University of Zurich[UZH]

Agent-based Financial Economics
Lesson 4: Growth

Luzius Meisser, Prof. Thorsten Hens

luzius@meissereconomics.com

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

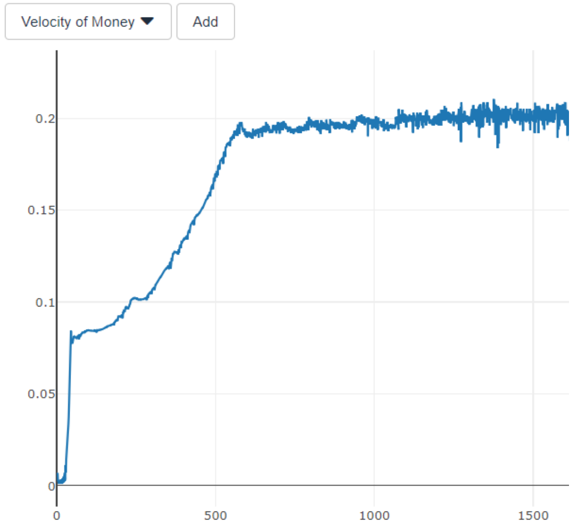
- Richard Feynman

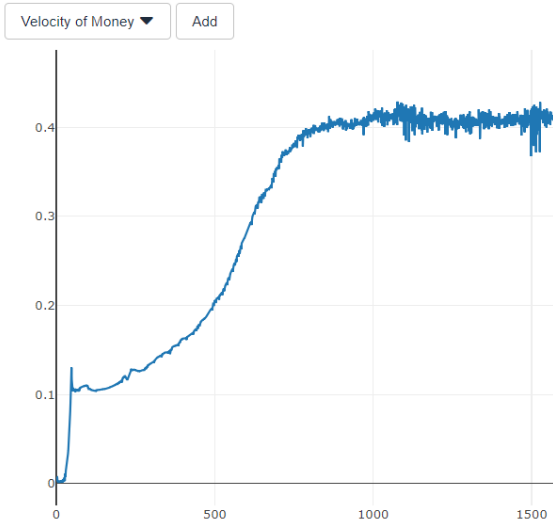
Today

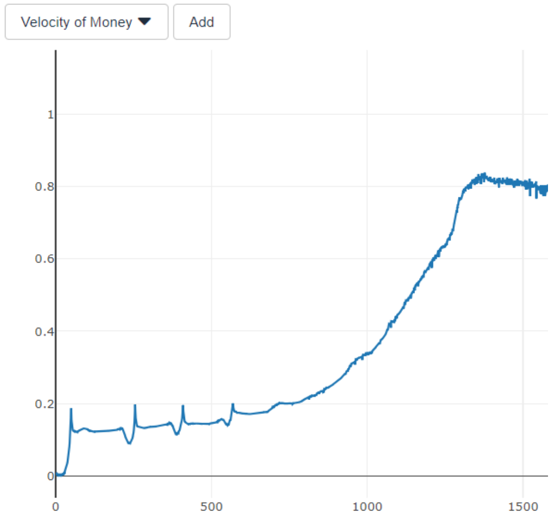
- Discussion of exercise 3, money
- Methodology: Agile Software Development
- Classic growth model from “economic foundations of finance”
- Exercise 4: growth

Exercise 3, Task 1, Discussion

Playing with the farmer's capital buffer:







