University of Zurich[UZH]

Agent-based Financial Economics
Lesson 6: Stocks

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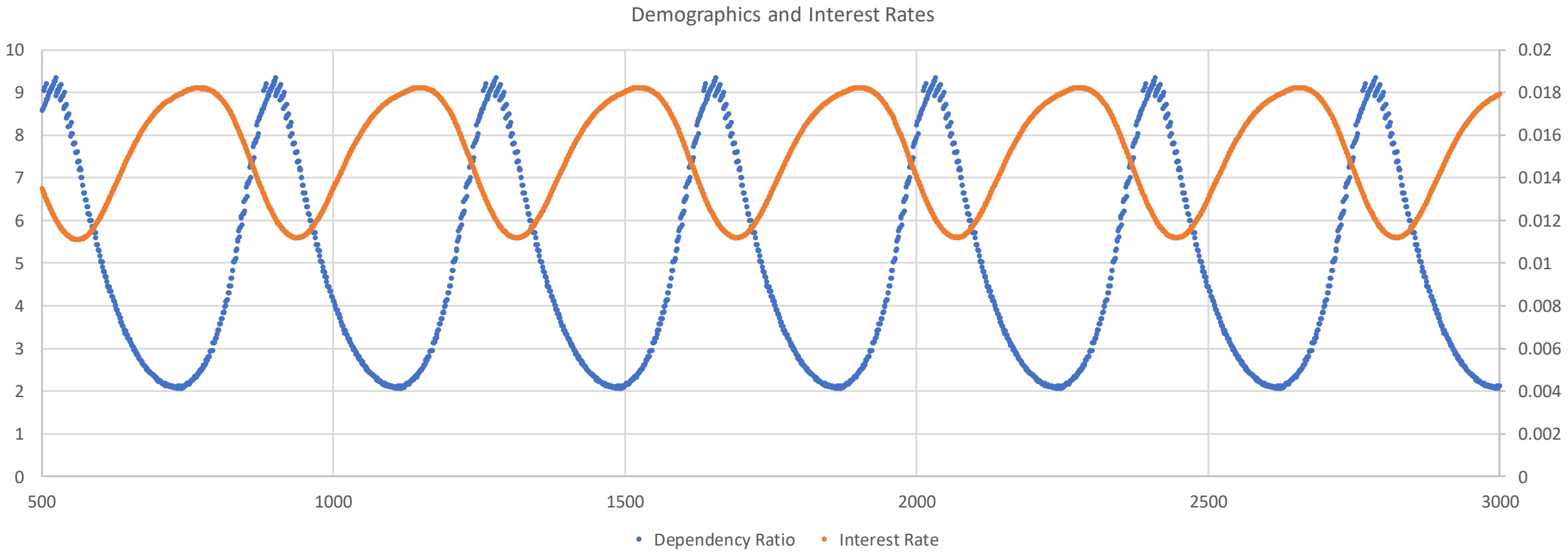
"What I cannot create, I do not understand."

- Richard Feynman

Today

- Discussion of exercise 4
- Stocks
- Santa Fe Artificial Stock Market
- Ad-hoc work: what should firms maximize?
- Introducing the InvestementFund class

Exercise 4 - Discussion



Correlation: -0.0008 -> Interest drops by about 0.1% when dependency ratio increases by 1

-> If there are lots of young savers, interest is lower.

-> Alternate regression: more retirees lead to higher interest rate, more young to lower interest rate

Exercise 4 - Discussion

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.803169
R Square	0.64508
Adjusted R Square	0.644938
Standard Error	0.001497
Observations	2500

Note about t-stats in simulations: as long as there is a significant effect, one can get an arbitrarily high t-stat simply by running the simulation for longer. T-stat does not say much in that case. What matters is how strong the effect is and the explanatory power (r squared).

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	0.010177	0.010177	4540.211
Residual	2498	0.005599	2.24E-06	
Total	2499	0.015776		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.018992	6.62E-05	286.826	0
Inv. Dependency Ratio	-0.00083	1.24E-05	-67.3811	0

Exercise 4 - Discussion

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.988912626
R Square	0.977948182
Adjusted R Square	0.977530039
Standard Error	0.000373258
Observations	2500

ANOVA

	df	*SS*	*MS*
Regression	3	0.015427913	0.005142638
Residual	2497	0.000347885	1.39321E-07
Total	2500	0.015775798	

	Coefficients	*Standard Error*	*t Stat*
Intercept	0.025185327	5.87308E-05	428.8267115
Population	0	0	65535
Retirees	1.80273E-05	5.00156E-07	36.04325152
Workers	-5.48937E-05	2.05045E-07	-267.7149471

Note that 65535 = 2^16 – 1, looks like a computational artefact

Exercise 4 - Discussion

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.988912626
R Square	0.977948182
Adjusted R Square	0.97793052
Standard Error	0.000373258
Observations	2500

ANOVA

	df	*SS*	*MS*
Regression	2	0.015427913	0.007713956
Residual	2497	0.000347885	1.39321E-07
Total	2499	0.015775798	

	Coefficients	*Standard Error*	*t Stat*
Intercept	0.025185327	5.87308E-05	428.8267115
Population	-5.48937E-05	2.05045E-07	-267.7149471
Retirees	7.2921E-05	4.34701E-07	167.7497841

