10. Markets (and Money)

Modelling Social Interaction in Information Systems

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I will now tell you
(on the next slide)
the secret of
how to get rich!

Buy low

and

Sell high!

Markets and Money

- Disclaimer – I am not an economist!
- This is a massive and complex area
- I will cover some general concepts and ideas as they relate to some algorithms
- I will grossly oversimplify and put my own spin on things based on what I know
- If you are seriously interested in one of the topics then you will need to pursue the background reading!

Markets

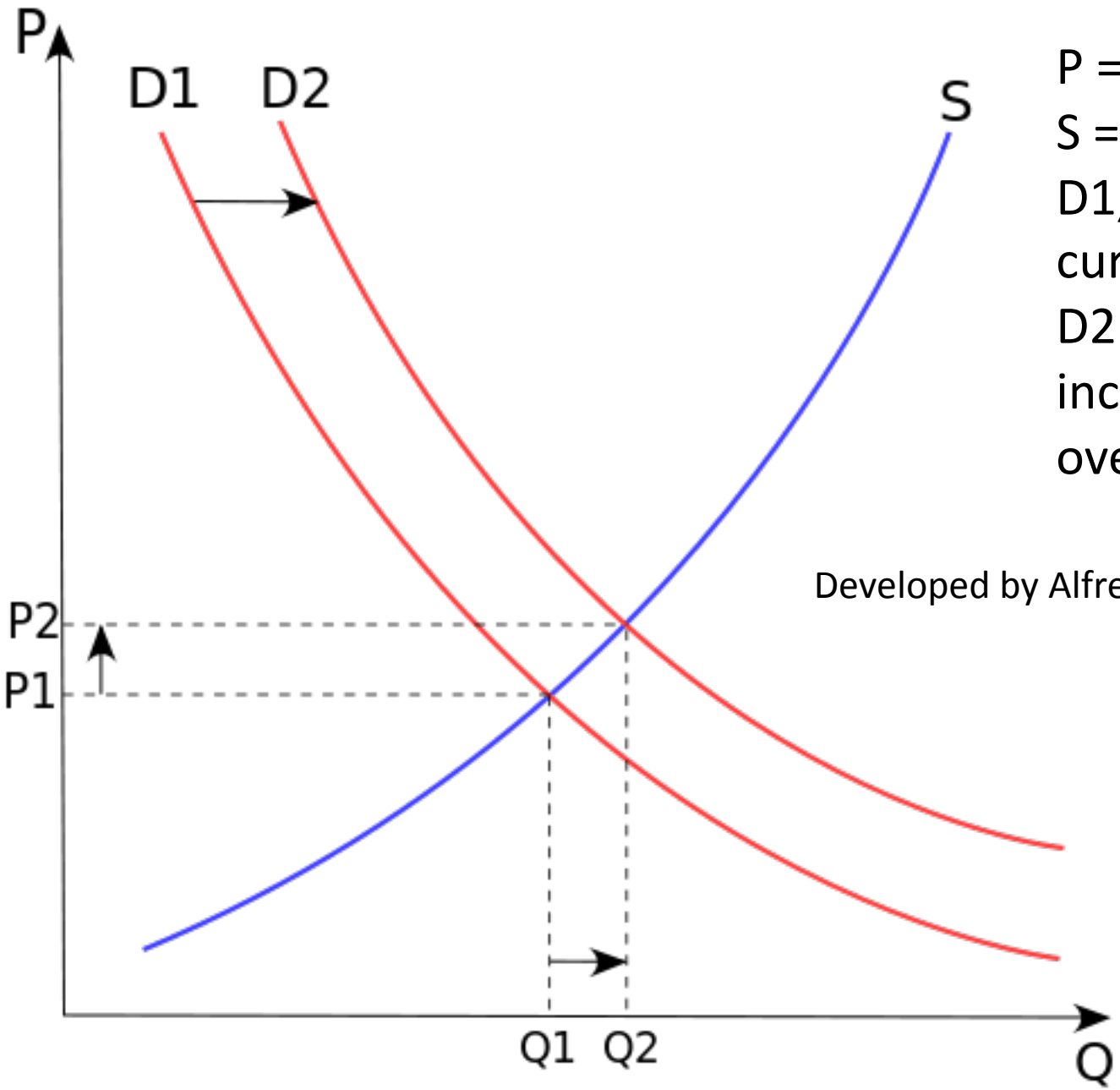
- What is a market? – here is *my* take on it..
- a social mechanism (or institution) for bringing together buyers and sellers of goods and services to facilitate “productive” exchange
- Where buyer and seller agents can set their own prices and anyone can buy / sell to anyone – might call it a “free market”
- assuming that two agents (buyer & seller) would not exchange (transact) unless both considered themselves better off after! (a Pareto improvement?)