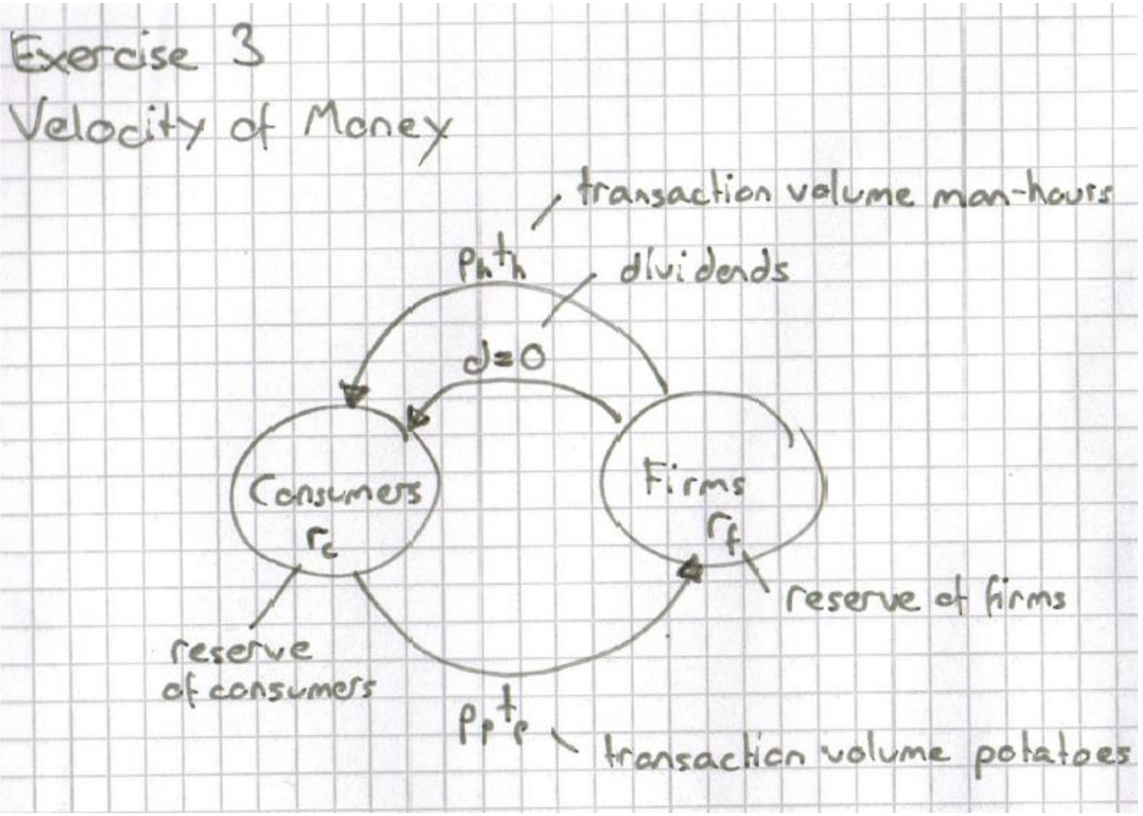
Buffer 0.9 → Velocity 0.2

Buffer 0.8 → Velocity 0.4

Buffer 0.6 → Velocity 0.8

→ Velocity seems proportional to (1-Buffer), which makes sense.

Exercise 3, Task 1, Discussion



Findings:
- Velocity of money stays more or less constant as long as the agents do not change the size of their capital buffers.
- Relatively simple to calculate as dividends are zero
- Dividends being zero in equilibrium, farm's "buffer" parameter does not have an impact in this configuration
- Assuming constant velocity of money seems reasonable in the short run, but questionable in the long run as the behavior of the economic participants might change.

Exercise 3, Task 1, Generalization

Configuration meissereconomics.com/vis/simulation?sim=ex3-money-buffer
Farm's budget now explicitly depends on its buffer → both buffers matter now.

$M \cdot V = P \cdot T$

$M \cdot V = p_h t_h + p_f t_f$

$p_h t_h = p_f t_f$ Consumer spends what he earns

$r_c = 5\, p_h t_h$ Consumer keeps 80% of income in buffer ⇒ buffer is 5x of income

$r_f = 10\, p_h t_h$ Same argument

$r_c + r_f \approx M$ not accurate because r_f and r_c not measured at same point in time

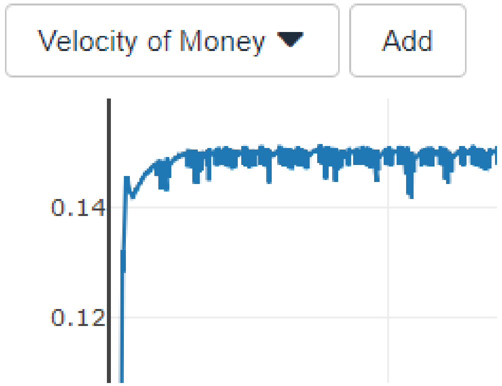
$\Rightarrow r_f = 2 r_c \Rightarrow r_f \approx \frac{2}{3} M \quad r_c \approx \frac{1}{3} M$

$\Rightarrow MV = 2 p_h t_h = \frac{2}{5} r_c = \frac{2}{15} M \Rightarrow V = \frac{2}{15}$

```java
public class Farm2 extends AbstractFarm {

    private static final double CAPITAL_BUFFER = 0.9;

    protected double calculateBudget() {
        return getMoney().getAmount() * (1.0 - CAPITAL_BUFFER);
    }
```



