1 Abstract

The aim of this exercise is to build an AB version of the models of chapter 3 (SIM model) and 4 (PC model) of [2].

2 SIM model

Assumptions are

1. closed economy

2. agents other than government can be conceptually divided in Households, when they receive income and consume and accumulate assets, and Production when they sell service and pay out wages.

3. production undertaken by providers of services; they have no capital and no intermediate production costs

4. there are no banks, no firms, no profit

5. there are not interests payment

6. there is only government money

2.1 non formal model

Target system: imaginary population where economy is simplified.

There is a government that creates money. Citizens can sell and pay wages, recive wages, pay taxes, consume and deposit money. These activities in the book are ideally subdivided in two: household activities and producer or production firm owner activities.

2.2 formal model

Since we want an ABM of this target system we have to explicitly represent entities and their relations in our model.

Following Galan et al. [1]:

> Modelling is the process of building an abstraction of a system for a specific purpose. Thus, in essence, what distinguishes one modelling paradigm from another is precisely the way we construct that abstraction from the observed system. [...] agent-based modelling is a modelling paradigm with the defining characteristic that entities within the target system to be modelled and the interactions between them are explicitly and individually represented in the model (see Figure 1). This is in contrast to other models where some entities are represented via average properties or via single representative agents.

So every agent can act both as household or as producer. Agents are inserted in networks that represent interactions and relations among agents. In our model relation between agents are encoded in two static (exogenous) directed networks, one for the working relations, the other for selling relations. In a more realistic model networks co-evolve with agents.

2.3   executable model

Two class of agents, government and Eagent (economic agent).

Government	
Data member	
1	G
2	θ
3	cash
4	TFM
Methods	
1	consume
2	receiveTaxes
3	createList
4	write on DB
5	resetTFM

Table 1: Government class

Table 1 shows Government class. G and θ are external parameters of the (formal) model. *cash* is the only stock of Government. *TFM* is a Transaction Flow Matrix object that the government use to accounting its activities; this is a data member introduced to the needs of executable model. The first three methods are due to the formal model, the last two belong to the executable model: in order to simplify data acquisition we introduce the hypothesis that every agent takes track of its economic activity through a transaction flow matrix.

Every time

In table 2 it is shown the Eagent class. As for the government there are variables whose existence is due to executable model needs. So the first 3 data members and the first seven methods pertain to the theoretical model, the others to the executable one.

VERY IMPORTANT: agents consume until their income is lower than 0.00001. This is the way we implement the fact that in the tematitian model agents consume (and deposit) all their wages. This introduce finite time effect that may led the model to slightly different states from those observed in the theoretical model.

2.4   Results

First we reproduce the results shown in table 3.4 of [2]. Here $\alpha_1 = 0.6$, $\alpha_2 = 0.4$, the tax rate $\theta = 0.2$. Every reference period is 30 iterations long, and the system has been observed for 100 of periods.

Then we explore model behavior to changing parameters.

Then we exploit the proprieties of ABM to analyze the distribution of wealth among agents. In the figure 2 are shown the histograms of wealth distribution. The first is relative to homogeneous agents, all having the same values of the paramameters α_1 and α_2. The second refers to heterogeneous agents: the values of α_1 are picked at random from a uniform distribution in the interval $[0, 1]$.

Eagent	
Data member	
1	α_1
2	α_2
3	cash
4	householdTFM
5	producerTFM
6	workersList
7	sellerList
8	income
9	sold
Methods	
1	receiveWage
2	payTaxes
3	consume
4	consumeFromCash
5	deposit
6	sell
7	payWages
8	createList
9	write on DB
10	resetTFM

Table 2: Economic agent class

What happen if we change the structure of interactions graph?
The steady state (which is a stationary state) is characterized by the relation

$$Y^* = \frac{G}{\theta} \tag{1}$$

Our purpose is to check if this equation still holds when we deal with heterogeneous agents (for instance: heterogeneous in their consumption function)

References

[1] José Manuel Galán, Luis R Izquierdo, Segismundo S Izquierdo, José Ignacio Santos, Ricardo Del Olmo, Adolfo López-Paredes, and Bruce Edmonds. Errors and artefacts in agent-based modelling. *Journal of Artificial Societies and Social Simulation*, 12(1):1, 2009.

[2] Wynne Godley and Marc Lavoie. *Monetary economics: an integrated approach to credit, money, income, production and wealth.* Springer, 2006.

Stock	0	1	2	99
G	20	20	20	20
Y	38.461392	47.928837	55.939828	1.000000e+02
T	7.692278	9.585767	11.187966	2.000000e+01
YD	30,769113	38,343070	44,751862	79,999997
C	18.461392	27.928837	35.939828	8.000000e+01
ΔH	12.307722	10.414233	8.812034	8.084872e-07

Table 3: Here $\alpha_1 = 0.6$, $\alpha_2 = 0.4$, the tax rate $\theta = 0.2$. Every reference period is 30 iterations long, and the system has been observed for 100 of periods.
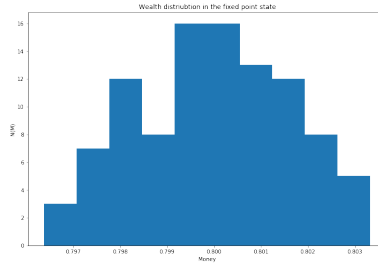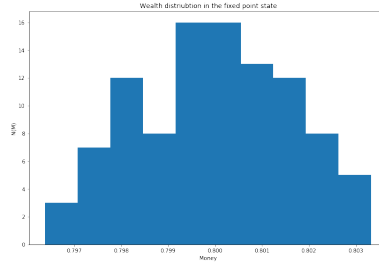

(a) Homogeneous agents
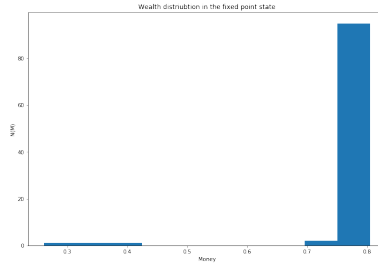
(b) Heterogeneous agents

Figure 1: Wealth distribution

| Period	0	1	2	99
Y	47.284729	60.659901	71.388738	116.192949
C	27.284729	40.659901	51.388738	96.192949
H	10.543054	7.868020	5.722252	3.238590
T	9.456946	12.131980	14.277748	23.238590

Table 4: Final results with 10 agents in a E-R graph, with heterogeneous consumption function

Sector	Government	Household	Producer
C	0.000000	-82.268884	82.268884
G	-20.000000	0.000000	20.000000
WB	0.000000	102.268884	-102.268884
T	20.453777	-20.453777	0.000000
ΔH	0.453777	-0.453777	0.000000

Table 5: asymptotic TF matrix. 100 of agents, with heterogeneous consumption function and with a E-R graph to represent working relation

(a) Homogeneous agents in a complete graph
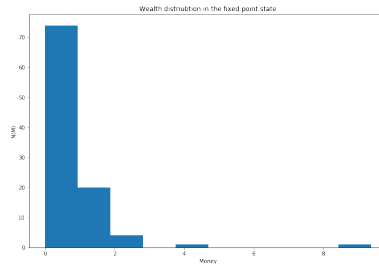
(b) Heterogeneous agents in a Erdos-Renyi graph

Figure 2: Wealth distribution