Markets

- Given a sufficient number of small independent buyers and sellers then this supports “perfect competition”
- Given all agents have perfect information about the market and perfect competition it has been argued that free markets should find an “efficient”- equilibrium (a fair price)
- Assuming agents are “rational” and attempt to maximise utility = buy at lowest price and sell for highest price

Supply / Demand functions

- Sometimes supply and demand for a given product are represented as functions over price say: D(P), S(P)
- Meaning that for a given price (P) the market would supply and demand a given quantity (Q) of a product (based on agent preferences)
- If a P can be found where D(P) = S(P) then a market equilibrium is found in which supply = demand for the given price
- It can be argued that markets function as “price discovery mechanisms” locating such equilibria



P = price, Q = quantity
S = supply curve
D1, D2 = two demand curves
D2 represents an increase in demand over D1

Developed by Alfred Marshall (1842-1924)

From wikipedia: http://en.wikipedia.org/wiki/Supply_and_demand

Real Markets

- Real markets are never free or in perfect competition because:
  - Government regulation (taxes, standards etc)
  - Monopoly (seller power), Monopsony (buyer power)
  - Collusion between buyers or sellers
  - Incomplete (asymmetric) information
  - Many other things..

Real Markets

- Often appear to fail producing non-efficient outcomes ("market failure")
- Volatility – rarely in equilibrium? ("in the long run we're all dead!" – Keynes)
- Bubbles, speculation, co-evolving behavours
- Agents don't behave "rationally" (behavioural economics) "fear and greed"
- Empirical (and ABM) work shows concepts like loyalty between buy/seller can emerge and play a productive role in markets (Kirman)

Paper: Kirman, A. & N. Vriend) (2000), "Evolving Market Structure: A Model of Price Dispersion and Loyalty for the Marseille Fish Market", in Interaction and Market Structure, Edited by Delli Gatti, Gallegati and Kirman , Springer Verlag, Heidelberg.

Micro / Macro Issues

- Even if we stuck to an idealised market the demand / supply curves don't tell us:
  - How agents in a market would actually find an equilibrium (micro)
  - How different demand / supply functions would interact across different markets (macro)
  - How financial markets / money supply / interest rates effect things (macro)

Economics

- A lot of work in economics (both macro and micro) attempts to address these kinds of problems
- Asymmetric information in used car market – Akerolf
- A general theory of an entire economy - Keynes
  - Paper: Akerlof, George A. (1970). "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism". Quarterly Journal of Economics (The MIT Press) 84 (3)
  - Book: Keynes, John Maynard, (1936) The General Theory of Employment, Interest and Money, London: Macmillan

One implication of Keynes book was that government could stimulate the economy during depressions by boosting demand (giving people jobs so they get money to spend thus boosting demand => creating more jobs etc.)

An algorithmic market example

- One way to implement a market is to use an auction algorithm – of which there are many
- Electronic financial markets implement such algorithms (e.g. NASDAQ) – called exchanges
- Agents (buyers or sellers) may place bids or asks onto the exchange
  - A buyer places a bid: quantity + buy price
  - A seller places an ask (offer): quantity + sell price

Algorithmic market example

- The exchange implements a “matching engine” algorithm that pairs asks and bids producing transactions
- All agents can view the market: pending asks and bids + cleared transactions
- The price at which the last transaction cleared is the current market clearing price
- Often the current set of bids and asks is called the “order book” or “market depth”

