each with only partial, private information. Lawrence Choo, a post-doctoral researcher at the University of Erlangen-Nuremberg and research fellow at the University of Haifa, Todd R Kaplan, Professor of Economics at the University of Exeter Business School and Associate Professor in the Department of Economics at the University of Haifa, and Ro'i Zultan, Associate Professor of Economics at Ben-Gurion University, are addressing this question in their research into the information aggregation properties of markets.

HARNESSING THE WISDOM OF THE CROWD

The researchers explain that "by aggregating the information held by many people, one can harness the wisdom of the crowd. This, however, requires the ability to elicit truthful reports from people and to somehow combine many such reports into a prediction".

The logic behind the success of prediction markets is that when some traders are fully informed about the true state of the world, the ensuing competitive bidding moves prices to reflect the true state, subsequently revealing the information to the uninformed traders. The researchers convey that situations where each trader has only partial information about the true state are more challenging. For instance, if traders use the process they observe to update their information and condition their market demands, then market prices would continuously move until the traders have learned everything possible from the prices. This theory may work but there is no guarantee that it will always be successful in practice.



The research team has developed a novel model that allows them to differentiate between situations where traders hold homogeneous beliefs and those where traders hold heterogeneous beliefs about the true state of the world. This model employs a more complex, asymmetric information structure than has been used to date, in order to solve problems that require traders to deduce what other traders already know by the price movements.

THE RED HAT PUZZLE

An example of this more complex problem is the Red Hat Puzzle: three people each wear a hat that is either red or black. The participants can see each other's hat but not their own. Individually, they don't know how many red hats are there, but collectively they do. Converting this into a financial market problem, we have assets that are bought and sold with each one based discretely on how many red hats are involved. In the event that everyone has a red hat, each person sees two red hats and prices would reflect the 50% chance of 2 red hats and 50% chance of 3 red hats, so only the assets associated with two or three (but not zero or one) hats are traded. Without a deeper understanding, the prices will continue to reflect uncertainty between 2 and 3 red hats, instead of the true state of 3 red hats. In previous studies of prediction markets, the trades that participants make reveal their private information to others. The red hat problem is more challenging, because

sometimes all of the traders are willing to make the same trades, hence there is nothing new to learn from observing the market activity of others. The research team has found that, nonetheless, the red hat problem can be solved using markets.

By aggregating the information held by many people, one can harness the wisdom of the crowd.

While market prices reflect the true state, most traders tend to remain ignorant and do not interpret the prices into the correct number of red hats.

THE FRE REASONING MODEL

The researchers have developed a fully revealing rational expectation equilibrium (FRE) reasoning model. This FRE model reveals that information aggregation and full revelation of the true state is possible in both situations when traders' beliefs over the assets' values are either heterogeneous or homogeneous. The model also predicts that a small group of traders (the minority traders) holding heterogeneous private information, will learn about the true state before the others. It also predicts that these minority traders will be influential in driving the market prices towards the FRE.

RESEARCH QUESTIONS

The research team are investigating three questions in particular. Firstly they

are examining whether Arrow-Debreu markets can be successful at aggregating private information about the true event into prices, even when traders have homogeneous beliefs. Secondly, they are exploring whether minority traders are

better informed about the true event. If this is the case, can the minority traders use this knowledge to gain profit, and are they influential in driving prices in order to reveal the true state? Thirdly, the researchers want to find out if individual traders can learn the true event from the movement of prices, and if individual learning is a necessary condition for information aggregation with respect to prices.

EXPERIMENTAL DESIGN

The research team ran seven experimental sessions with twelve participants in each. The participating traders were randomly allocated into three groups of four and randomly assigned to be type X or O. There are eight equally probable states and, like the red hat puzzle, at each state the traders can see the types of the other groups, but they do not know their own group's type. Each trader was allocated working capital and assets and trade was conducted using the Continuous Double mechanism.