Exercise 4 - Discussion

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Regression Statistics	
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ANOVA

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Retirees	1.80273E-05	5.00156E-07	36.04325152
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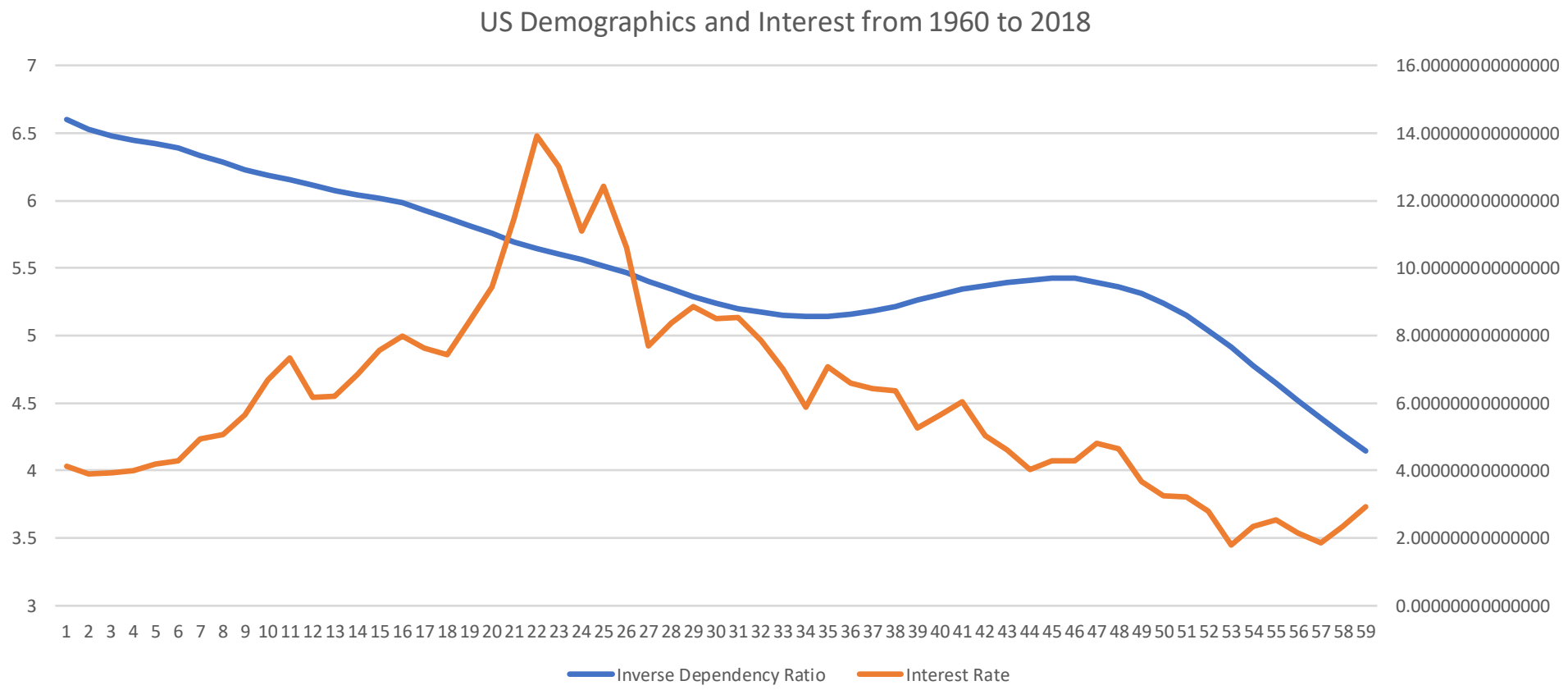
Exercise 4 - Discussion

Interpretation:
Interests are higher when the dependency ratio is lower. Interest depends on: dividends and savings, whereas savings depend on demographics and dividends on prices and production. And prices and production again depend on demographics. → Complex system driven by demographics. Explains high explanatory power of demographics.

Our finding is in line with Geanokoplos et al. also find that price-earning ratios climb together with the number of retirees/workers.

Intuition: stock prices should drop once the retirees have to start selling their shares.
(J. Geanakoplos, M. Magill, and M. Quinzii. Demography and the long-run predictability of the stock market.)