NESN (NESTLE N) Orderbook

Last trade / volume	CHF 44.66 / 500	Date / Time	18.11.2008 / 09:32:50
Daily change / absolute	0.09% / +0.04		

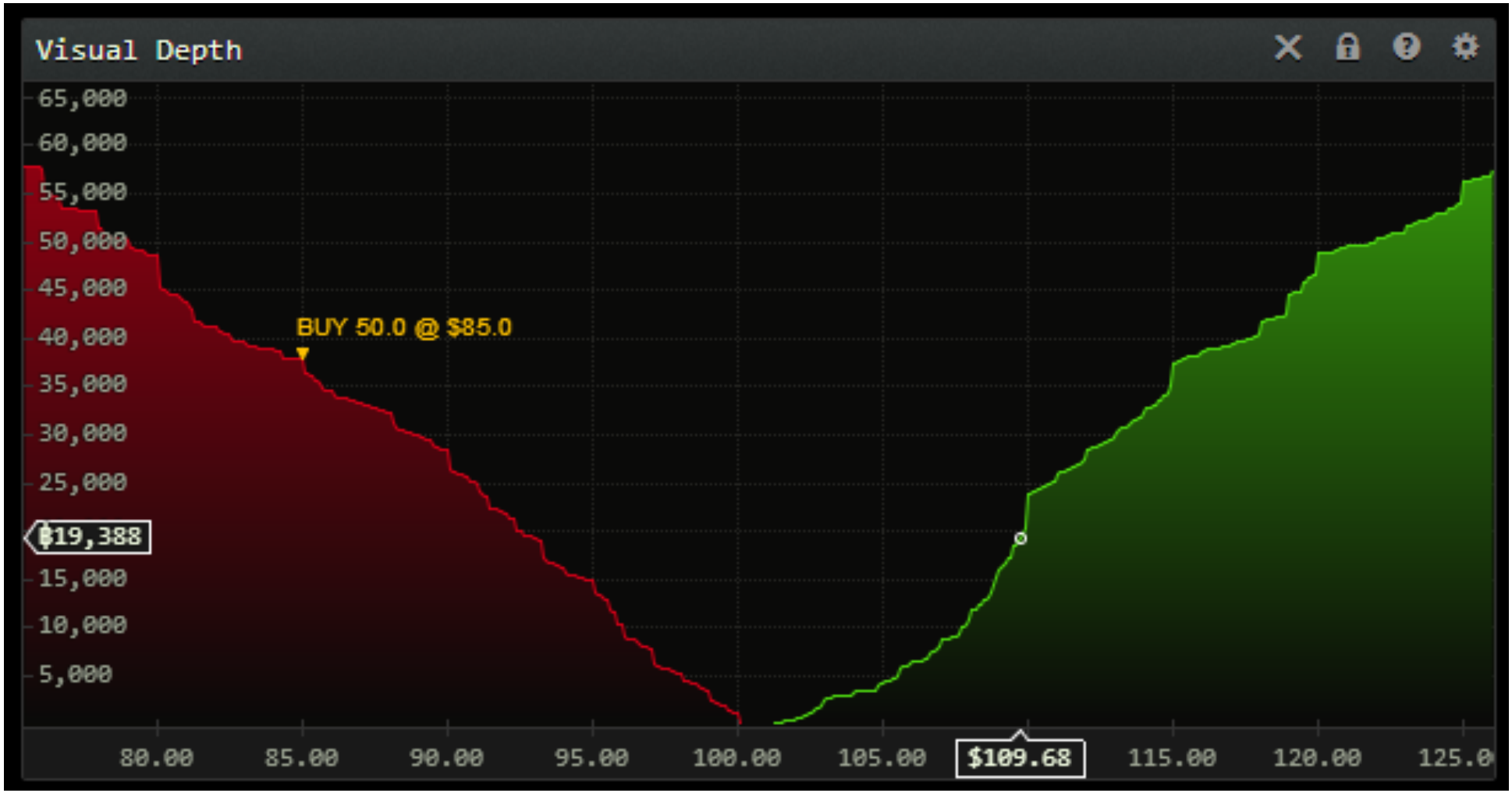
Cum. Volume	Bid Volume	Price	Ask Volume	Cum. Volume
		44.90	1'000 (1)	68'370 (29)
		44.86	8'539 (3)	67'370 (28)
		44.84	10'000 (1)	58'831 (25)
		44.82	5'576 (6)	48'831 (24)
		44.80	10'551 (3)	43'255 (18)
		44.78	3'677 (1)	32'704 (15)
		44.76	6'800 (2)	29'027 (14)
		44.70	9'061 (3)	22'227 (12)
		44.68	6'593 (4)	13'166 (9)
		44.66	6'573 (5)	6'573 (5)
2'049 (3)	2'049 (3)	44.60		
7'225 (4)	5'176 (1)	44.54		
8'305 (5)	1'080 (1)	44.50		
13'305 (6)	5'000 (1)	44.48		
30'081 (8)	16'776 (2)	44.46		
32'081 (9)	2'000 (1)	44.44		
47'430 (12)	15'349 (3)	44.42		
58'757 (16)	11'327 (4)	44.40		
60'757 (17)	2'000 (1)	44.38		
68'557 (20)	7'800 (3)	44.30		
Cum. Volume	Bid Volume	Price	Ask Volume	Cum. Volume