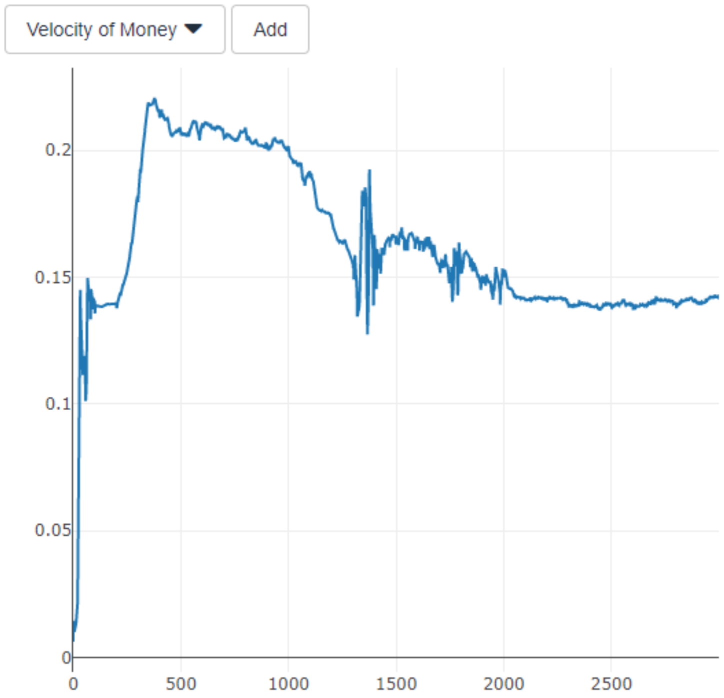
Not entirely accurate as consumer spends some of the income on the same day.