Exercise 4 - Discussion



Source: https://fred.stlouisfed.org/series/SPPOPDPNDOLUSA

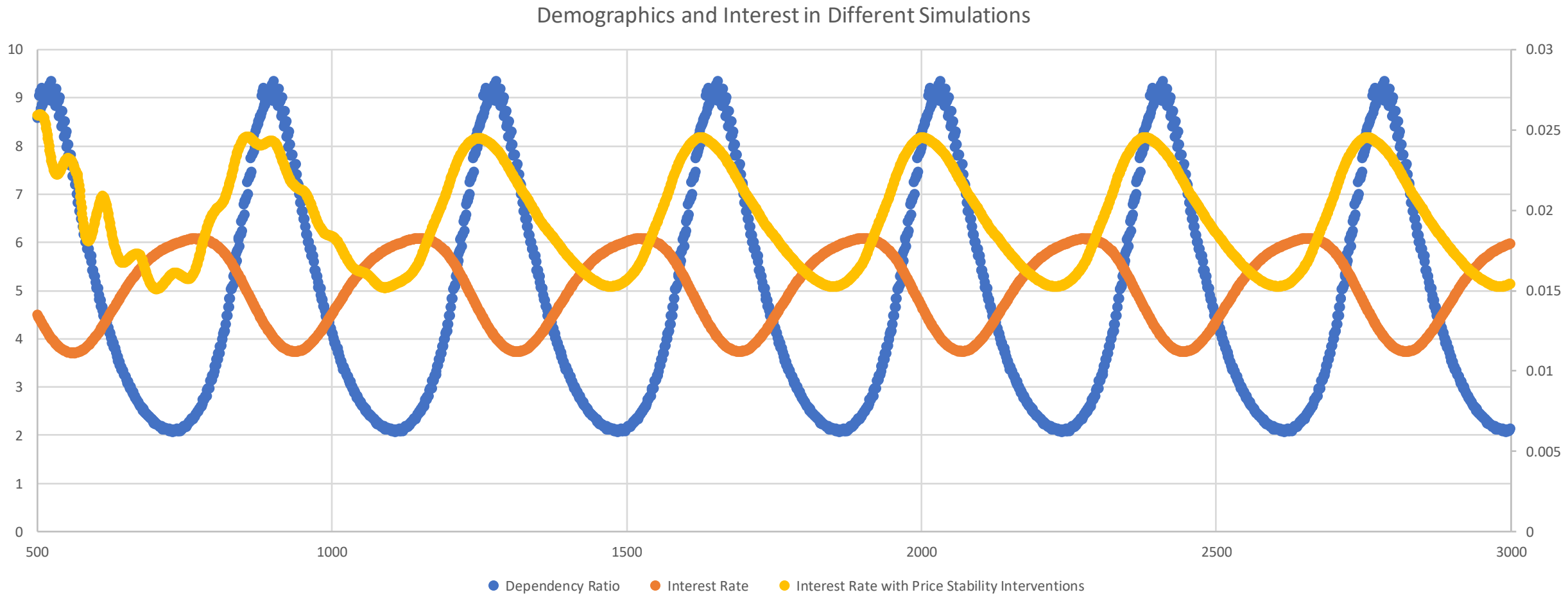
Note: our “dependency ratio” is actually the “inverse dependency ratio”

Exercise 4 - Discussion

SUMMARY OUTPUT			
Regression Statistics			
Multiple R	0.233249457		
R Square	0.054405309		
Adjusted R Square	0.037815929		
Standard Error	2.784748958		
Observations	59		
ANOVA			
	df	SS	MS
Regression	1	25.43215803	25.43215803
Residual	57	442.0251253	7.75482676
Total	58	467.4572834	
	Coefficients	Standard Error	t Stat
Intercept	-0.210133821	3.511667098	-0.059838765
Inv. Dependency Ratio	0.01145233461	0.00632395065	1.810946234

→ We find that the opposite from our simulation in the real world. ☺

Adding price stability mechanisms…



Adding price stability mechanisms…

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.926020637
R Square	0.85751422
Adjusted R Square	0.85745718
Standard Error	0.00121061
Observations	2500