The values in brackets in the column Ask volume / Bid volume show the amount of sell- respectively buy orders. In the columns Cum. volume the cumulated amount of sell- respectively buy orders are stated.

Example of an order book

From: http://www.six-swiss-exchange.com/index.html

Example of visual depth display of an order book



From: https://zeroblock.com/support/platform/visual-depth/

Electronic markets

- The kind of market discussed here is sometimes called a "Continuous Double Auction" (CDA)
- Many variants of this used in electronic exchanges
- Flexible: allow anyone to submit buy or sell requests for any amount at any time (they can be cancelled too)
- The specifics of the matching engine will determined what transactions are cleared, when and at what prices
- But in general the basic mechanism is the same
- Real exchanges often involve "specialists" (or "market makers") agents that buy and sell to keep the market "liquid" – think of currency x-change shops

Paper: Parsons, S., Marcinkiewicz, M., Niu, J., and Phelps, S. 2008. Everything you wanted to know about double auctions, but were afraid to (bid or) ask. Tech. rep., Department of Computer and Information Science, Brooklyn College.

Electronic markets

- Although electronic markets allow human agents to trade (via a GUI interface)
- Much trading on such markets is performed by software agents (algorithmic trading)
- Most exchanges provide an API in order to interact with the exchange directly
- This allows for more sophisticated and quick trading strategies (high-frequency trading)
- Some claim this is good – increases “market liquidity”
- Others point to sneaky tactics using repeated rapid bids / asks and cancellations plus feedback effects etc. => increased volatility (“flash crash” phenomena)

See: http://en.wikipedia.org/wiki/2010_Flash_Crash

Electronic markets

- In some sense many exchanges can now be viewed as complex tournaments between unknown trading algorithms (black-box trading)
- Producing all kinds of emergent outcomes that are far from simple notions of supply, demand and equilibrium
- All kinds of tricks can be used to speculate with algorithms but in general nobody is going to tell you what works right now! (buy low, sell high)
- However, it has been shown that very simple trading algorithms can lead to “good” results (such as locating a supply/demand equilibrium, doing well against humans etc)

Electronic markets

- This is potentially useful in computing applications where we wish a set of agents to buy / sell resources to / from each other productively and automatically
- Dave Cliff used computer simulations to show how very simple ZIP agents (zero-intelligence-plus) could do this in a CDA type exchange
- It uses a simple machine learning delta (Widrow-Hoff) rule to attempt to maximise profit

Cliff, D. 1997. Minimal-intelligence agents for bargaining behaviours in market-based environments. Tech. rep. HP-97-91, Hewlett-Packard Research Laboratories, Bristol, England.