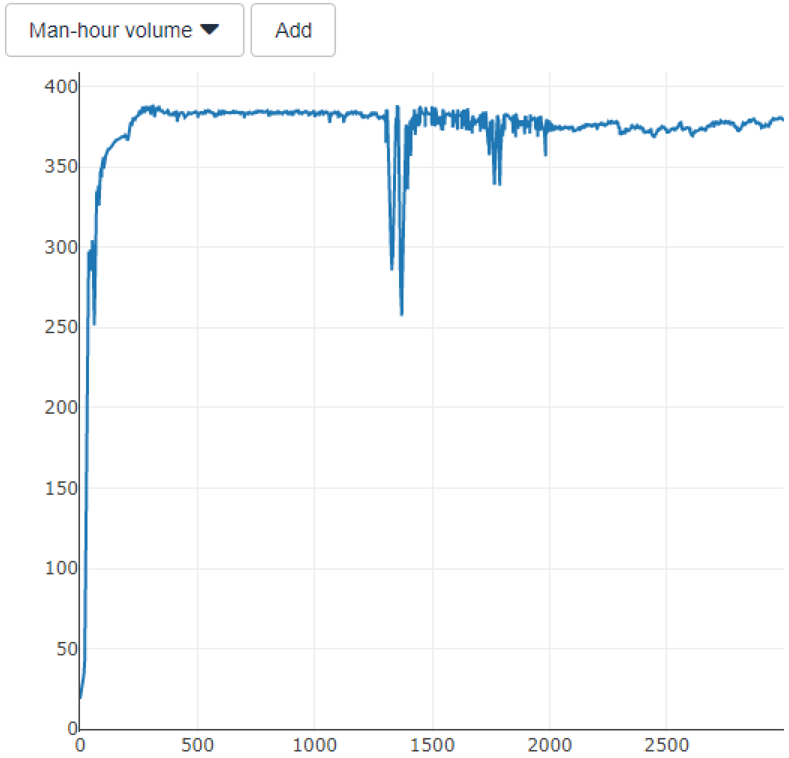
Exercise 3, Task 2, Discussion

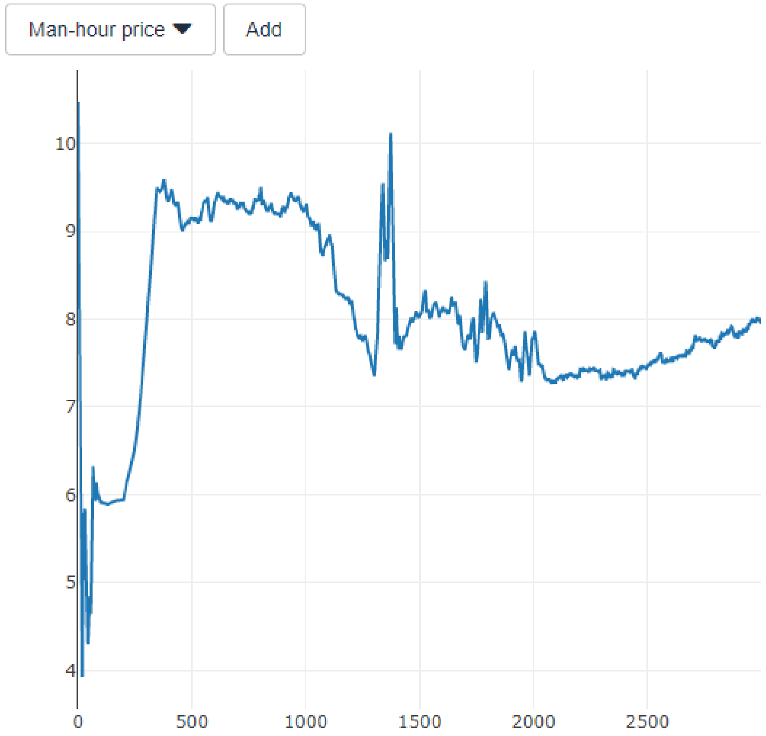
$MV = PT$

What happens to the other three variables as the money supply M is increased? (Once simulation is stable.)

- Velocity stays constant
- Production and amount of traded goods stay constant
- Prices goes up

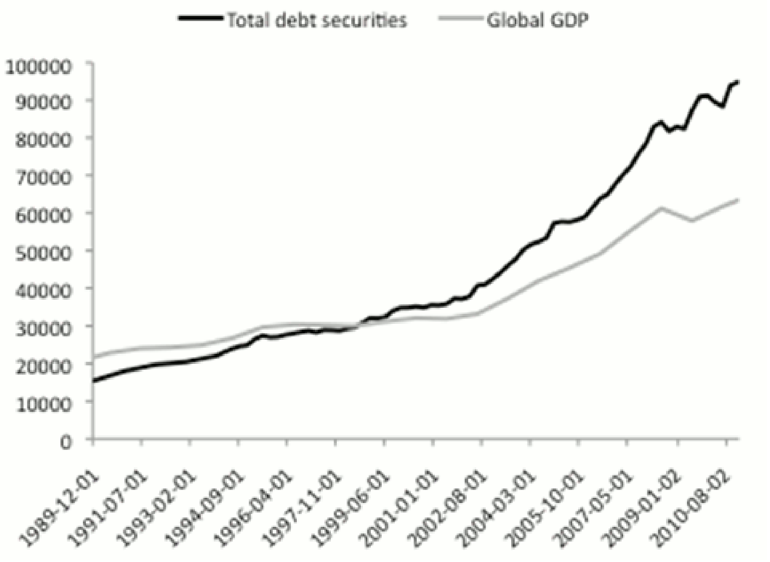






Exercise 3, Task 2, Discussion

It looks like higher nominal interest rates lead to higher inflation!
In fact, in our simulation, it holds that interest rates = inflation rate.
This is exactly the opposite of what can be observed in reality, where national banks lower interest rates to increase inflation and vice versa.
Why is that? Our model has no credit yet. In reality, lower interest rates make firms borrow more money from the central bank, thereby increasing money supply, at least for as long as the debt is not repaid.
Excellent thoughts by John Cochrane on this issue can be found here:
Cochrane, J.H., 2016. Do higher interest rates raise or lower inflation?. *Unpublished paper, February, https://faculty.chicagobooth.edu/john.cochrane/research/papers/fisher. pdf*



Total global debt has grown faster than global GDP. Source: http://voxeu.org/article/global-saving-glut-will-hold-bond-yields-down

Exercise 3, Task 3, Discussion

An interesting question you might have asked yourself while doing task 2 is: if interest is being paid on cash holdings, can an agent gain an advantage by hoarding cash?

The answer is: no! As long as the inflation rate is the same as the interest rate, hoarding cash is futile.

However, inflation rate could fall below interest rate as soon as negative cash balances are allowed. In such a scenario, net money supply and thus also inflation grows at a slower rate than the interest rate. This is equivalent to agents being in debt with other agents.

Generally, money should be neutral if everyone acts rationally. I.e. the nominal amount of money in circulation should make no difference for real economic activity.

Neutrality of Money (Patinkin, D. (1987). Neutrality of money, The New Palgrave: A Dictionary of Economics v.3, 639–644.)

