

# **Economic Simulation with NetLogo**

“A monetary experiment”

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# Section 1

## The Project

### 1.1) Introduction

In this economic simulation we want to model the outcomes of the introduction in the economy of two alternative, with respect to the default currency (the EURO), means of payment, and to inspect the conditions under which they diffuse in the economy.

These new currencies are of completely different type: we will introduce in the economy the Tickets-restaurant and a new currency called EAC<sup>1</sup>.

The Tickets-restaurant are those tickets provided by the firms, together with the salary, currently used in the real world, that allow employees to have meals in the places (bars, restaurants) that accept these.

The Tickets-restaurant, in our simulation, are given to agents with a certain frequency that coincides with the payment of the salary (in EURO).

The EAC, differently, is a new currency given randomly and one-off to agents in the system.

Each one of this two means of payments, can be used to buy goods and services in the economy as well as to pay debts, depending, clearly, on whether they are accepted or not, both by shops and by creditors, and at what extent.

We have set two versions of the model: the first is called “Version 1.0” and the second, not surprisingly, “Version 1.1”.

Let us examine the basic characteristics of each one of them.

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<sup>1</sup> “EAC” stands for Elena and Claudio, the names of the two creators of this simulation.

It is worth to say that this kind of simulation has been encouraged by the studying upon a virtual currency, used only for buying goods and services on Internet, called Bitcoin. For information and news see <http://bitcoin.org/> and <http://en.wikipedia.org/wiki/Bitcoin> .

## 1.2) Version 1.0 of the model

In the first version of the simulation, we have constructed a closed world composed of one hundred and fifty agents, four shops and two bars, and we have defined five variables referring to each agent. These variables are:

- credit
- debt
- EURO-cash
- EAC-cash
- ticket-cash.

The credit and debt variables define the financial situation of each agent, whereas the EURO-cash, EAC-cash and ticket-cash variables define the patrimonial situation (that is, how much money does an agent have).

When the “setup” button is pressed, each agent comes into the world with a casual value of each one of these five variables<sup>2</sup>.

Then, when the “go” button is pressed, agents move across the world, and carry out the normal economic activities: they go to work, and so each month they receive the salary both in EURO and in Ticket-restaurant, with which they can have their meals in the bars; they receive a small part of their credit and pay a small part of their debt every day; and every day they get new credits as well as new debts; then, they go shopping and buy food, clothes, or whatever they need; finally, they go to bars to have a coffee or to have a meal during the lunch break<sup>3</sup>.

In this first and simple version of the simulation, it is assumed that the only situation in which there can be “acceptance problems” of the alternative means of payments (i.e. the EAC and the Tickets-restaurant), is the collection of receivables and therefore the payment of debts. This means that the payment of debts has to respect what we can call “acceptance constraints”, that in the simulation identify with the desired (by

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<sup>2</sup> The random level of these variable can range between two values, that are chosen as realistically as possible for each variable.

<sup>3</sup> Each tick in the simulation is assumed to be one day.

creditors) percentage quantity of the due payment, respectively in EURO, EAC, and Tickets-restaurant<sup>4</sup>.

Therefore, here, there are no problems of acceptance with respect to the purchase of goods and services both at shops and at bars. In this case, in fact, agents simply pay according to their proportional quantity of each currency out of the total quantity of cash owned.

In this model, moreover, we have introduced three monitors, that represent respectively:

- the average quantity between agents of EAC in cash, updated at each tick; variable called “EAC-average-in-cash”
- the average quantity between agents of EURO in cash, updated at each tick, that we have called “EURO-average-in-cash”
- the average quantity between agents of Tickets-restaurant in cash, updated at each tick, called “ticket-average-in-cash”.

We have, then, added a graph, named “Average quantities of EURO, EAC, Ticket owned by agents”, that represents the three variables above.

### 1.3) Version 1.1 of the model

In the second version of the simulation, again we have a closed world made of one hundred and fifty agents, four shops and two bars. We have defined seventeen variables referring to each agent. These variables are:

- exactly the same of the Version 1.0 of the model
- EURO-spent, EAC-spent and ticket-spent
- EURO-spent-at-bars, EAC-spent-at-bars and ticket-spent-at-bars
- credit-received-in-EURO, credit-received-in-EAC and credit-received-in-ticket
- debt-paid-in-EURO, debt-paid-in-EAC and debt-paid-in-ticket.

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<sup>4</sup> These three parameters can be selected by the user via the sliders located in the Interface Section of NetLogo.

Now, a part from the variables already present in the first version of the simulation, the variables we have used here represent:

- the amount in each of the three currencies that each agent has spent to buy goods and services at shops (EURO-spent, EAC-spent and ticket-spent)
- the amount in each of the three currency that each agent has spent to buy food and drinks at bars (EURO-spent-at-bars, EAC-spent-at-bars and ticket-spent-at-bars)
- the amount of credit that each agent has received in each of the three currencies (credit-received-in-EURO, credit-received-in-EAC and credit-received-in-ticket)
- the amount of debt paid by each agent in each of the three currencies (debt-paid-in-EURO, debt-paid-in-EAC and debt-paid-in-ticket)<sup>5</sup>.

As before, when the “setup” button is pressed, each agent comes into the world with a casual value of each one of the variables in the first set of the above list (credit, debt, EURO-cash, EAC-cash, ticket-cash).

Again when the “go” button is pressed, agents move across the world, and carry out the normal economic activities.

The news is that at each tick, the second, third, and fourth set of variables we have listed above, record the transactions done by each agents, in buying good and services at shops, in buying food and drinks at bars, in paying debts and in receiving credits.