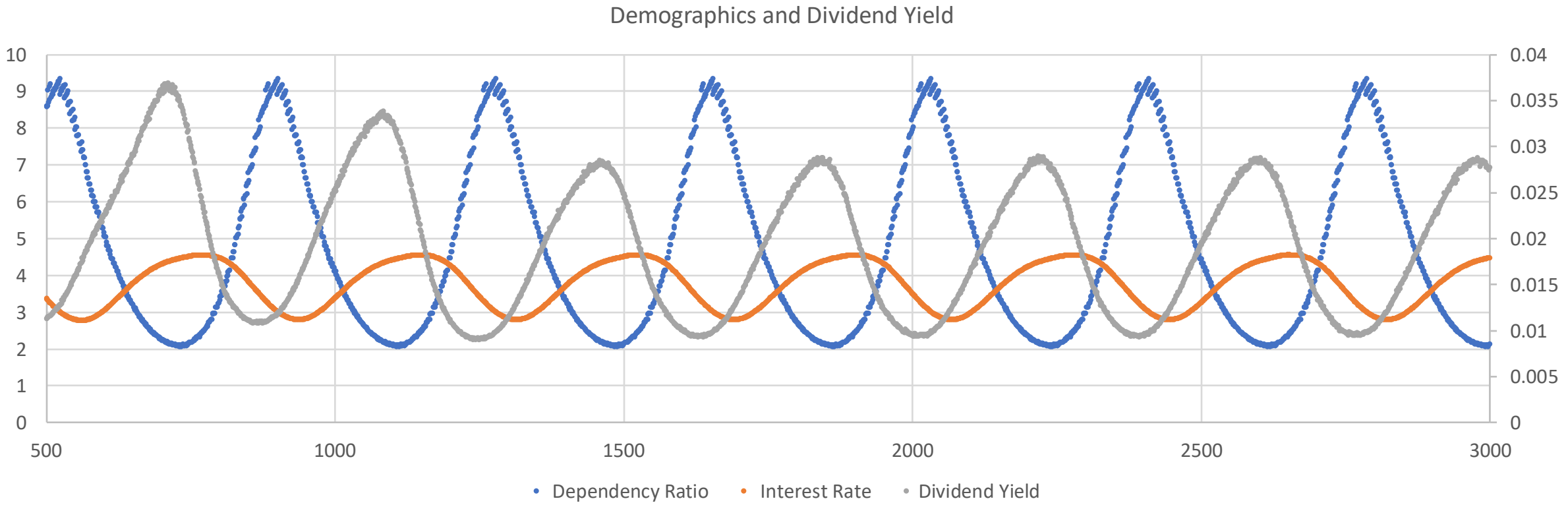
ANOVA

	df	*SS*	*MS*
Regression	1	0.022032839	0.022032839
Residual	2498	0.003661008	1.46558E-06
Total	2499	0.025693847	

	Coefficients	*Standard Error*	*t Stat*
Intercept	0.013550851	5.35414E-05	253.0909362
Inv. Dependency Ratio	0.001226921	1.00066E-05	122.6114759

→ Relation has turned upside down.
→ Explanatory power went up.
→ We are now qualitiatively in line with reality, but that could be an accident. ☺

Extending the model: stock market



Keeping demographics the same, we replace the interest regime direct savings in stocks.
→ Adds one moving part: stock prices.

Stocks

So far:

- Central bank held all stocks
- Central bank paid dividends to consumers
- Consumers saved money for retirement and got an interest on their savings

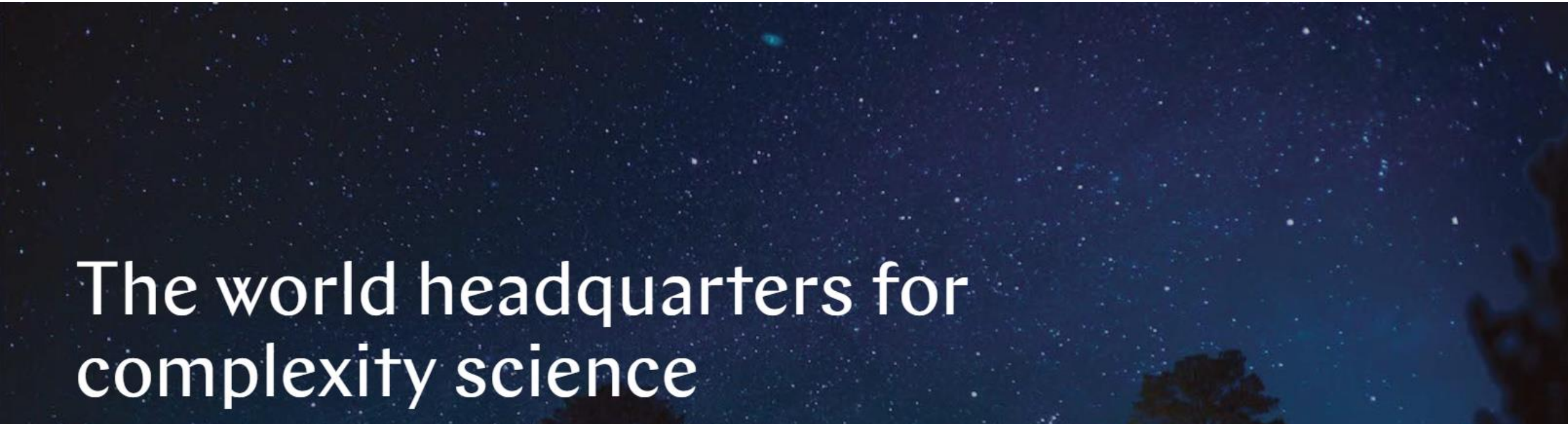
Now:

- Consumers invest in stocks directly, no more stock holdings for central bank
- Adding 5 market makers
- Wealth tax of 0.1% per day → Imposes a discount rate on (immortal) firms.
- CentralBank distributes the wealth tax

Santa Fe Artificial Stock Market

SANTA FE INSTITUTE

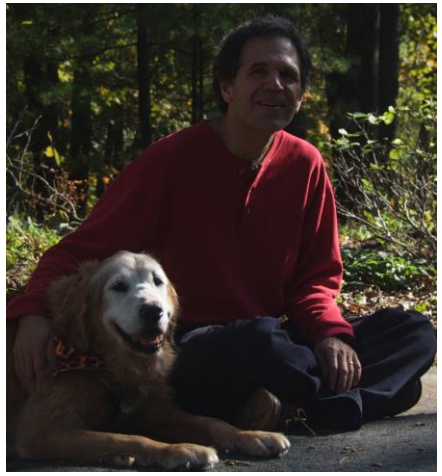
- Small, alternative research institute in New Mexiko
- Known for complexity science and social simulations
- Created the “Santa Fe Artificial Stock Market” in the 90ies, one of the earliest attempts to construct a financial market model with heterogeneously learning traders.