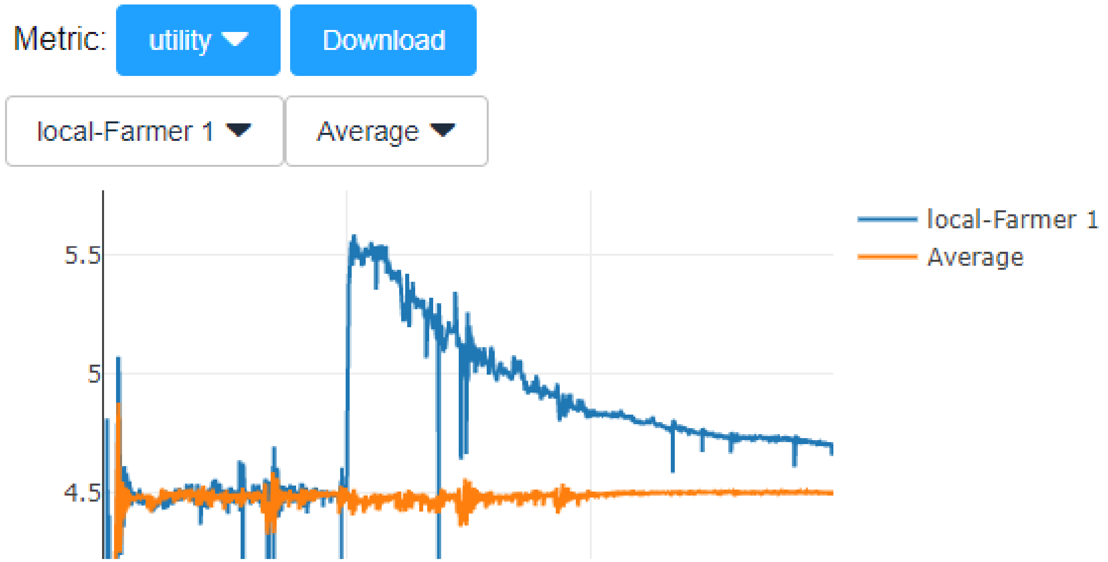
Exercise 3, Task 3, Discussion

Money is not neutral any more when having a monetary economy and not equally distributing it.

In this exercise, lucky farmer number 1 gets 100 freshly printed dollars per day from the national bank, which initially is a huge advantage over the others. This advantage diminishes with inflation.

Once the helicopter money stops (not shown here), the economy returns to its usual equilibrium.

Sidenote: in theory, the other agents could switch to a new currency, thereby destroying the lucky farmer's advantage. In practice, changing currencies is prohibitively expensive.



→ While the neutrality of money holds in the long run, it matters a lot who gets the freshly printed money first!
→ Who gets the freshly printed money first in reality?

The Code is the Model

- How to apply principles from modern software engineering to building computational economic models
- Published in the Journal of Microsimulation, 2018
- Very mixed feedback, from fierce resistance to enthusiastic agreement ☺