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AUCTION MECHANISM

The model assumes that traders can update their beliefs on observed prices only. After 5 minutes, the market was closed and traders entered the post-market stage where they were asked to guess how many type X groups took part in the market before receiving feedback on the true state.

When only one or two Xs have been allocated to the three groups, heterogeneous events occurred as these generated different beliefs among the traders. For example, if two groups are allocated type X, those groups will know that either one or two Xs have been allocated, whereas the third group, the minority traders, will know that two or three Xs have been allocated, depending on what type they believe their group to have.

Homogeneous events occurred when zero or three Xs have been allocated. For instance if all three groups have been allocated type X, then all traders have the same information and they will all believe that the true state is either two or three groups with type X. It follows that homogenous events do not have any minority traders.

FINDINGS

The researchers found Arrow–Debreu markets to be successful at aggregating dispersed information in the prices in the later rounds with experienced traders, but not in the earlier rounds. While market prices do reflect the true state, most traders appeared to remain ignorant during the post-market stage. The researchers reflect that this is consistent with the marginal trader

hypothesis that efficiency in market prices requires only a small population of sophisticated traders, who drive prices to the competitive equilibrium.

The research team observed successful price convergence even when the traders had homogeneous beliefs. They did not find any significant differences in the information aggregation properties of markets regardless of whether traders initially had homogeneous or heterogeneous beliefs. In the case of heterogeneous beliefs, the researchers found evidence that suggests that the minority traders do learn about the true event before others and that they are influential in driving prices towards the FRE. They did not find any evidence, however, to support the notion that these better informed minority traders can extract a greater share of the surplus as a result.

CONCLUSION

The research team found that the FRE reasoning model allows them to examine market scenarios involving more complex information structures. It also enables them to compare market results. Analysis of post-market beliefs disclosed that Arrow–Debreu markets can aggregate dispersed information efficiently, even when the individual traders are uninformed throughout. They conclude that when markets are comprised of experienced traders, they can successfully aggregate dispersed information, even in complex situations when only a few of the traders possess all of the information.

The research team observed successful price convergence even when the traders had homogeneous beliefs.



Behind the Research



Dr Lawrence Choo

E: lawrencez@gmail.com
W: <https://sites.google.com/view/lawrence-choo/home>



Prof Todd R Kaplan

E: toddrkaplan@gmail.com
W: www.toddrkaplan.com



Prof Ro'i Zultan

E: zultan@bgu.ac.il
W: <http://www.bgu.ac.il/~zultan>

Research Objectives

Dr Choo and Profs Kaplan and Zultan are interested in economic theory, industrial organisation and experimental economics.

Detail

Bio

Todd R. Kaplan is an Associate Professor in the Department of Economics at the University of Haifa and a Professor of Economics at the University of Exeter Business School. His research interests include auctions, industrial organisation, and experimental economics, with eclectic topics that include explaining gift-giving, modelling research contests, and testing understanding of uncertainty in weather forecasts.

Lawrence Choo is an experimental economist and post-doctoral

researcher at the University of Erlangen-Nuremberg and research fellow at the University of Haifa. His research uses experiments to better understanding how group behaviour is influenced by social norms, market interactions and the use of prediction markets.

Ro'i Zultan is an Associate Professor of Economics at Ben-Gurion University. He is an experimental economist with a background in cognitive and experimental psychology. His interests include understanding how groups

shape cognitions and behaviour, broader issues of cooperation and behaviour in teams, as well as basic game theoretical issues, behaviour in markets, and experimental methodology.

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Collaborators

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Personal Response

What are your plans for future research in this area?

“ In this work, we showed how robust prediction markets are in their ability to aggregate information. In our next work, we want to examine what happens when prediction markets are used to make decisions. We ask if policy makers use prediction markets to guide decisions, and if parties with vested interests successfully manipulate the market prices (at a cost) in order to influence decisions. We find that, although manipulators have a substantial effect on market prices, policy makers would still benefit from following the information revealed in market closing prices. Nonetheless, manipulation is detrimental to policy making by eroding trust in the market. ”