The other news in this version, and the substantial one, is that the situations in which there can be “acceptance problems”, concern no more just the collection of receivables and consequently the payment of debts, but also the purchases at both shops and bars. Therefore, not only the payments of debts, but also the payments for purchases have to respect the “acceptance constraints” above mentioned, that again identify in the model as the desired (by shops owners) percentage quantity of the due payments for goods and services purchased at the shops, respectively in EURO, EAC and Tickets-restaurant on one hand, and as the desired (by bars owners) percentage

<sup>5</sup> Notice that all these variables are cumulative (i.e. they don't reset at each tick).

quantity of the due payments for food and drinks purchased at the bars, respectively in EURO, EAC and Tickets-restaurant, on the other hand; keeping valid the already known constraint on the payments of debts<sup>6</sup>.

A note is important: in the Version 1.0, the shops and the bars are treated as very similar, since they accept each one of the three currencies without any constraint (there, the agents pay their purchases both at shops and at bars with the mix of currencies depending on the proportion of each of them on the total cash at their disposal). In the Version 1.1 of the model, instead, the shops and the bars are treated as different entities, since both of them (actually, the owners of both of them) have their own desired mix of currencies in received payments. This means that there is the possibility for the user to insert the acceptance parameters for the shops and the bars he or she wants; for example, it seems logical to define bars as more prone to accept Tickets-restaurant than shops.

In this version of the simulation, we have maintained the three monitors and the plot of the Version 1.0, and we have introduced some other of these tools.

Let us see them in detail:

- we have created three monitors called respectively, “EAC-average-in-received-credits”, “EURO-average-in-received-credits” and “ticket-average-in-received-credits”, which represent the average amount between agents, updated and increasing at each tick, of the received credits in each one of the three currencies in the system.
- in a specular way, we have introduced three monitors called respectively, “EAC-average-in-paid-debts”, “EURO-average-in-paid-debts” and “ticket-average-in-paid-debts”, which represent the average amount between agents, updated and increasing at each tick, of the paid debts in each one of the three currencies present in the economy.
- then, we have introduced three monitors called respectively, “EAC-average-expenditure”, “EURO-average-expenditure” and “ticket-average-expenditure”, which are defined as the average amount between agents, updated and

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<sup>6</sup> All these (nine) parameters can be selected by the user via the sliders located in the Interface Section of NetLogo.

increasing at each tick, of the expenditure for goods and services purchased at the shops, in each one of the three currencies in the economy.

- in a specular way, we have created three monitors called respectively, “EAC-average-expenditure-at-bars”, “EURO-average-expenditure-at-bars”, “ticket-average-expenditure-at-bars”, which are defined as the average amount between agents, updated and incrementing at each tick, of the expenditure for food and drinks purchased at the bars, in each one of the three currencies in the system.

Finally, we have represented graphically each set of monitors via a plot. So we have set four plots, beyond the one already present in the Version 1.0.

These four plots are respectively called “Average quantities of EURO, EAC, Ticket received as payment of credits”, “Average quantities of EURO, EAC, Ticket used as payment of debts” , “Average quantities of EURO, EAC, Ticket spent by agents in buying goods” and “Average quantities of EURO, EAC, Ticket spent by agents at bars”.

## Section 2

### A comment on the code

#### 1.1) Comment on the code of the Version 1.0

In the first version of the model, we have three breeds, one represented by agents, the other by shops, and the last by bars:

```
breed [agents agent]
breed [shops shop]
breed [bars bar]
```

Each agent has five variables, that are those seen in the paragraph 1.2) of the Section 1:

```
agents-own [credit debt EURO-cash ticket-cash EAC-cash]
```

Moreover, the use has been made use in the code of four globals<sup>7</sup>:

```
globals [total-cash EAC-average EURO-average ticket-average]
```

After having created the procedure for the “setup” button, that simply generates and places the agents, the shops, and the bars, and gives a random numerical value to each one of the agents-own variables, we have defined the “go” procedure as follows:

```
to go
  if ticks >= 1000 [stop]
  move-agents
  move-EURO-and-ticket-cash
  move-financial-situation
  receiving-payments
```

---

<sup>7</sup> We have already commented the EAC-average, EURO-average and ticket-average globals in the paragraph 1.2) of the first section. For what concerns the total-cash global, it is simply defined as the sum of each of the three currencies owned by each agent.

```

    paying-debts
    buying-goods
    tick
    do-plot
end

```

Let us consider in detail the key points of this procedure.

For what concerns `move-EURO-and-ticket-cash`, it makes the variables `EURO-cash` and `ticket-cash` increase by a random amount, that can oscillate between 1.000 and 10.000 for the `EURO-cash` and between 30 and 100 for the `ticket-cash`. But this happens only every 30 ticks, via the “if” statement that, basically, says: if the number of ticks divided by 30, gives as remainder 0, then do what it is written inside the square brackets<sup>8</sup>.

Here is the procedure:

```

to move-EURO-and-ticket-cash
  ask agents [
    if remainder ticks 30 = 0 [
      set EURO-cash (EURO-cash + random 9000 + 1000)
      set ticket-cash (ticket-cash + random 70 + 30)
    ]
  ]
end

```

With respect to the procedure `receiving-payments`, it defines the way in which agents receive the payments of their credit. In particular, it is assumed that agents receive, at each tick, the payment of a small part of their credit<sup>9</sup>.

This will make the credit decrease by the same amount of the received payment, and, contextually, will make each cash increase proportionally to the values of the desired percentage of received payments in each of the three currencies, that are set by the user via the three sliders in the Interface section of NetLogo. Here is the procedure:

```

to receiving-payments
  ask agents [
    let a random-float 0.002

```

<sup>8</sup> In fact, here, we suppose that each tick is one day, and, as it seems natural, that the salary (given both in EURO and in Tickets-restaurant) is received every month.