ZIP Buyer Heuristic

- Has a fixed limit price (L) above which it will *never* bid. Aim: get the lowest price < L
- Store a current bid price P < L (init. random)
- Look at transactions on the market, adjust P *towards* transaction price (-ve small amount)
- If no transactions, adjust P *towards* best bid at top of market depth (+ve small amount)
- Periodically put a bid on the market at current P
- If P changes cancel old bid and submit new bid

Basic ZIP Heuristic

Buyer agents:
If transaction then
  T = transaction price – d
else
  T = B_{max} + d

Seller agents:
If transaction then
  T = transaction price + d
else
  T = A_{min} - d

B_{max} = highest bid, A_{min} = lowest ask, from current market depth
d = randomised value small with respect to $B_{max,}$ $A_{min,}$ transaction price
T = a new target trade price.

Price P is updated towards T with a simple delta rule incorporating a learning rate, r, and a momentum, m. Hence new trade price P at time t+1 is given by:

$$delta = m * delta(t-1) + (1 - m) * r(T – P)$$
$$P(t+1) = P + delta$$

Typical values for r = 0.3, m = 0.05 - but can be tweaked

ZIP applications

- Beat humans in a simulated market (Das et al)
- In Cliffs original paper he mentioned that such markets could be used to trade bandwidth or storage or other applications
- Do cloud providers use markets and trader algorithms like this? (I don't know but I have not searched)

Das, et al (2001) Agent-Human Interactions in the Continuous Double Auction, Proc. of the Int. Joint Conf. on Artificial Intelligence (IJCAI), Seattle, USA

Actual exchanges

- Algorithmic trading can be used in real exchanges to offload large quantities of stock without impacting the price too much (iceberg trade)
- Yet, given cleaver HFT strategies some people don't want others to "see" market depth or transactions
- This has lead exchanges and others to offer "dark pool" exchanges in which nobody can see what other people are doing. Hence strategies like ZIP would not work there – they would have to be modified to actively "ping" into the market with actual trades to get transaction data…

See: http://en.wikipedia.org/wiki/Dark_liquidity

Prediction Markets

- Used to buy and sell predictions (bets) on some future binary event (it either happens or doesn't)
- For example, "Hillary Clinton will be the next president of the USA"
- You can buy or sell any amount of prediction units (assuming you have money to cover it) another buyer / seller in the market
- Not like a traditional bet because you can sell your bet before the event happens
- Each unit will be worth, say, 10 Euro if it comes true and zero if not. The market prices the units up to the event
- The market price of the unit indicates a probability that the market "thinks" the event will occur
- Based on "efficient-market hypothesis"
- See bitcoin prediction market: www.predictious.com

Predictious

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Politics

Current Events | Expired Events

Odds format: Share Price

Sort by: Popular

- All Events 170
- US Politics
- US Senate elections 2014 3
- US House of Representatives elections 2014 3
- US Presidential Election 2016 Winner 31
- US Presidential Election 2016 Gender 2
- US Presidential Election 2016 Party 2
- Republican Presidential Primaries 2016 39
- Democratic Presidential Primaries 2016 38
- Gay Marriage 1
- Florida Governor 3
- Illinois Governor 2
- Michigan Governor 2
- Nebraska Governor 2
- Alaska Senate Race 2014 2
- Colorado Senate Race 2014 2
- New Hampshire Senate Race 2014 2
- Georgia Senate Race 2014 2
- Iowa Senate Race 2014 2
- Kansas Senate Race 2014 2

		Sell at	Buy at
	The Republicans to control the Senate after 2014 Congressional Elections — 3 hours left	7.20	-
	Pat Roberts to win the Senate election in Kansas — 4 hours left	6.25	7.10
	Michelle Nunn to win the Senate election in Georgia — 4 hours left	-	0.99
	David Perdue to win the Senate election in Georgia — 4 hours left	9.01	9.76
	Greg Orman to win the Senate election in Kansas — 4 hours left	2.90	3.75
	Kay Hagan to win the Senate election in North Carolina	Sell at	Buy at

Greed and Fear – "Animal Spirits"

Non-equilibrium market models

- Traditional approaches assume markets will find equilibrium
- If they are not in equilibrium then this must be the result of “external shocks”
- But several ABM attempt to explore non-equilibrium phenomena generated endogenously (within) the market itself
- Particularly relevant to speculative or financial markets where prices based on what people predict the future price to be