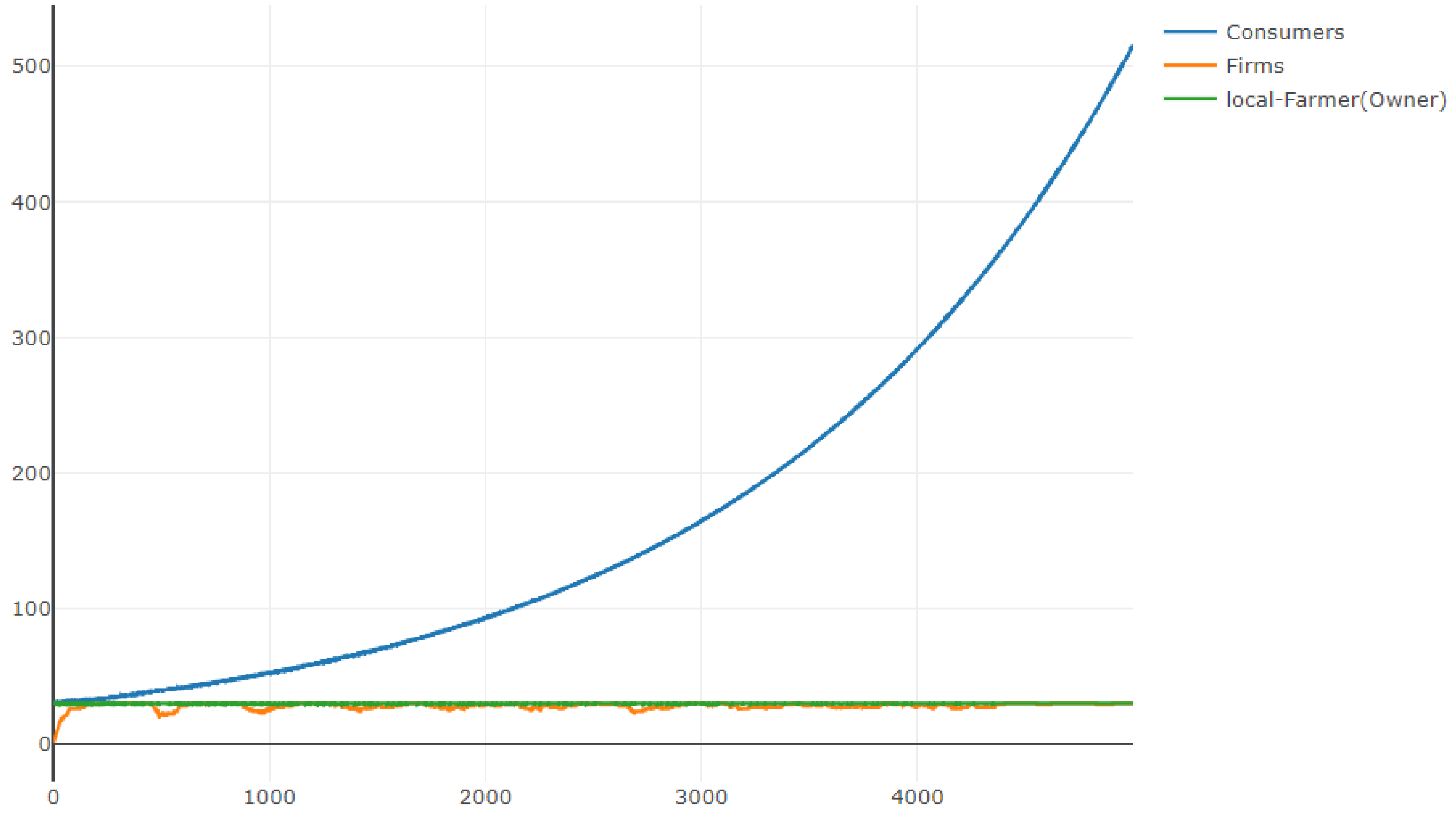
→ See separate slide deck

Growth

- We extend the existing simulation from the previous exercise by continuously adding additional agents. Unlike the initial agents, these additional agents do not get a land endowment, so the amount of land stays constant as the population grows.
- Furthermore, consumers are made mortal, living for 500 days each
- Farmers pass on their farm to a single heir when they die
- If you study this growth configuration in detail, you will notice that money is being printed to ensure money supply grows with the economy, thereby keeping prices in a useful range and also helping firms with price finding and optimizing profits. Price stability ensures that maximizing nominal profits and maximizing real profits is the same.

