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

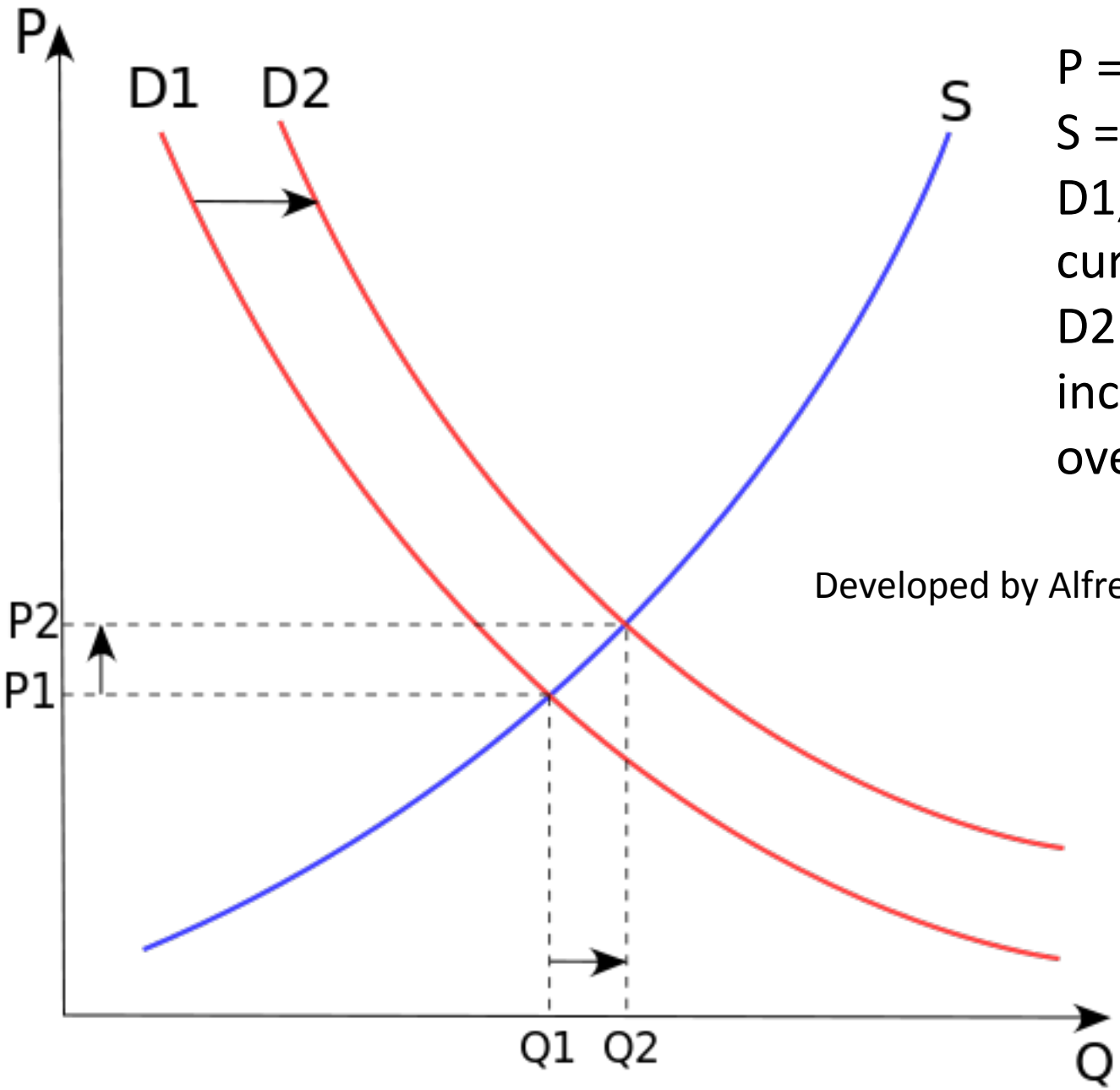
- What is a market? – here is *my* take on it..
- a social mechanism (or institution) for bringing together buyers and sellers of goods and services to facilitate “productive” exchange
- Where buyer and seller agents can set their own prices and anyone can buy / sell to anyone – might call it a “free 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		