El Farol bar

- There is a really good bar called El Farol Bar
- But when it's busy it's not much fun
- Each Thursday agents make decision:
  - Go to bar OR stay at home
- If T > 60% of the agents go to bar it's busy
- If it's busy it would be better to stay at home
- Hence agents have a preference ordering of:
  - Attend non-busy > stay at home > attend busy
- Problem: all make decision at once, no communication, to late to go home if busy

Paper: W. Brian Arthur (1994) "Inductive Reasoning and Bounded Rationality", American Economic Review, 84

See: Netlogo model library / social science / El Farol

El farol bar

- Arthur wishes to examine what happens when agents use induction to make decisions:
  - Agents know past attendance history at bar
  - Use simple rules to attempt to predict attendance
  - Each agent stores several such “predictor” rules
  - Map past attendance figures to next attendance
  - Uses the currently best predictor it has based on how well it would have worked predicting past attendance
- This can be contrasted with traditional economic deduction (such as Nash Equ.)

El farol bar

- Examples of predictors could be:
  - Same number as last week
  - Same number as 3 weeks ago
  - Average of last 4 weeks
- Arthur notes no single predictor could work best for everyone since:
  - If all predicted same all would lose
- Hence any pattern that emerged in attendance would tend to disappear

What does Arthur find?