<sup>9</sup> This can oscillate between 0 and 0.2 percent of their whole credit.

```

    let x desired-percentage-of-EURO-in-received-payments
    let y desired-percentage-of-EAC-in-received-payments
    let w desired-percentage-of-ticket-in-received-payments
    set credit ((1 - a) * credit)
    set EURO-cash (EURO-cash + credit * a * x)
    set EAC-cash (EAC-cash + credit * a * y)
    set ticket-cash (ticket-cash + credit * a * w)
  ]
end

```

For what concerns the procedure `paying-debts`, it defines the way in which debts are paid. As in the previous procedure, at each tick, a random quantity of the debt (that again can range between 0 and 0.2 percent) has to be repaid by agents. But things, here, are a little bit more complicated than in the previous case; this is so because there is the constraint that the agents' cash can not assume a negative value. This means that, if the part of the debt that has to be repaid in each of the three currencies, in accordance with the values of the desired (by creditors) percentage of EURO, EAC and Tickets-restaurant of received payments set via the sliders in the Interface, is greater than at least one of the three cash, then the debt can only be paid partially.

This is the reason why it has been necessary to specify all the eight possible combinations through the use of the “if” statements.

The entire procedure is therefore the following:

```

to paying-debts
  ask agents [
    set total-cash (EURO-cash + ticket-cash + EAC-cash)
    let a random-float 0.002
    let x desired-percentage-of-EURO-in-received-payments
    let y desired-percentage-of-EAC-in-received-payments
    let w desired-percentage-of-ticket-in-received-payments
    if (x * a * debt <= EURO-cash) and (y * a * debt <= EAC-cash)
and (w * a * debt <= ticket-cash)
      [set debt ((1 - a) * debt)
        set EURO-cash (EURO-cash - debt * a * x)
        set EAC-cash (EAC-cash - debt * a * y)
        set ticket-cash (ticket-cash - debt * a * w)]
    if (x * a * debt <= EURO-cash) and (y * a * debt <= EAC-cash)
and (w * a * debt > ticket-cash)

```

```

    [set debt (debt - (x * a * debt + y * a * debt + ticket-
cash))
    set EURO-cash (EURO-CASH - debt * a * x)
    set EAC-cash (EAC-cash - debt * a * y)
    set ticket-cash (ticket-cash - ticket-cash)]
    if (x * a * debt <= EURO-cash) and (y * a * debt > EAC-cash)
and (w * a * debt <= ticket-cash)
    [set debt (debt - (x * a * debt + w * a * debt + EAC-cash))
    set EURO-cash (EURO-CASH - debt * a * x)
    set ticket-cash (ticket-cash - debt * a * w)
    set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a * debt > EURO-cash) and (y * a * debt <= EAC-cash)
and (w * a * debt <= ticket-cash)
    [set debt (debt - (y * a * debt + w * a * debt + EURO-
cash))
    set EURO-cash (EURO-cash - EURO-cash)
    set ticket-cash (ticket-cash - debt * a * w)
    set EAC-cash (EAC-cash - debt * a * y)]
    if (x * a * debt > EURO-cash) and (y * a * debt > EAC-cash)
and (w * a * debt > ticket-cash)
    [set debt (debt - total-cash)
    set EURO-cash (EURO-cash - EURO-cash)
    set ticket-cash (ticket-cash - ticket-cash)
    set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a * debt <= EURO-cash) and (y * a * debt > EAC-cash)
and (w * a * debt > ticket-cash)
    [set debt (debt - (x * a * debt + ticket-cash + EAC-cash))
    set EURO-cash (EURO-cash - debt * a * x)
    set EAC-cash (EAC-cash - EAC-cash)
    set ticket-cash (ticket-cash - ticket-cash)]
    if (x * a * debt > EURO-cash) and (y * a * debt > EAC-cash)
and (w * a * debt <= ticket-cash)
    [set debt (debt - (w * a * debt + EURO-cash + EAC-cash))
    set ticket-cash (ticket-cash - debt * a * w)
    set EURO-cash (EURO-cash - EURO-cash)
    set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a * debt > EURO-cash) and (y * a * debt <= EAC-cash)
and (w * a * debt > ticket-cash)
    [set debt (debt - (y * a * debt + EURO-cash + ticket-cash))
    set EAC-cash (EAC-cash - debt * a * y)
    set EURO-cash (EURO-cash - EURO-cash)
    set ticket-cash (ticket-cash - ticket-cash)]
    ]
end

```

The last relevant procedure, `buying-goods`, defines the purchase of goods and services of agents both at shops and at bars.

Since in this version of the model, as we have said, there are no problems such

“acceptance constraints” for purchases at bars and shops, the definition of this procedure is quite simple. It only disposes that, if the amount of the total cash is different from zero, each agent that is near<sup>10</sup> to a generic shop (both shops and bars, in this model), will *desire* to spend a random quantity of money, that can range between 30 and 330, for purchasing goods and services. Now a further restraint has to be satisfied, that is: if, on one hand, the the desired expenditure is lower than the total cash owned by the agent, than the purchase will take place entirely and according to the proportional quantity of each of the three currencies out of the total cash; if, on the other hand, the desired expenditure is higher then the total cash owned by the agent, than the purchase will not take place entirely, since the agent will buy just until each of the three cash goes to zero.

The entire procedure is the following:

```
to buying-goods
  ask agents [
    set total-cash (EURO-cash + ticket-cash + EAC-cash)
    if total-cash != 0 [
      let y EURO-cash / total-cash
      let z ticket-cash / total-cash
      let w EAC-cash / total-cash
      let x random 300 + 30
      if (any? shops in-radius 6) and (total-cash >= x) [
        set EURO-cash (EURO-cash - x * y)
        set EAC-cash (EAC-cash - x * w)
        set ticket-cash (ticket-cash - x * z)]
      if (any? shops in-radius 6) and (total-cash < x) [
        set EURO-cash (EURO-cash - EURO-cash)
        set EAC-cash (EAC-cash - EAC-cash)
        set ticket-cash (ticket-cash - ticket-cash)]
    ]
  ]
end
```

## 1.2) Comment on the code of the Version 1.1

In the second version of the model, we have, as before, three breeds: one represented by the agents, the other by the shops, and the last by the bars.

