University of Zurich[UZH]

Agent-based Financial Economics
Lesson 3: Money

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

- Richard Feynman

Today

- Discussion of exercise 2, the Farmer
- Famous model: the crisis economics model
- Multilateral vs bilateral trading
- Cash-in-advance model
- Inflation, price normalization
- Exercise 3: printing money

Exercise 2: Final Ranking

Rank	Agent	Utility	Method
1	team002-Farmer	4.519484916910302	Analytic profit maximization, dividend above 500.
2	team007-Farmer	4.518869425356523	Hardcoded 16 man-hours. Dividend above 980.
3	team001-Farmer	4.435516880949909	Spending 100, dividend above 1000.
4	team010-Farmer	4.432707964682674	Spending sometimes 100, sometimes 80, depending on creative heuristic. Dividend is 9.
5	team003-Farmer	4.432643149844514	Spending 43% of cash reserves. Dividend above 1490.
6	team005-Farmer	4.4151494404185545	Intended to hardcode 12.75 man-hours. Dividends above 1000.

Notes:

- Error on slide 13 of lesson two, thanks team 7 for noticing!
- Simulation can react sensitively to parameter changes. Sometimes this is due to bad snapshot timing.
- Student request: spend more time explaining the code.

Exercise 2: Analytical Solution

1. Use aggregate production function to solve the aggregate firm's optimization problem

→Only one feasible price ratio.

→Labor share: 1.0, Profit share: 0.0
(This is always the case with linear production functions.)

Exercise 2 - Analytical Solution

$p_x = 1$ normalize potatoe price to 1

p_h price of a man-hour

Aggregate firm production function: (don't forget the land)

$$F^*(x) = x \cdot \underbrace{c^{\alpha-1}\,\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}}_{k=0.626} \cdot 100^{0.2} \qquad \alpha = 0.6,\ c = 6$$

Profits: $\Pi(H) = p_x \cdot F^*(H) - p_h \cdot H = kh - p_h H$

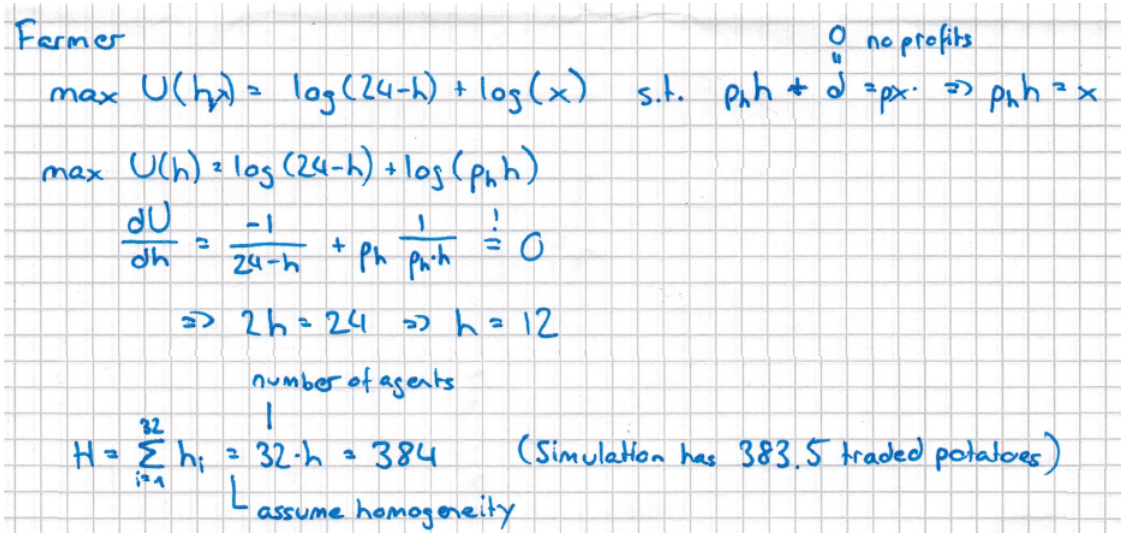
Three cases:
- $k > p_h \Rightarrow \infty$ profits by choosing $H = \infty$
- $k = p_h \Rightarrow$ 0 profits, any H is feasible
- $k < p_h \Rightarrow$ 0 profits, $H = 0$ no production

This always holds with constant returns to scale (linear production functions).