Growth

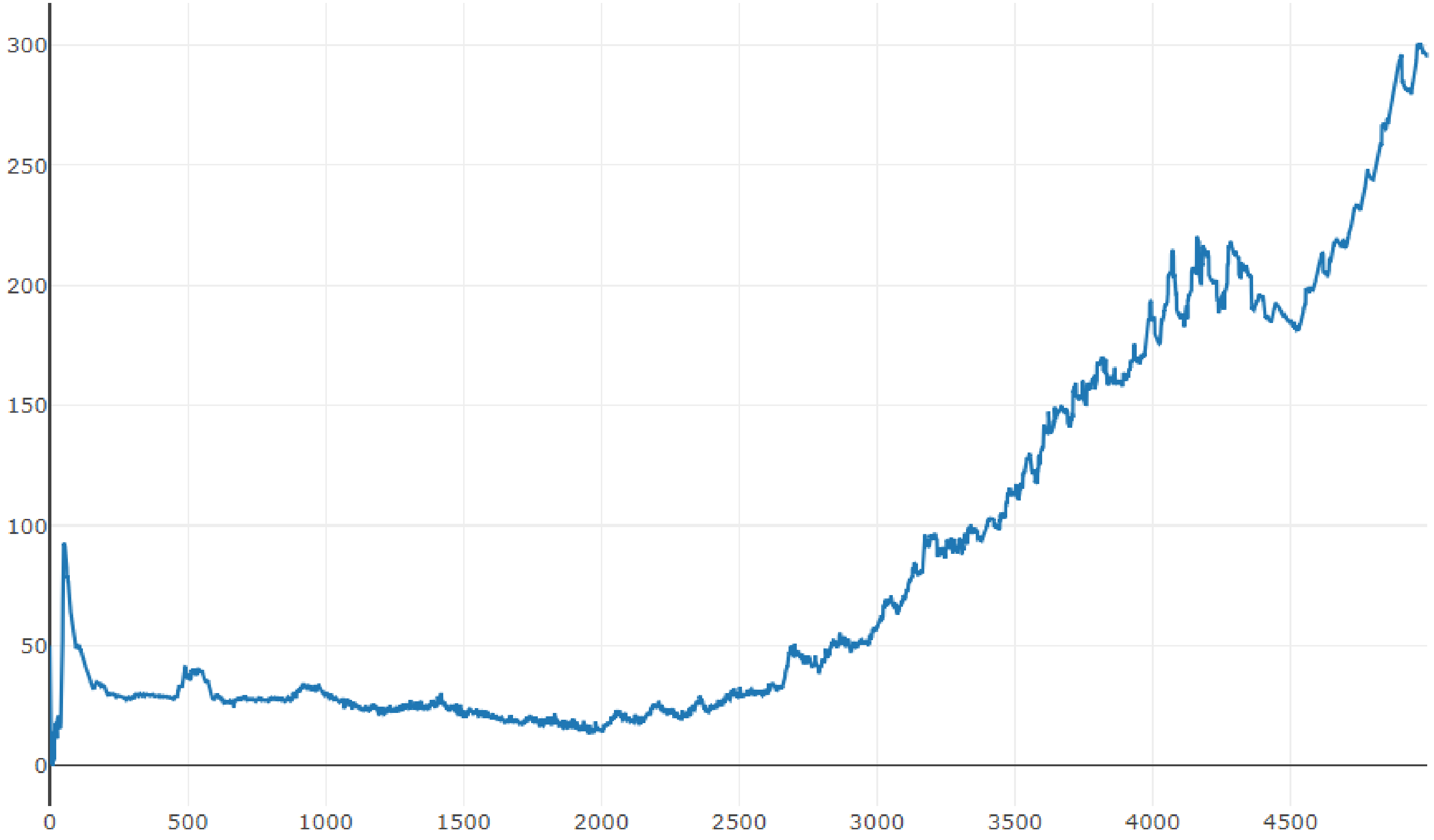
What happens when adding additional consumers to the simulation?



Growth

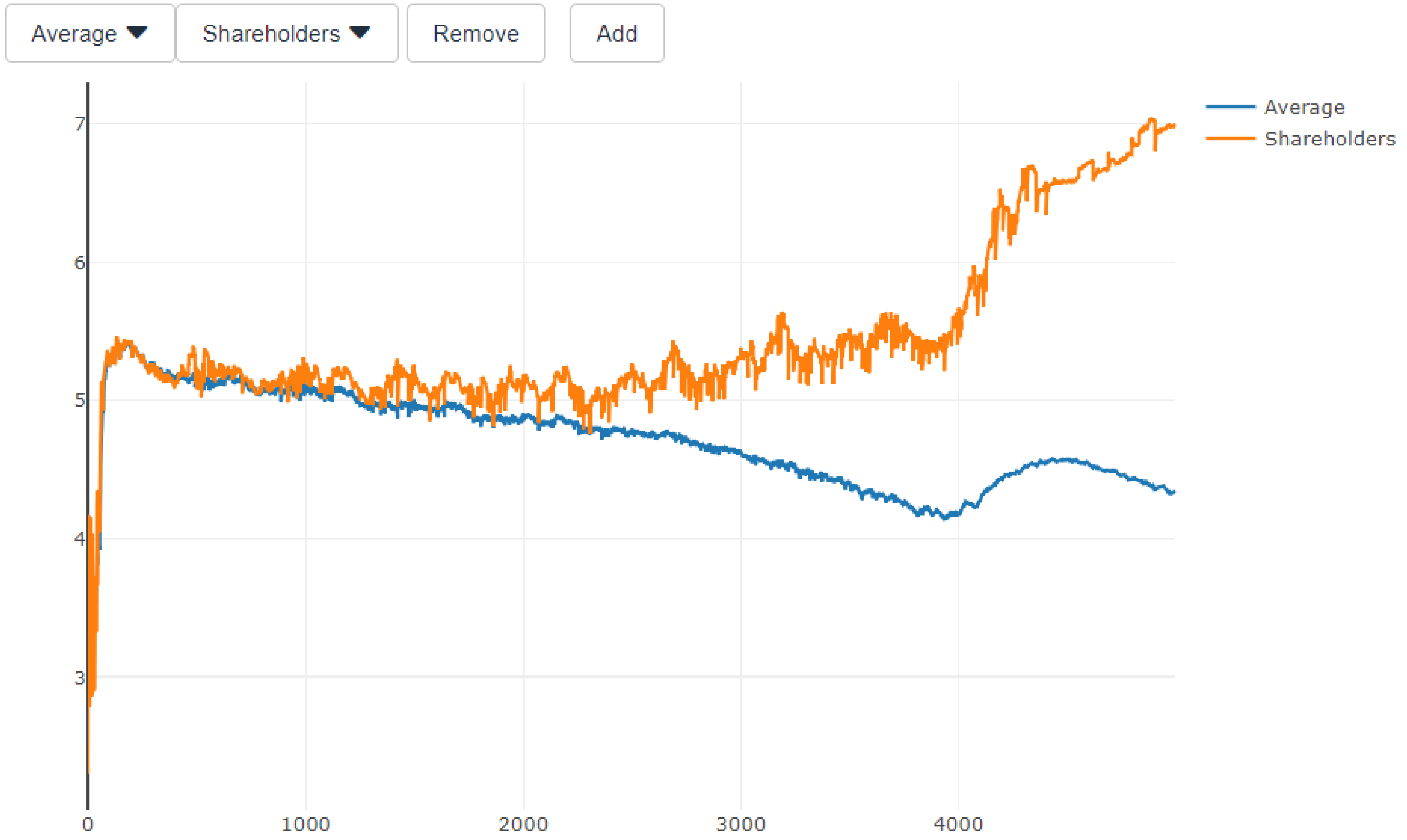
As the number of workers grows, so does the number of man-hours traded every day, and along with it the optimal number of firms until it reaches the ceiling of 30 (there are only 30 lots of land).