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<sup>10</sup> “Near” is defined as less the radius six away.

Moreover, we have introduced some new agents-own variables, maintaining the five of the previous version. So the agents-own variables we have defined are the following<sup>11</sup>:

```
agents-own [credit debt EURO-cash ticket-cash EAC-cash EURO-spent
EAC-spent ticket-spent EURO-spent-at-bars EAC-spent-at-bars
ticket-spent-at-bars credit-received-in-EURO credit-received-in-
EAC credit-received-in-ticket debt-paid-in-EURO debt-paid-in-EAC
debt-paid-in-ticket]
```

We have also introduced some new globals with respect to the previous version; they are the following<sup>12</sup>:

```
globals [total-cash EAC-average EURO-average ticket-average EAC-
average-expenditure EURO-average-expenditure ticket-average-
expenditure EAC-average-expenditure-at-bars EURO-average-
expenditure-at-bars ticket-average-expenditure-at-bars EURO-
average-in-received-credits EAC-average-in-received-credits
ticket-average-in-received-credits EURO-average-in-paid-debts EAC-
average-in-paid-debts ticket-average-in-paid-debts]
```

As for the “setup” procedure, this is exactly the same of that in the Version 1.0.

Now, coming to the “go” procedure, it is:

```
to go
  if ticks >= 1000 [stop]
  move-agents
  move-EURO-and-ticket-cash
  move-financial-situation
  receiving-payments
  paying-debts
  buying-goods-to-shops
  buying-goods-to-bars
  tick
  do-plot-1
  do-plot-2
  do-plot-3
```

---

<sup>11</sup> These variables have been already commented in the Section 1, paragraph 1.3).

<sup>12</sup> Also these globals have been commented in Section 1, paragraph 1.3).

```
do-plot-4
do-plot-5
end
```

Let us now examine in detail what are the key procedures.

As for the procedures `move-EURO-and-ticket-cash`, `receiving-payments` and `paying-debts`, they are exactly the same as before, a part from the fact that in the second and in the third, we have add a command with which the variables `credit-received-in-EURO`, `credit-received-in-EAC`, `credit-received-in-ticket`, `debt-paid-in-EURO`, `debt-paid-in-EAC` and `debt-paid-in-ticket` are updated at each tick, in order to take into account the amount of debt and credit respectively paid and received in each of the three currencies by each agent<sup>13</sup>.

What is new in this version, is the definition of the `buying-goods-to-shops` and `buying-goods-to-bars` procedures.

Let us examine only the first, since the second is exactly the same, a part from the fact that, whereas the `buying-goods-to-shops` procedure defines the purchase of goods and services at shops, the second defines the purchase of food and drinks at bars, being the mechanism of payments equal.

So, considering the the `buying-goods-to-shops` procedure, it can be synthesized as follows: each agent that is near<sup>14</sup> to a shop, *desires* to spend a random quantity of money, that can range between 30 and 300, in the purchase of goods and services. Now, the mix of currencies in the payment is no more free, but has to respect the conditions imposed by the shop owners, that are *de facto* chosen by the user via the three sliders put in the Interface section.

So, things here are quite more complicated than in the Version 1.0, where there was no such “acceptance problems”.

Here, in fact, apart from the necessity of keeping into account the possibility that the

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<sup>13</sup> Variables of which use have been made to compute the averages among agents of debt and credit paid in each of the three currencies, that are shown in the six monitors and in the two plots of the Interface.

<sup>14</sup> “Near” is defined as less the radius six away.

agent can not afford the whole payment for buying the desired amount of goods and services, as in the previous version of the simulation, it is needed the specification of all the eight possibilities in which the agent can occur and this is made through the use of the “if” statements. To clarify the necessity of specifying these possibilities, let us consider the following example: if the desired (by the shop owners) percentage of EAC in the received payment for goods and services, is such that the agent does not dispose of that amount of EAC that would permit to purchase the desired amount of goods, then he can only pay, and therefore buy, the quantity of goods and services for which the EAC expenditure is exactly equal to the quantity of EAC he has in cash.

Moreover, in this procedure, we have added also the variables `EURO-spent`, `EAC-spent` and `ticket-spent`, in such a way that the level of EURO, EAC, and Tickets-restaurant used to purchase at shops by each agent, is constantly updated.

As we have already said, these variables have been used for the construction of the globals `EAC-average-expenditure`, `EURO-average-expenditure` and `ticket-average-expenditure`, which simply represent the averages between the agents, updated at each tick, of the expenditure for goods and services bought at the shops, respectively in EURO, EAC, and Tickets-restaurant. These average quantities are represented both numerically, via the monitors, and graphically, via the plot, in the Interface of NetLogo.

We underline again that the procedure for the purchases at bars is specular to this just described<sup>15</sup>.