Interesting case is $k = p_h = 0.626$

Exercise 2: Analytical Solution

2. Solve the aggregate consumer's problem. Since there are no profits, we do not need to distinguish farm owners and the others.



Resulting utility per farmer: U = 4.501

Exercise 2: Optimality Conditions

- Labor share: 0.6 for individual firm, 1.0 in the aggregate
- Profit share: 0.4 for individual firm, 0.0 in the aggregate
- The aggregate one prevails. Why?

→ Profits are 0 in the efficient outcome.

Exercise 2 - Simulation

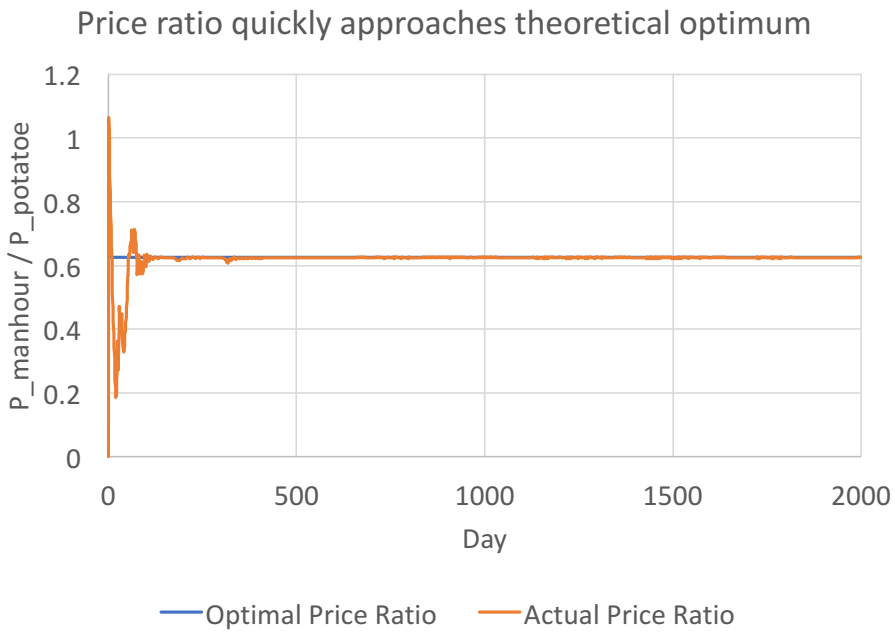
Prices quickly converge towards what theory predicts, namely p=0.626.

Using:

```
protected double calculateDividends(int day) {
        double money = getMoney().getAmount();
        return money - 1000;
}
```

Why does this work:

1. At average, there is less than 1000$ per firm, so this dividend schedule leads to 0 dividends in equilibrium, which is in accordance with the efficient outcome.
2. By emitting everything above 1000$, the situation of a firm hoarding excessive amounts of money is avoided.