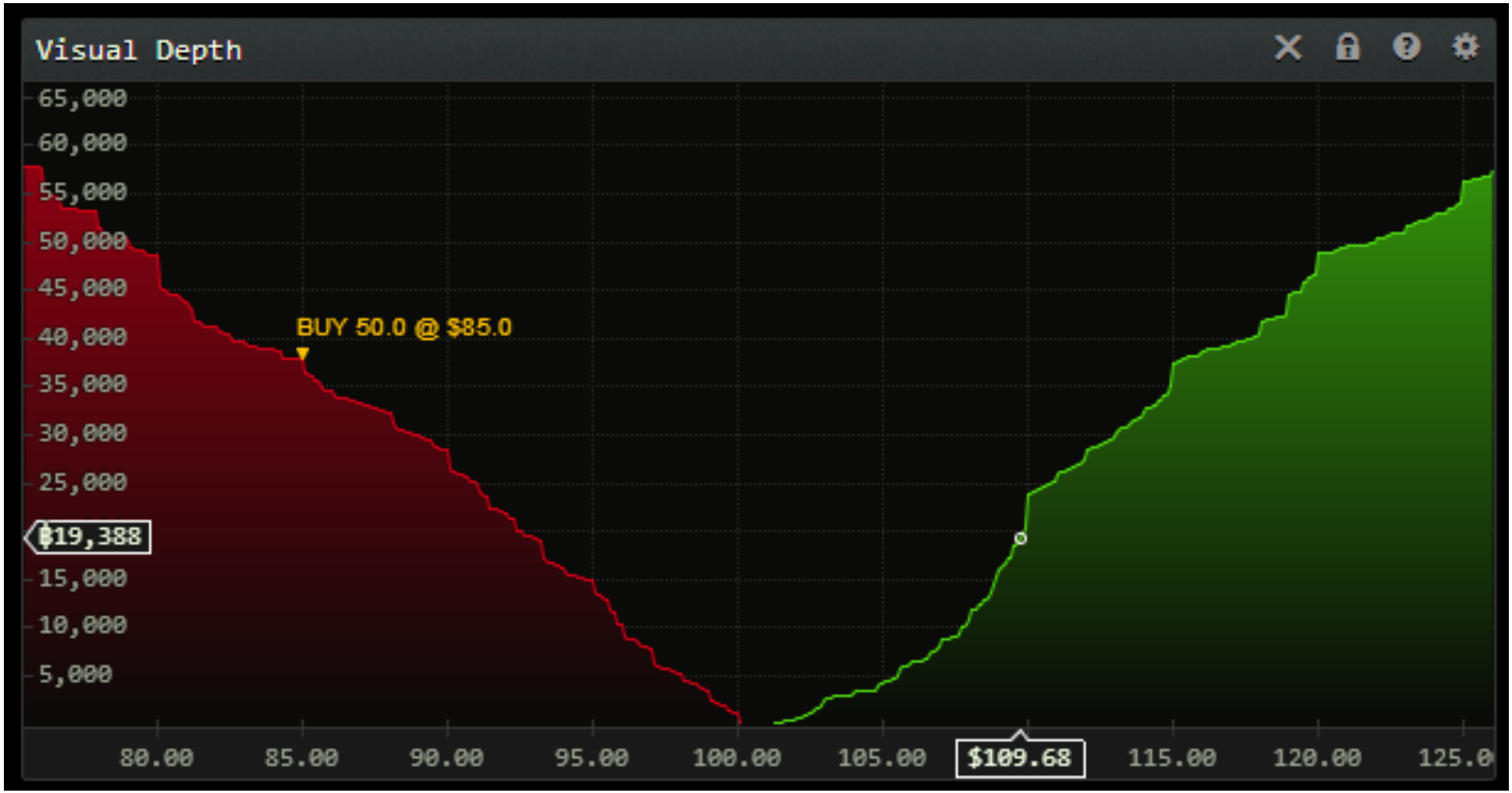
Cum. Volume	Bid Volume	Price	Ask Volume	Cum. Volume
		44.90	1'000 (1)	68'370 (29)
		44.86	8'539 (3)	67'370 (28)
		44.84	10'000 (1)	58'831 (25)
		44.82	5'576 (6)	48'831 (24)
		44.80	10'551 (3)	43'255 (18)
		44.78	3'677 (1)	32'704 (15)
		44.76	6'800 (2)	29'027 (14)
		44.70	9'061 (3)	22'227 (12)
		44.68	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 an 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 is 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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Odds format: Share Price

Sort by: Popular

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- 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

- Modelling the economy as an emergent, evolving complex system
- El Farol Bar (and derived minority game) – **Brian Arthur**
- Remember: buy low, sell high! (prediction!)
  - Prices are low when everyone is selling
  - Prices are high when everyone is buying
  - Try to be in the minority! (but in the long run we're all dead!)
- Santa Fe artificial stock market (early 1990's included LeBaron, John Holland, Brian Arthur and others)
- Co-evolving strategies in a market of many stocks. Traders try to predict future prices to make money
- Feedback effects, bubbles, crashes etc.
- Clustered volatility, fat tails of price distribution, power laws etc. generated endogenously from simple ABM models

See: Netlogo model library / social science / El Farol

Non-equ. Market models

- Great blog post on minority game by Mark Buchanon: http://physicsoffinance.blogspot.hu/2012/02/minority-games.html
- Paper: W. Brian Arthur (1994) “Inductive Reasoning and Bounded Rationality”, American Economic Review, 84
- Paper: B. LeBaron (2002) “Building the Santa Fe Artificial Stock Market,” Working Paper, Brandeis University
- Review paper: Tobias Galla, et al (2006) Anomalous fluctuations in Minority Games and related multi-agent models of financial markets. arXiv:physics/0608091v1
- Brian Arthur at World Economic Forum talking about complexity economics: https://www.youtube.com/watch?v=Lx-pRkp7pM8


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 (Guest Lecturer Mario Paulucci will talk about ABM of this)
- You can buy / sell money (with the same money) in a market based on an interest rate as price

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 (Marco Polo story)
- It all gets very complex and political!

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
- 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

My opinion: Extreme Libertarians (an infantile disorder!)

- Some people claim that free markets should be applied to (almost) everything (law, police, money itself etc)
- Thus eliminating the need for a state or taxation => complete individual freedom (is it freedom?)
- However, for markets to operate it is generally agreed that the state is needed – to enforce contracts, regulate money, impose standards, collect tax
- Without redistribution via taxation some people might go hungry => political instability
- Without bank / money regulation prices would be highly volatile and people would lose money when banks fail
- A lot of extreme Libertarians appear to be rich (but not all)
- *But I would say this because I've been funded from government grants for the last 15 years!*

Bitcoin

- Victor Greshenko talked about it in the last 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

- Victor Greshenko talked about it in the last lecture!
- 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, it has been argued central banks were created to stop such cascade failures that used to occur before central banks existed
- However the current ripple.com has change 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