We report here the entire procedure that rules the purchases of goods and services at shops.

```
to buying-goods-to-shops
  ask agents [
    let a random 270 + 30
    let x desired-percentage-of-EURO-in-payments-of-goods
    let y desired-percentage-of-EAC-in-payments-of-goods
    let w desired-percentage-of-ticket-in-payments-of-goods
    if any? shops in-radius 6 [
      if (x * a <= EURO-cash) and (y * a <= EAC-cash) and (w * a <=
```

---

<sup>15</sup> Also the average quantities of expenditures at bars in each of the three currencies are defined in the same way and the question about the monitors and the plot is again valid.

```

ticket-cash)
    [set EURO-cash (EURO-cash - x * a)
     set EURO-spent (EURO-spent + x * a)
     set EAC-cash (EAC-cash - y * a)
     set EAC-spent (EAC-spent + y * a)
     set ticket-cash (ticket-cash - w * a)
     set ticket-spent (ticket-spent + w * a)]
    if (x * a <= EURO-cash) and (y * a <= EAC-cash) and (w * a >
ticket-cash)
    [set EURO-cash (EURO-cash - x * a)
     set EURO-spent (EURO-spent + x * a)
     set EAC-cash (EAC-cash - y * a)
     set EAC-spent (EAC-spent + y * a)
     set ticket-spent (ticket-spent + ticket-cash)
     set ticket-cash (ticket-cash - ticket-cash)]
    if (x * a <= EURO-cash) and (y * a > EAC-cash) and (w * a <=
ticket-cash)
    [set EURO-cash (EURO-cash - a * x)
     set EURO-spent (EURO-spent + a * x)
     set ticket-cash (ticket-cash - a * w)
     set ticket-spent (ticket-spent + a * w)
     set EAC-spent (EAC-spent + EAC-cash)
     set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a > EURO-cash) and (y * a <= EAC-cash) and (w * a <=
ticket-cash)
    [set EURO-spent (EURO-spent + EURO-cash)
     set EURO-cash (EURO-cash - EURO-cash)
     set ticket-cash (ticket-cash - a * w)
     set ticket-spent (ticket-spent + a * w)
     set EAC-cash (EAC-cash - a * y)
     set EAC-spent (EAC-spent + a * y)]
    if (x * a > EURO-cash) and (y * a > EAC-cash) and (w * a >
ticket-cash)
    [set EURO-spent (EURO-spent + EURO-cash)
     set EURO-cash (EURO-cash - EURO-cash)
     set ticket-spent (ticket-spent + ticket-cash)
     set ticket-cash (ticket-cash - ticket-cash)
     set EAC-spent (EAC-spent + EAC-cash)
     set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a <= EURO-cash) and (y * a > EAC-cash) and (w * a >
ticket-cash)
    [set EURO-cash (EURO-cash - a * x)
     set EURO-spent (EURO-spent + a * x)
     set EAC-spent (EAC-spent + EAC-cash)
     set EAC-cash (EAC-cash - EAC-cash)
     set ticket-spent (ticket-spent + ticket-cash)
     set ticket-cash (ticket-cash - ticket-cash)]
    if (x * a > EURO-cash) and (y * a > EAC-cash) and (w * a <=
ticket-cash)
    [set ticket-cash (ticket-cash - a * w)
     set ticket-spent (ticket-spent + a * w)
     set EURO-spent (EURO-spent + EURO-cash)

```

```
        set EURO-cash (EURO-cash - EURO-cash)
        set EAC-spent (EAC-spent + EAC-cash)
        set EAC-cash (EAC-cash - EAC-cash)]
    if (x * a > EURO-cash) and (y * a <= EAC-cash) and (w * a >
ticket-cash)
        [set EAC-cash (EAC-cash - a * y)
        set EAC-spent (EAC-spent + a * y)
        set EURO-spent (EURO-spent + EURO-cash)
        set EURO-cash (EURO-cash - EURO-cash)
        set ticket-spent (ticket-spent + ticket-cash)
        set ticket-cash (ticket-cash - ticket-cash)]
    ]
]
end
```

## Section 3

### Experiments<sup>16</sup>

#### 1.1) Introduction

In this section, we will discuss some experiments.

In the paragraph 1.2), we will chose some combinations of the parameters of the model, and we will discuss the results coming from each one of these combinations.

In the paragraph 1.3), the different situations for the diffusion of the EAC and the Tickets-restaurant will be treated.

We will proceed in this way:

- for every experiment, it will be defined the value of each of the parameters in the simulation, clarifying the economic meaning of the combination chosen.
- Then, the results of particular interest will be presented
- and finally, these will be briefly discussed, taking care of the economics behind them.

#### 1.2) Analyzing outcomes with different settings

Following the method we have just explained, let us start with the first experiment.

##### EXPERIMENT 1.

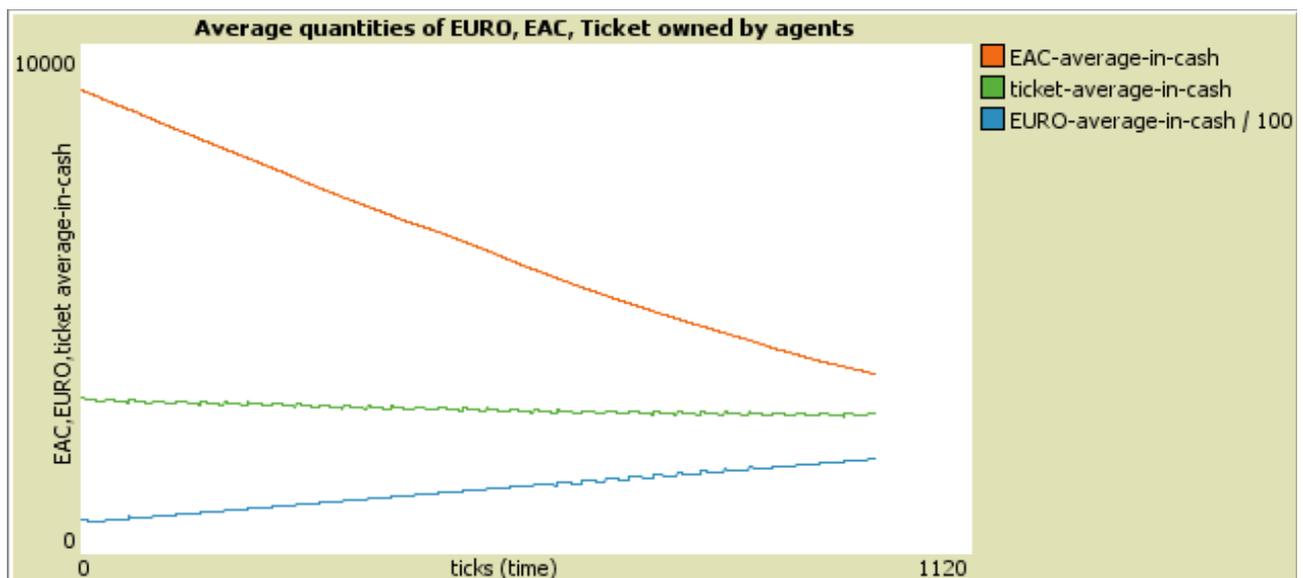
In this first experiment, we choose a combination of the values of the parameters that seems “normal”. This means, that this combination depicts an intermediate situation in which the EURO is the predominant currency and in which the EAC and the Tickets-restaurant play a marginal role in the payments of debts and in the purchases of goods and services at shops. We also assume here, as it seems logical in a “normal”