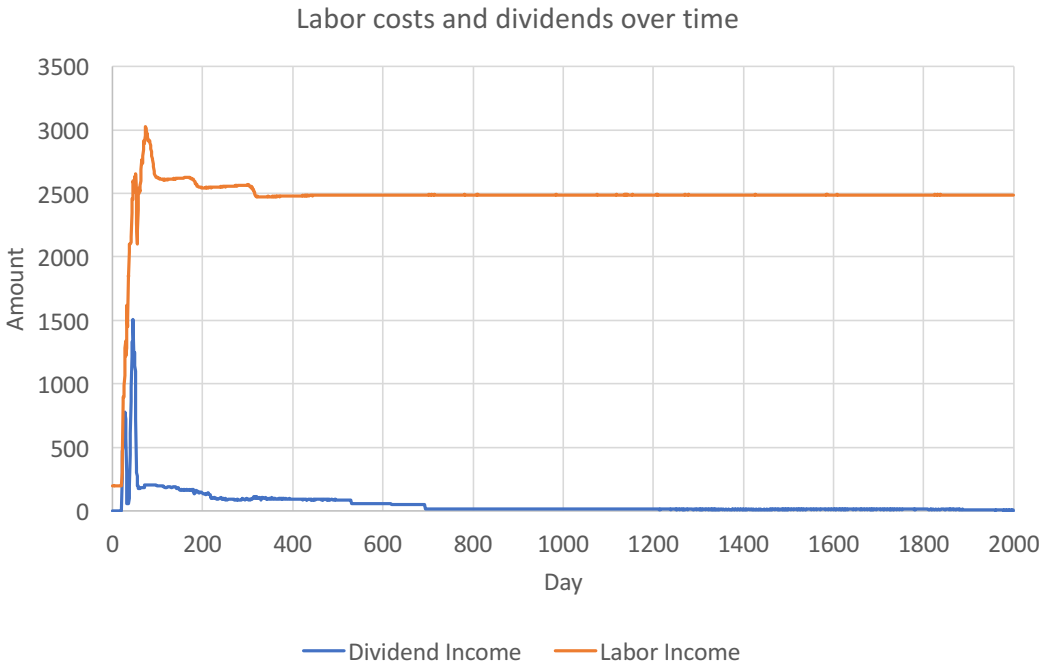


Exercise 2 - Simulation

In case of efficient outcome:

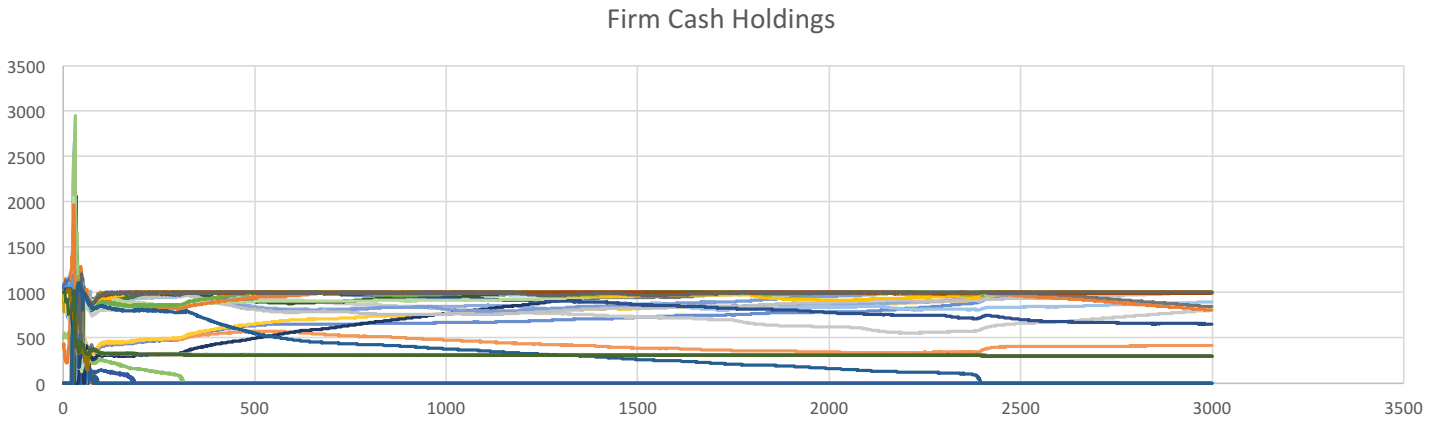
- Firms make (almost) no profits in equilibrium, i.e. profit share is neglibile
- This is a consequence of having a linear aggregate production function (slide 16 of previous lesson)
- Linear production function = constant returns to scale = profit share is zero

→ Farmers that own a farm and farmers that do not own a farm are (almost) equally well off. Slight difference comes from not being able to have fractions of firms.



Exercise 2 - Simulation

The dividend rule of emitting everything above 1000 prevents one firm from hoarding too much money and makes sure that enough stays in circulation.
In the long run, dividends are 0, but setting them to zero from the beginning does not work either for the reason above.



Exercise 2 – More Adaptive Solution

```
private double calculateBudget() {
        double profits = marketing.getFinancials(getInventory(),
        getProductionFunction()).getProfits();
        control.reportOutput(profits);
        return control.getCurrentInput();
}
```

Using the CovarianceControl method.
No more fixed amounts, makes the agents fit for dealing with changing prices and money supply.

→ Code discussion.