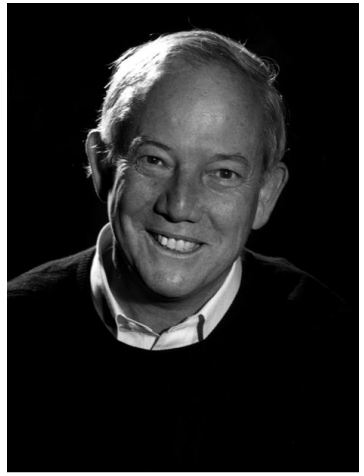
Santa Fe Artificial Stock Market

Resources:

- Tesfation: www2.econ.iastate.edu/tesfatsi/SFISTOCKDetailed.LT.htm
- LeBaron: Building the Santa Fe Artificial Stock Market, 2002
- Brian Arthur: Complexity Economics: A Different Framework for Economic Thought, 2013



Blake LeBaron



Brian Arthur

Leigh Tesfatsion

Santa Fe ASM: Assets

Two assets:

- Risk-free asset, paying $r_f = 0.10$
- Risky stock paying a stochastic dividend: $d_t = \bar{d} + \rho(d_{t-1} - \bar{d}) + \mu_t$

$$\text{with } \bar{d} = 10, \text{ and } \rho = 0.95, \text{ and } \mu_t \sim N(0, \sigma_\mu^2)$$

→ Dividend mean-reverts to 10.

Santa Fe ASM: Market Clearing

announced by a market maker to all the traders. Agents found a matching rule for the current market conditions, and came to the market with an order to buy or sell 1 share of stock. Most of the time this market was out of equilibrium with either more buyers or sellers. The smaller of these two sets would get satisfied while the other would get rationed. For example if there were 100 buyers (B_t) and 50 sellers (S_t), the sellers would all be able to sell 1 share, and the buyers would get only $1/2$ share. The price would then be adjusted to reflect either the excess demand or supply.

$$p_{t+1} = p_t + \lambda(B_t - S_t) \tag{1}$$

I have commented previously on some of the problems with this pricing mechanism[4], but it is important to repeat them here. The first problem is that the results were very sensitive to λ. Setting λ too low generated long persistent trends during which the market stayed in excess demand or supply. Setting λ too high yielded markets in which the price overreacted, and the market thrashed back and forth from excess supply to excess demand.[5] The second problem

Price function in the Santa Fe Artificial Stock Market.
Source: “Building the Santa Fe Artificial Stock Market”, 2002, Blake LeBaron

Demand and Supply

- Demand for stock depends on price prediction
- Each agent makes individual price prediction using prediction rules
- Each agents has 100 prediction rules, but only uses the recently best one.
- Rule-set is evolved through genetic learning
  - Mutation: randomly change rules sometimes a little
  - Selection: delete the worst rules every now and then
  - Reproduction: recombine some of the best rules to replace the deleted ones
- Rules are linear: $\hat{E}_t^i(p_{t+1} + d_{t+1}) = a_j(p_t + d_t) + b_j$
- But only applied if they match current market conditions, see next slide.

Rule matching

$(\#, 0, 1, \#; a_j, b_j, \sigma_j^2)$.

Agent always applies the best active rule.
(Unclear from the paper how inactive rules are ranked…)

Rule	Matches
$(1, \#, 1, \#, 0)$	$(1, 0, 1, 0, 0)$
	$(1, 1, 1, 0, 0)$
	$(1, 0, 1, 1, 0)$
	$(1, 1, 1, 1, 0)$