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<sup>16</sup> In this section, we will make use of the Version 1.1 of the model, since the Version 1.0 is just a special case of that.

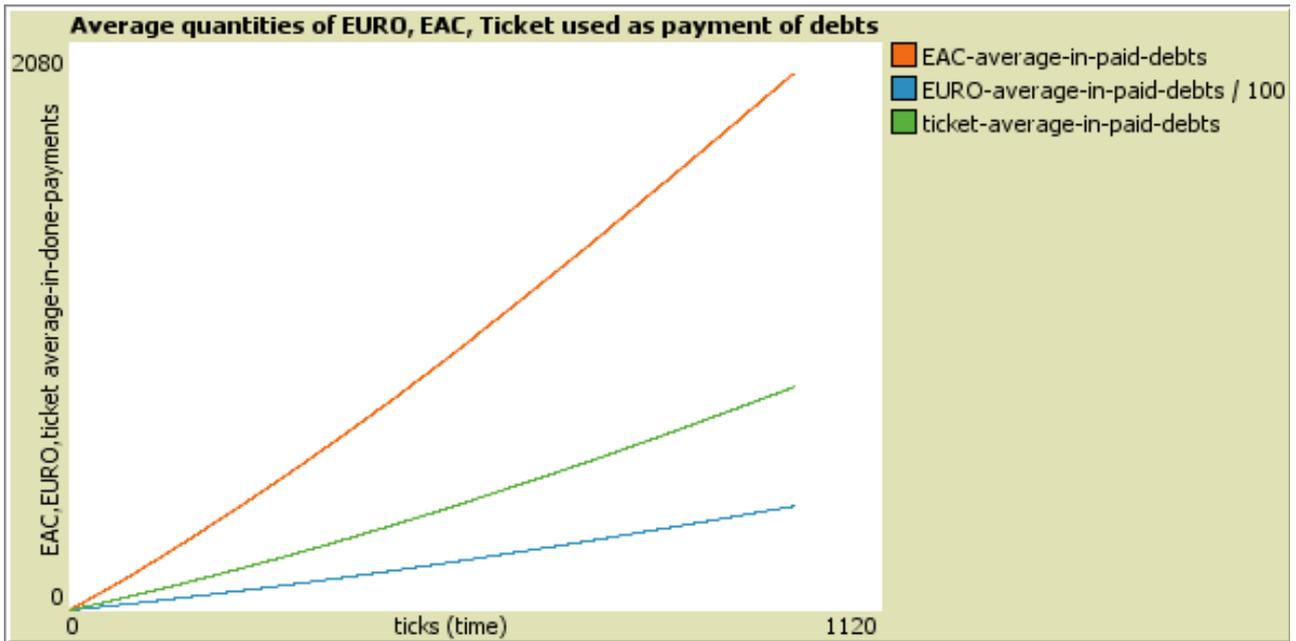
situation, that the bars are quite willing to accept Tickets-restaurant as a mean of payment, since the classical use of these is to buy food and drinks to consume during the lunch break. The value that we have chosen for each one of the nine parameters is reported in the table at the end of this paragraph. Now we run the model, and the more interesting outcomes we observe are:

- The level of EAC owned on average by agents is decreasing over time at a quite high speed. And decreasing is the level of Tickets-restaurant owned on average by agents, but at a much slower rate. The quantity of EURO owned on average by agents is increasing<sup>17</sup>. So we can see an increase in the total wealth of the agents. We can therefore say that on average they save a consistent quantity of the money (the EURO) that they receive as remuneration for work.