The aggregate production function starts resembling a Cobb-Douglas with fixed costs, and does not morph into a linear production function any more.



Growth

Daily average utility, as well as the minimum and maximum experienced by an agent.



What happens when adding additional consumers to the simulation?

Utility of owners grows as that of workers declines.

As firms start distributing dividends, the firm owners start being better off than the works. In this scenario, the “capitalists” benefit from immigration, while the workers suffer.

Growth – Theory Check

What we found matches the predictions from classic theory.

While there is only population growth (n), but no technological progress (g) yet in our model, we can tell something the aggregate model from the book does not: even though consumption per capita falls with population growth, consumption of the firm owners grows.

(In this case, this conclusion could also be drawn relatively easily by extending the mathematical model, but that is not always the case.)

- Results under the assumption of a Cobb-Douglas production function:
  - Real wage increases with technological progress
  - Real wage falls with population growth
  - Consumption per capita falls with population growth
  - Real profits increase with technological progress
  - Real profits increase with population growth

	g	n
$\frac{L}{1+n}$	$=$	$=$
$\frac{C}{1+n}$	$+$	$-$
$\frac{Y}{1+n}$	$+$	$-$
π	$+$	$+$
w	$+$	$-$

In their model, hours worked per capita does not change as leisure does not enter their utility function. In ours, this does change as the firm owners work less as they receive more dividends.

From "Economic Foundations of Finance" by Thorsten Hens and Sabine Elmiger

Growth and Death

- The aggregate model only has a growth rate g, which actually is the net growth rate: birth rate – death rate
- In the agent based model, we can separate the two by making consumers mortal and setting the birth rate accordingly.
- However, we have to come up with inheritance laws: whenever an agent dies, he leaves an inheritance behind. And whenever an agent is born, he receives at most one inheritances if there any left.

→ We get dinasties of shareholders, no redistribution, comparable to previous result.

Retirement and Savings

- Trading volume is hard to explain with equilibrium models – because trading usually only happens out of equilibrium! Once the equilibrium is reached, there is no need to trade any more.
- “Volume is The Great Unsolved Problem of Financial Economics. In our canonical models — such as Bob’s classic consumption-based model — trading volume is essentially zero.” (John Cochrane in faculty.chicagobooth.edu/john.cochrane/research/papers/Atkeson_Alvarez_comments.pdf)
- One way to introduce trading volume is to have mortal consumers that save for retirement and sell their assets again when they are retired. An example of a paper that does so is:
  J. Geanakoplos, M. Magill, and M. Quinzii. Demography and the long-run predictability of the stock market. Brookings Papers on Economic Activity, 2004(1):241–325, 2004.
- We will do the same in exercise 4, but for now, savings are not on the stock market, but in cash.

Exercise 4: Retirement Savings

- Consumers live for exactly 500 days
- They retire at age 400 and won’t work any more henceforth

Your task is to find a good savings heuristics that maximizes life-time utility.

github.com/meisser/course/blob/master/exercises/journal/exercise04-task.md