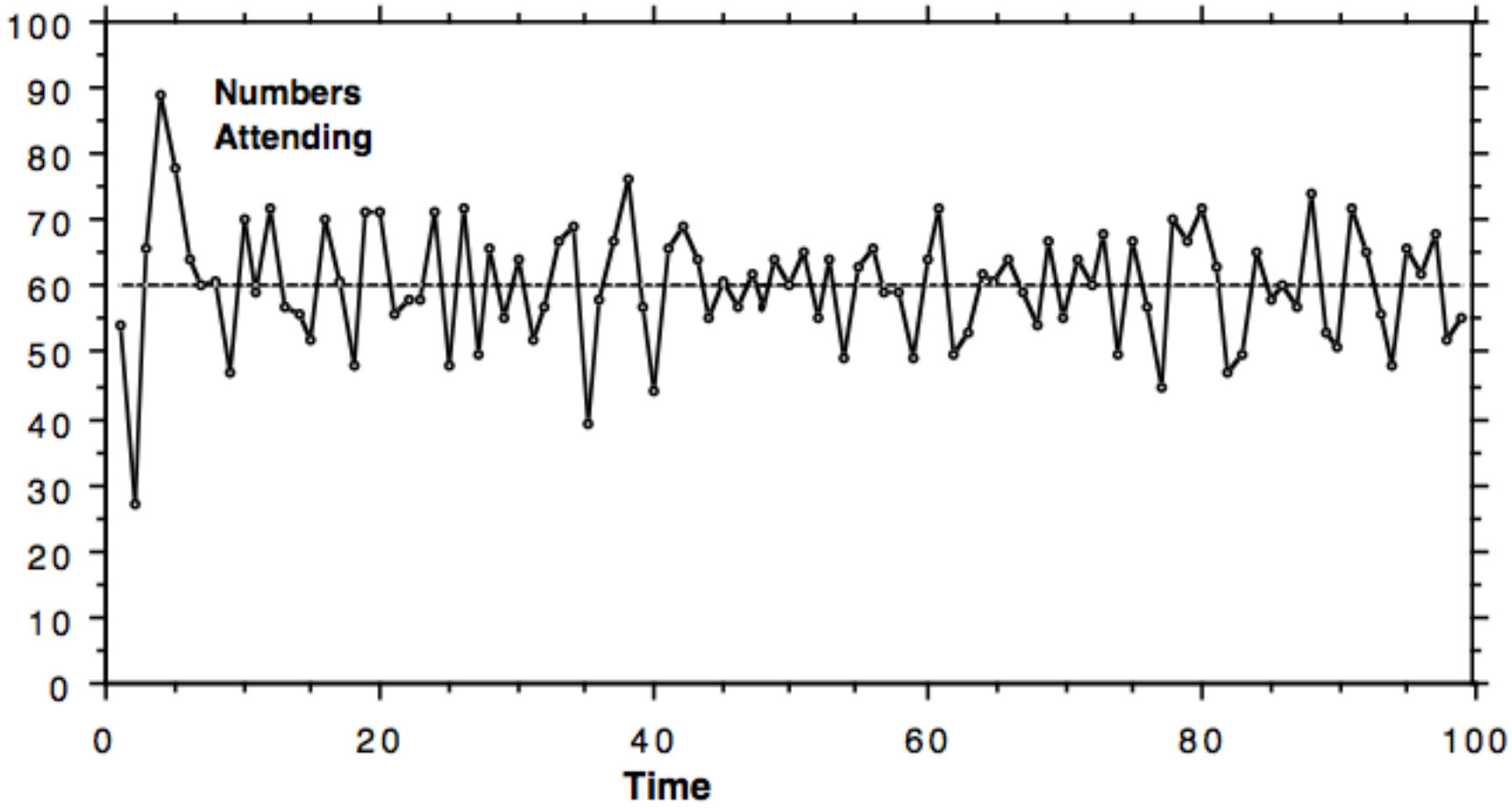

FIGURE 1. BAR ATTENDANCE IN THE FIRST 100 WEEKS.

Observations

- Arthur notes that attendance averages to 60%
- But that a dynamic "ecology" of active predictors causes this
  - Agents constantly changing which of their predictors is the best based on history
- This is because if too many active predictors predicted wrongly then others would become active

Aside: Nash eq.

- In fact there is a Nash eq. for this game if we assume so-called “mixed strategies”
  - pure strategy = move in the game
  - mixed strategy = probability dist. over moves
- So Nash eq. go to bar with prob(0.6)

What has this got to do with markets?

- Go to the bar = sell, stay at home = buy (or vice versa)
- If everyone is selling price goes down
- If everyone is buying price goes up
- To win (buy low, sell high) you need to:
  - Buy when everyone is selling
  - Sell when everyone is buying
  - Be in a minority!
- Everyone is predicting what will happen next

Minority Game

- A simplification of El farol bar
- N agents (odd number)
- One of two actions at each time step (0 or 1)
- Those who choose minority action win
- Agents store:
  - M last outcomes (which action in minority)
  - Some number of predictors map M last outcomes to predicted next outcome
- This formulation used to
  - apply various forms of analysis
  - modified to produce outcomes that capture various forms of "stylised facts" found in real markets

Review paper: Tobias Galla, et al (2006) Anomalous fluctuations in Minority Games and related multi-agent models of financial markets. arXiv:physics/0608091v1

Netlogo model library / social science / Minority Game

Non-equ. Market models

- Good blog post on minority game by Mark Buchanon: http://physicsoffinance.blogspot.hu/2012/02/minority-games.html
- Paper: B. LeBaron (2002) "Building the Santa Fe Artificial Stock Market," Working Paper, Brandeis University
  - More sophisticated model capturing various aspects of a stock market
- Brian Arthur at World Economic Forum talking about complexity economics: https://www.youtube.com/watch?v=Lx-pRkp7pM8
- Good lecture by Brian Arthur on economics (history) technology development and algorithmic approaches: https://www.youtube.com/watch?v=WQ6ppznYl-Q


Money!

Money

- Markets generally *assume* money by which price is measured and exchange facilitated
- Much market theory has little to say about money or how it comes about
- What is money?
- It is not entirely clear what it is, where it comes from and where it goes – but there are theories!
- Considered historically emergent phenomena
- Some argue it emerged from barter in markets, others from credit in social networks

Money

- It has certain functions*:
  - Unit of account (a unit to measure / compare things)
  - Means of exchange
  - Store of value
- "Money is a medium for the communication of value over space and time" (Ian Harris & Michael Mainelli)?
- What is "value"? – the way value is understood defines different economic approaches (theories of value)
- Objective / subjective (labour, usefulness, positional etc..)
- If enough people believe something is money then it functions as money (taxes, Marco Polo story)
- It all gets very complex and political!