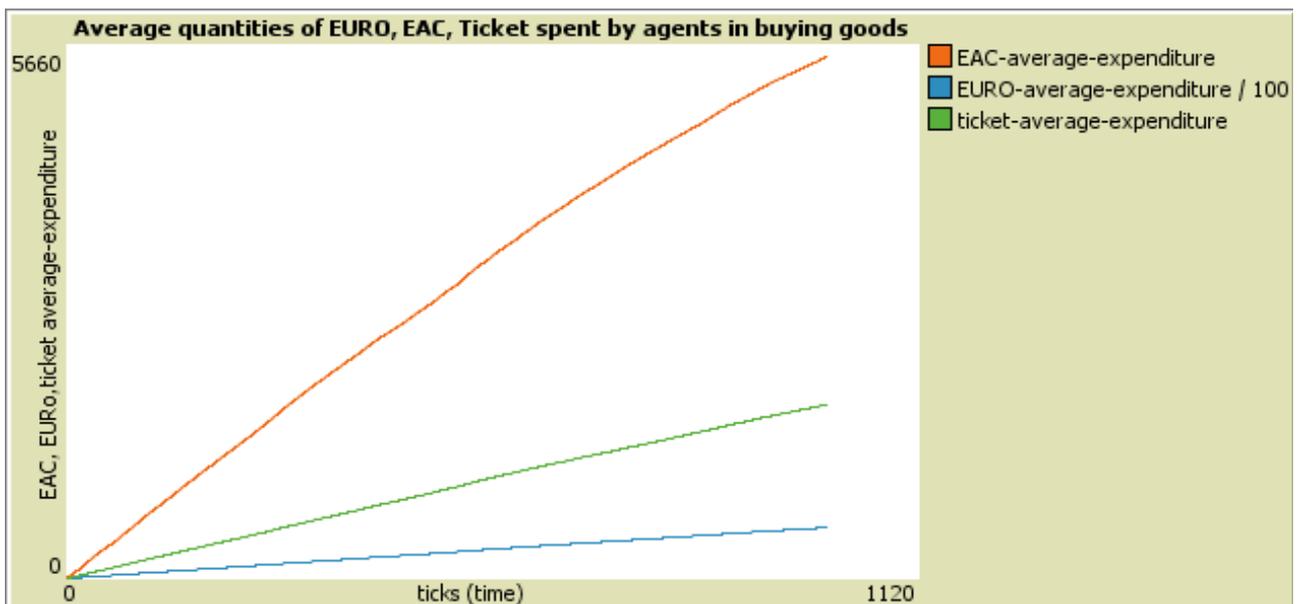


- Moreover, it could be interesting to notice the average levels of each of the three currencies used to repay debts. As expected, the EURO is the more used currency, followed by the EAC and by the Tickets-restaurant respectively. This respects the level of the parameters that define the degree of acceptance of creditors of each of the three currencies we have selected.

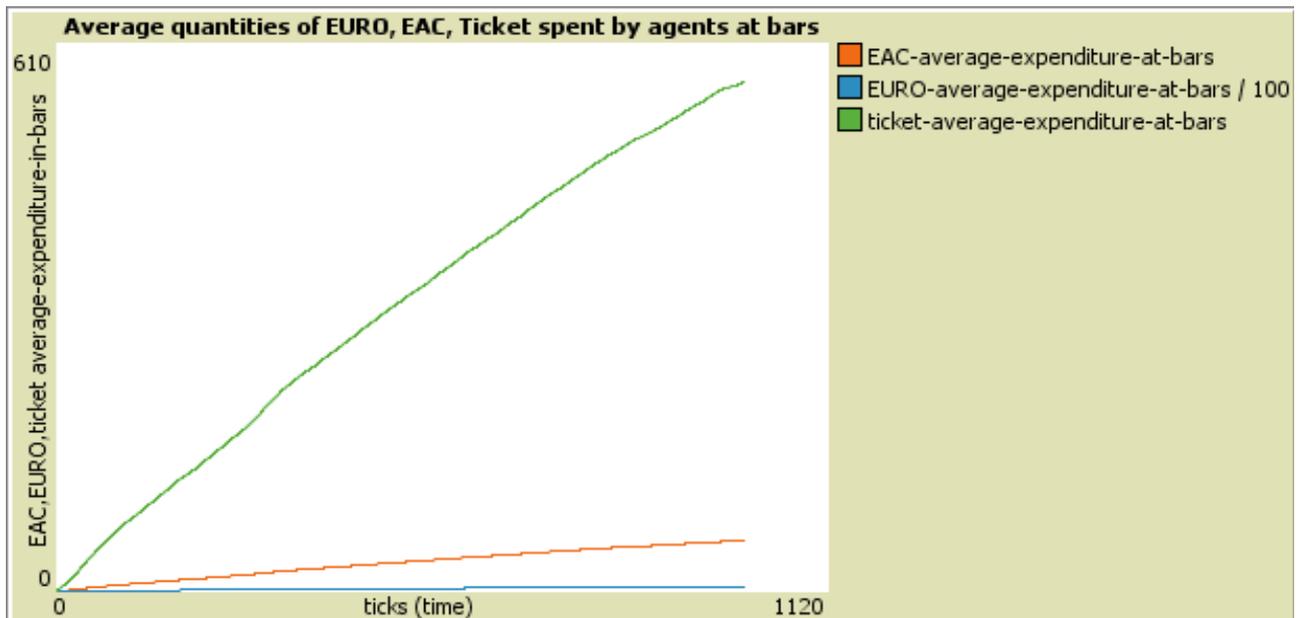
<sup>17</sup> Notice that in all the plots the average quantity of EURO is divided by one hundred in order to make more visible the average quantities of EAC and Tickets-restaurant.



- The last outcome that is interesting to examine is the evolving of the average expenditure over time on each of the three currencies both on purchases at shops and at bars. The first of these (average purchases at shops) is plotted in the following graph:



It could be noticed that the EURO is the most used currency, followed by the EAC and the Tickets-restaurant. This outcome is not surprising since it reflects the values of the parameters that refer to the acceptance of each of the three currencies by the shop owners that we have chosen. The average expenditure in purchases at bars, in each of the three currencies is represented instead by the following plot:



Here we observe how the quantity of Tickets-restaurant spent is very high with respect to the other two currencies. Again, this is an expected result, since, in the selection of the values of the parameters referring to the acceptance level of each of the three means of payment of the bar owners, we have chosen a high level of the acceptance of Tickets-restaurant, as we have already mentioned.