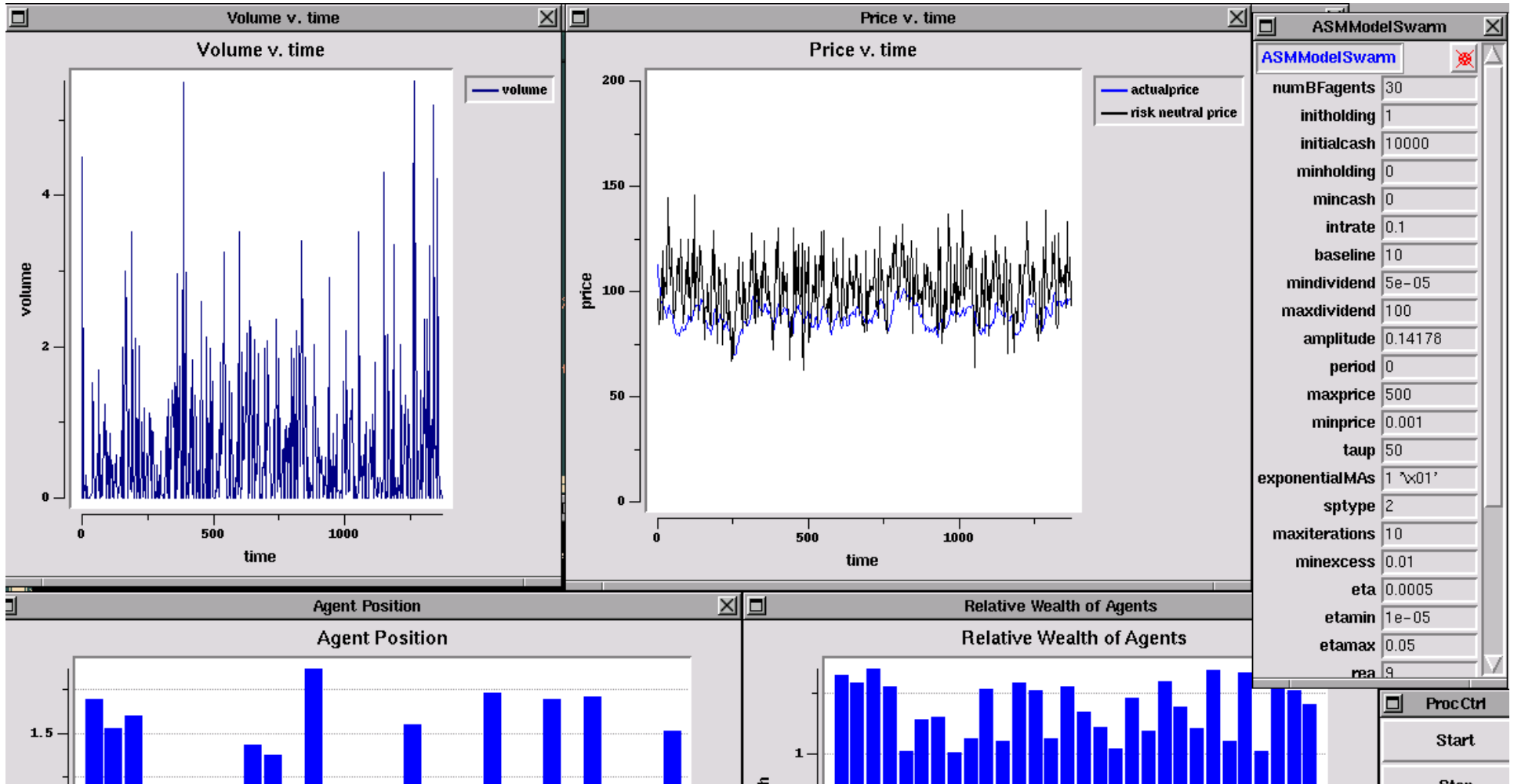
Table 1: Matching Examples

Bit	Condition
1	Price*interest/dividend $> 1/4$
2	Price*interest/dividend $> 1/2$
3	Price*interest/dividend $> 3/4$
4	Price*interest/dividend $> 7/8$
5	Price*interest/dividend > 1
6	Price*interest/dividend $> 9/8$
7	Price $>$ 5-period MA
8	Price $>$ 10-period MA
9	Price $>$ 100-period MA
10	Price $>$ 500-period MA
11	On: 1
12	Off: 0

Table 2: Condition Bits

Santa Fe Artificial Stock Market

Tried to run it myself, but without success… here's a screenshot from the Internet:



Terms 1/3

- Stocks, shares: units of account to keep track of who owns which percentage of a company. In our simulation, each company has exactly 100 shares. So 1 share represents 1% of the company. Unlike in reality, our shares are infinitely divisible.
- Dividends: money that is paid from the firm to its shareholders, in amounts proportional to their holdings.
- Dividend yield: the “interest rate” of stocks. Dividend yield = (dividends per share) / (price per share)
- Raising capital: creating and selling new shares, with the proceeds going to the firm.
- Outstanding shares: all the shares that are not owned by the company itself.
- Market capitalization: the total value of a firm, calculated by multiplying the number of outstanding shares with their price.
- Bankruptcy: a firm deciding to stop its business. The leftovers are distributed among the shareholders.

Terms 2/3

- Position: a number of shares owned by a specific investor. I.e. “I have a large position in Nestlé.”
- Portfolio: a collection of positions. Ideally, the positions in a portfolio are chosen such that they complement each other, such that the portfolio as a whole has a better risk-reward structure than each position on its own.
- Portfolio theory: the art/science of managing portfolios.
- Diversification: gets you better returns for the same “risk budget”. One of the very few things you get for free when investing.
- Order book: stock markets keep a book with all open orders for each stock.
- Bid (Geld): an order to buy shares
- Ask (Brief): an order to sell shares
- Spread: the difference between the highest bid and the lowest ask.
- Limit order: an order to buy for at most X $ per share, or to sell for at least Y $ per share.
- Market order: a bid or ask without limit, to be executed immediately regardless of the price.
- Liquidity: the extent to which shares can be bought and sold without moving the price much

Order book example

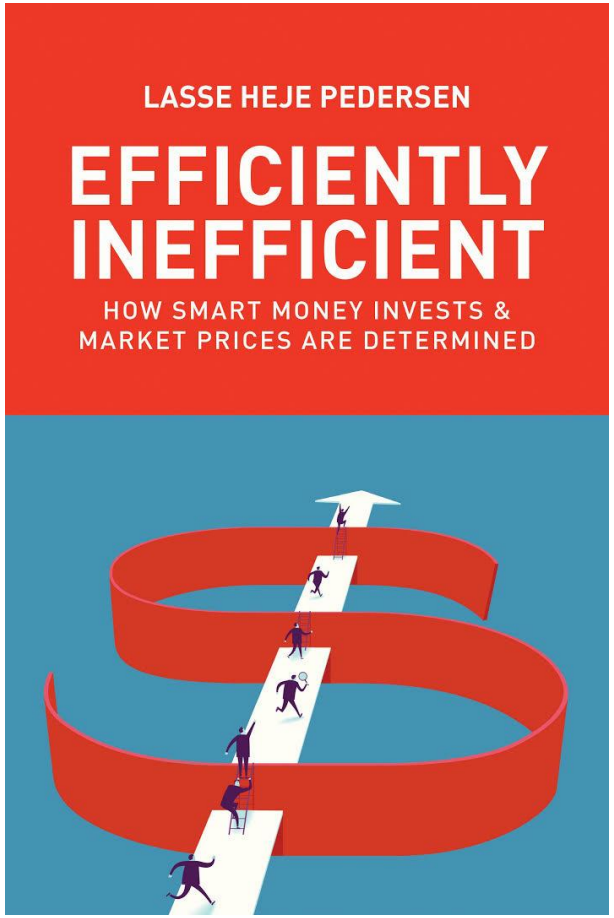
Bitfinex order book. Knowing the pending order allows to estimate the price impact of a larger trade.
However, there are also “hidden” orders that don’t show up in the order book.