*Fungible – meaning one unit functionally equivalent to another

Ian Harris Michael Mainelli (2011) The Price of Fish: A New Approach to Wicked Economics and Better Decisions. Nicholas Brealey Publishing

Money

- An old idea is the “quantity theory of money”
- Which basically says:
  - If there is “too much” money it loses value (prices go up)
  - If there is “too little” money it gains value (prices go down)
- But this is rather tautological and does not say anything about supply / demand / velocity of money
- Economic theorists such as Karl Marx, John M. Keynes, Carl Menger, F. A. Hayek, Milton Friedman have different ideas about money relating all these and concepts of value – these have sometimes become the basis of political ideologies which are still in conflict today

Modern Money – central bank fiat

- In a modern state there are two kinds of money:
  - Central bank (or base) money – physical cash in your pocket or in a bank vault or electronic cash in an account at the central bank (reserves) [can only be created by central bank]
  - Bank (credit) money – money listed in your bank account [can be created by any bank through loans]
- Most money in circulation is bank money and most of that money is created by banks through loans (regulated)
- The actual amount of base money in circulation is small relative to bank money
- Monetary policy: By setting the interest rate for base money central banks attempt to control quantity of money, prices, unemployment etc (with variable success!)

Money “packets” in an info. Network?

- Money can be seen as part of an information system in which prices are signals and markets are processes that generate those signals allowing for the coordination of agent plans and actions in a *distributed* way
- The idea that markets and money can spontaneously emerge to produce collective coordination was championed by Hayek (Catallaxy)
- He was against central planning and collectivised production – didn’t really like central banks either
- In this context Hayek is often viewed as a “Libertarian” thinker who is suspicious of regulation and the state

F. A. Hayek (1945). "The Use of Knowledge in Society," American Economic Review, 35(4), pp. 519-530

Book: F. A. Hayek (1990) “The Denationalisation of Money: The Argument Refined”. http://mises.org/books/denationalisation.pdf

Bitcoin

- Will talk about it in a little more detail in future lecture
- Some claim bitcoin is inspired by ideas from Hayek and Friedman (in an ECB report) (I am not so sure)
- It eliminates a central bank and local banks
- All money is “base money” (bitcoin)
- Money endogenously generated to a regular schedule up to a maximum (21m)
- But can not dynamically expand or contract supply based on need => volatile prices
- Also what will happen when we reach the limit?
- Constant deflation? (prices go down and down)
- However there are many (100’s) of variants called **Altcoins** which have different parameters

See: www.bitcoin.org

Paper: Satoshi Nakamoto (2009) Bitcoin: A Peer-to-Peer Electronic Cash System. https://bitcoin.org/bitcoin.pdf

Ripple

- An alternative approach is Ripple.
- Ripple effectively turns everyone into a bank (node) can receive / give credit lines to trusted others (nodes)
- “base money” in ripple has to be something like euro or bitcoin (or “ripples”)
- This allows for dynamic credit expansion and contraction but it is unclear (to me) if node failures (i.e. running out of base money) would lead to a cascade of failures over the network
- In fact, historically, central banks were created to stop such cascade failures that used to occur before central banks existed
- However the current ripple.com has changed a lot since I last looked at it so perhaps it functions very differently now

See: https://ripple.com/

Book: Charles Goodhart (1988) The Evolution of Central Banks. MIT Press

Readings and Questions

- Readings
  - Hayek, F. A. (1945) "The Use of Knowledge in Society," American Economic Review. [political]
  - Cliff, D. (1997). Minimal-intelligence agents for bargaining behaviours in market-based environments. Tech. rep. HP-97-91, Hewlett-Packard Research Laboratories, Bristol, England. [scientific]
- Questions
  - Jimmy Wales cites "The Use of Knowledge in Society" as "central" to his thinking about "how to manage the Wikipedia project" – why?
  - How would you combine buyer and seller algorithms in ZIP to create a "speculator"? When would it make money?
  - Which is more like a "free market" Tesco supermarket or Mars tér market? Why?
  - Can you think of a computer application that could use markets and ZIP like agents to solve a coordination / cooperation problem?

Hayek and Keynes had very different views of how the economy works. This popular rap video tries to explain this: https://www.youtube.com/watch?v=d0nERTFo-Sk