Exercise 2: The role of buffers

- Capital buffer of the consumer:
- Capital buffer of the firm:

Firm Decision Heuristics

- Working Paper
- Generally: dividends can be seen as a control variable for the size of the firm.
- Dividends < Profits: firm grows
- Dividends > Profits: firm shrinks

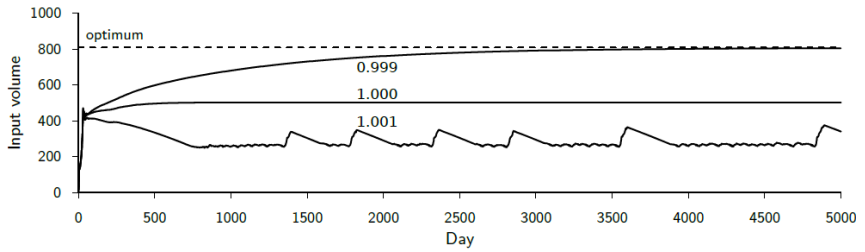
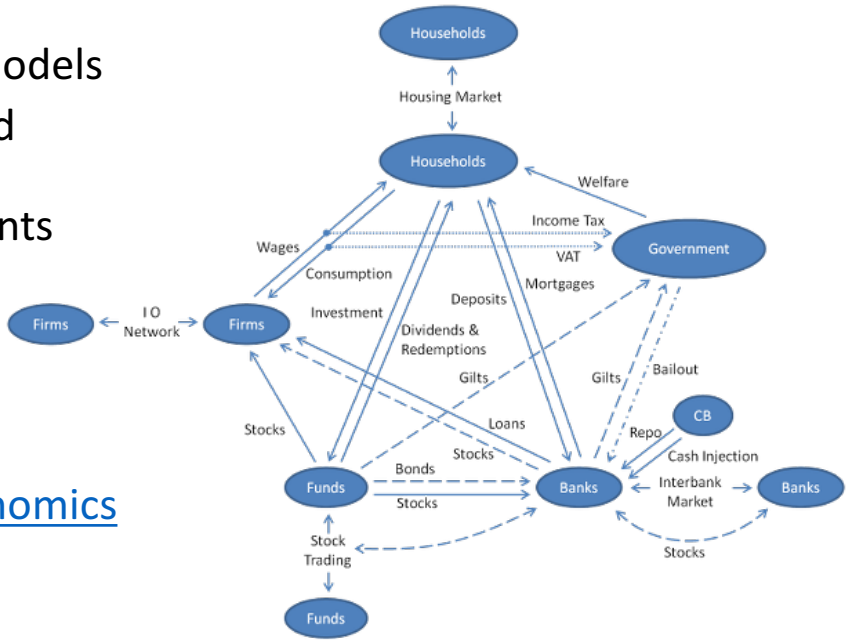


Figure 1: Setting the parameter b_R slightly below the standard value of 1.0 already allows the firms to converge towards the efficient production level.

Crisis-Economics

- “Crisis” actually does not mean crisis, but “Complexity Research Initiative for Systemic InstabilitieS”
- One of the largest agent-based economic models
- Lots of top European researchers in the field participated
- Dozens of papers and specification documents “produced”
- EU funding
- Dead since 2014
- Website: http://www.crisis-economics.eu/
- Source code: https://github.com/crisis-economics

→ Showing you a demo



Break

Money: three roles

Roles:

- Unit of account
- Store of value
- Medium of exchange

Properties:

- Durable
- Divisible
- Fungible

Money in classic economic models

Money works if:
- Everyone wants it
- Everyone has some (or can get some by selling something else)

(Bilateral trading processes, pairwise optimality, and Pareto optimality, Feldmann, 1973)

"Transactions role of money is not well approximated by simply putting money into the utility function."
(The Transaction Role of Money, Ostroy and Starr, 1990)

→ We don't put it into the utility function. It suffices if people want money because they can buy actually useful goods with it.

Money: Cash-in-advance model

- Creates a demand for money by requiring all transactions be made against money
- Allows to spend money only once per time step

-> We do not strictly adhere to this, consumers can spend money on the same they it was earned. Also, not all money is used every day.

Quantity Theory of Money

- **MV = PT (the Fisher Equation)**
- Each variable denotes the following:
  M = Money Supply
  V = Velocity of Circulation (the number of times money changes hands)
  P = Price level
  T = Volume of transacted of goods and services

Exercise 3 - Money

- Experimenting with the money supply
- Can an individual agents influence the price level by hoarding money?
- What happens if money pays interest?
- What happens when we issue helicopter money?