Terms 3/3

- Fund: a firm that owns a portfolio and has no “real” productive business.
- Index fund: a fund that manages its portfolio such that it reflects the whole market.
- Passive strategy: a portfolio management strategy that follows strict, mechanic rules and often only requires a minimal amount of trading.
- Active strategy: a portfolio management strategy in which one actively seeks to exploit market inefficiencies. This only works to the extent markets are not efficient and the manager succeeds in identifying the resulting opportunities.
- Efficient market hypothesis: the hypothesis that markets are efficient and thus prices always “right”. The only valid source of price changes is the arrival of new information, e.g. about a particular firm or the economy. There is no room for behavioral errors.

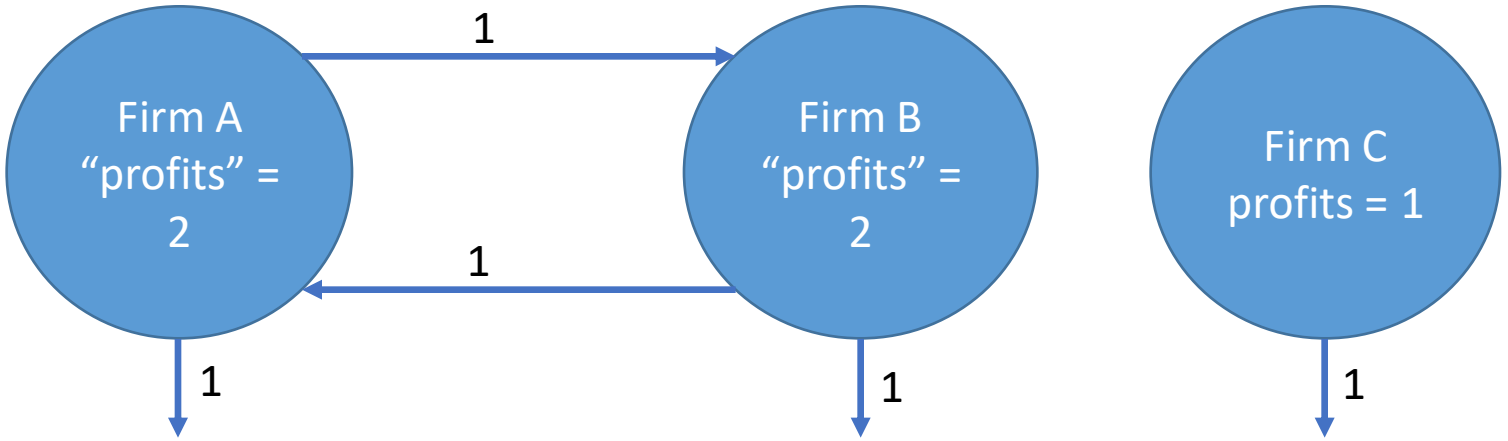
Interesting paper: Grossman, S.J. and Stiglitz, J.E., 1980. On the impossibility of informationally efficient markets. *The American economic review*, *70*(3), pp.393-408.

It says that markets cannot be fully efficient when it is costly to obtain information about what prices are right. Most up to date book on the topic: Efficiently Inefficient by Pedersen.



What should firms maximize?

- Usual assumption: firms maximize real profits
- In our model so far: firms maximize nominal profits
  (This should be equivalent to maximizing real profits as long as the central bank does its job well.)
- However, consider the following setup:



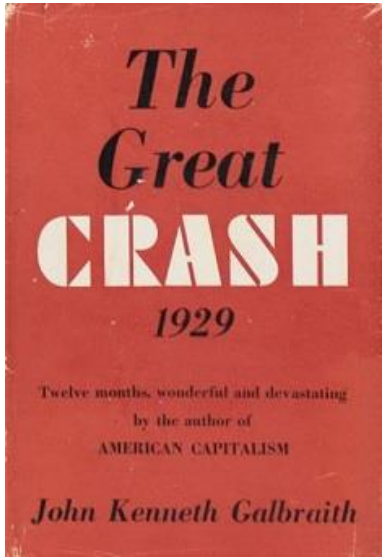
All firms make 1$ profits from real business per year, but A and B own 50% of each other, so they can add the dividends they receive from each other to their profits.
When the flows are in equilibrium, the A and B have doubled their profits in comparison to C!

What should firms maximize?

In economic theory, there is no problem as long as firms are not allowed to buy each other's shares.
In reality, direct and indirect self-ownership can lead to double accounting. It also contributed to the bubble and crash of 1929.

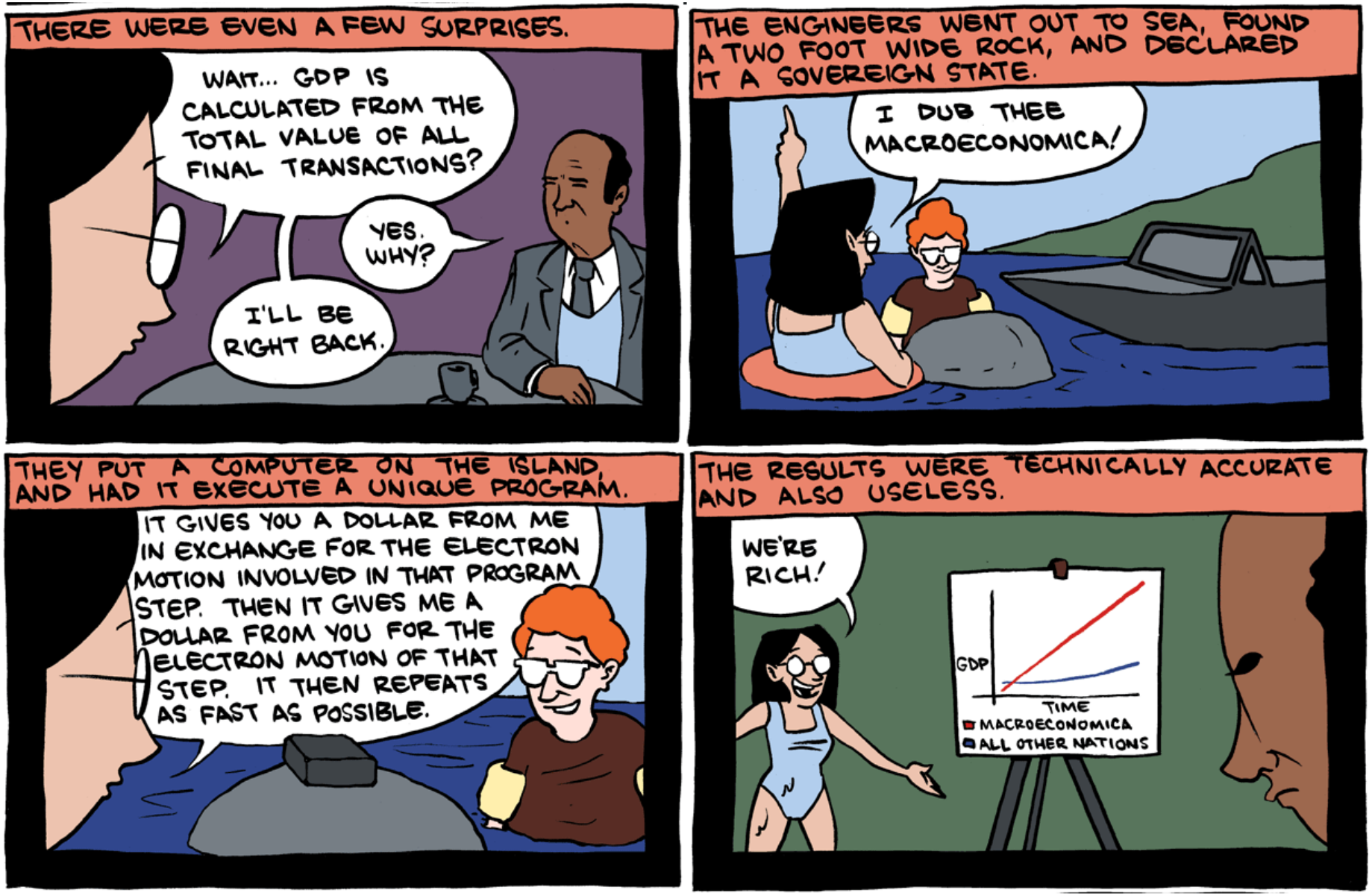
Third quarter[12][note 1]	
	Apple Inc. ▲791,726
	Alphabet Inc. ▲664,550[13]
	Microsoft ▲568,965
	Amazon.com ▼459,435
	Berkshire Hathaway ▲451,840[14]

Most of the market cap of Berkshire Hathaway, the 5th largest public firm in the world, comes from owning stocks of other listed companies, e.g. Coca Cola. So a part of Coca Cola's value is counted twice when calculating the total value of all US stocks.



As Galbraith describes, the bubble and the crash of 1929 was partially driven by funds buying each other's shares, creating an illustion of value that quickly deflated once the funds were forced to sell and sold each other's shares again, forcing them to sell even more.

Excerpt from www.smbc-comics.com/?id=2855



Ad-hoc Group Work

Problem: pure profit-maximization leads to those firms to win the ranking that own most of their own stocks and pay a large dividend to themselves.

How should this problem be solved?

How should we rank firms?

Project Setup: Funds

- Consumers invest in the stock market instead of saving
- Your funds are added to the simulation on day 1000
- How to choose the right stocks?

→ Your “task” for now & the next lesson: think about the strategies you want to try out, some investment ideas. We can discuss them and I can then make sure the simulation supports them.