## EXPERIMENT 2.

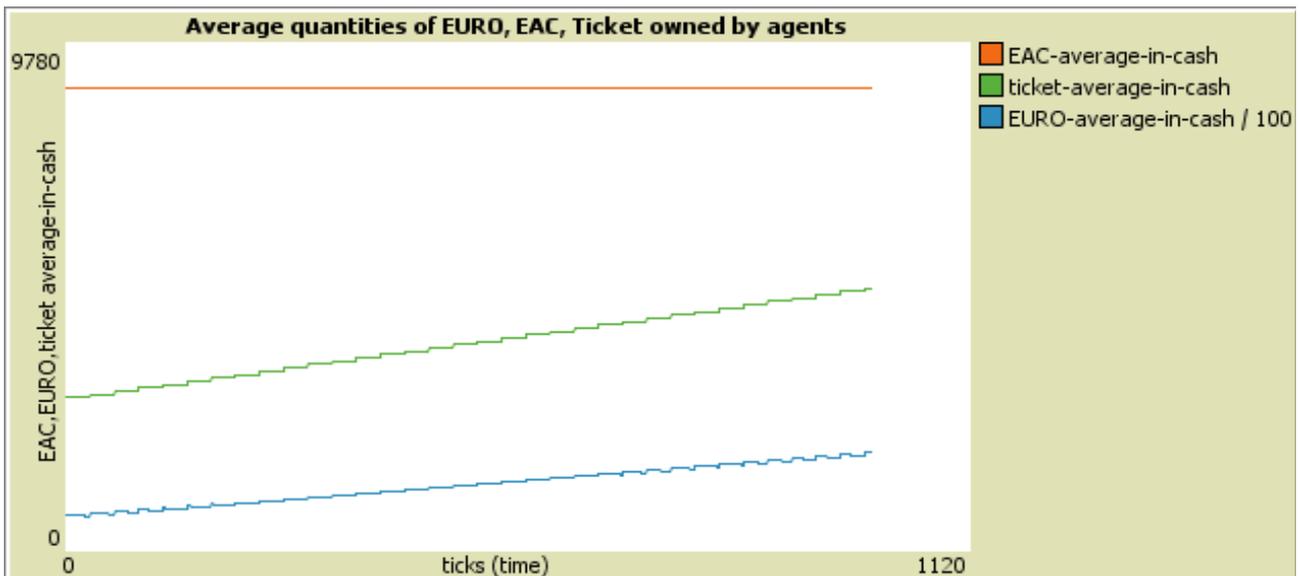
In the second experiment, we will examine an extreme situation, in which the EAC and the Tickets-restaurant are accepted nowhere in the economy, so that agents can

not use these neither to repay debts nor to pay goods and services purchased at shops, as well as to pay food and drinks purchased at bars. We can think of this as a situation in which agents have no trust in these alternative currencies. The values of the nine parameters are, as before, summarized in the table at the end of this paragraph. Then, we run the model and the most evident results we observe are the following:

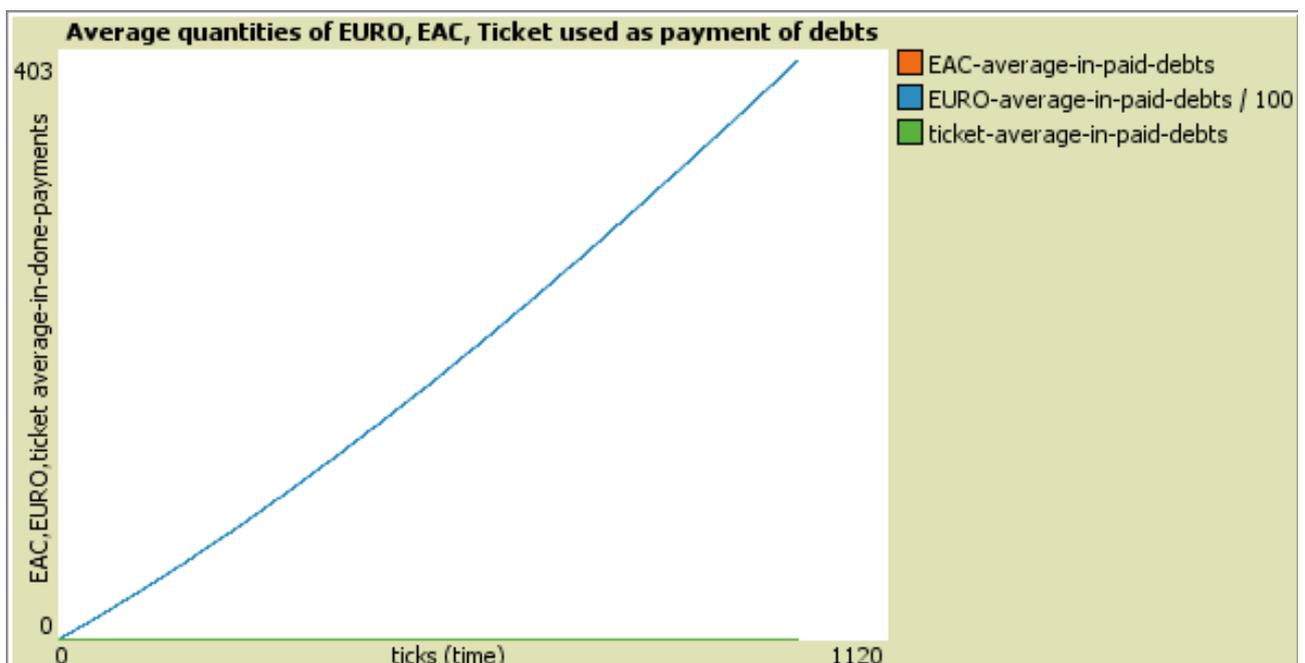
- The average level of EAC owned by agents is constant over time. This happens because agents can not use it to pay debts as well as to buy at shops and bars; therefore, the quantity of EAC with which each agents is provided in the “setup” of the simulation stay constant, clearly, making also the average level of EAC owned by agents stay constant.

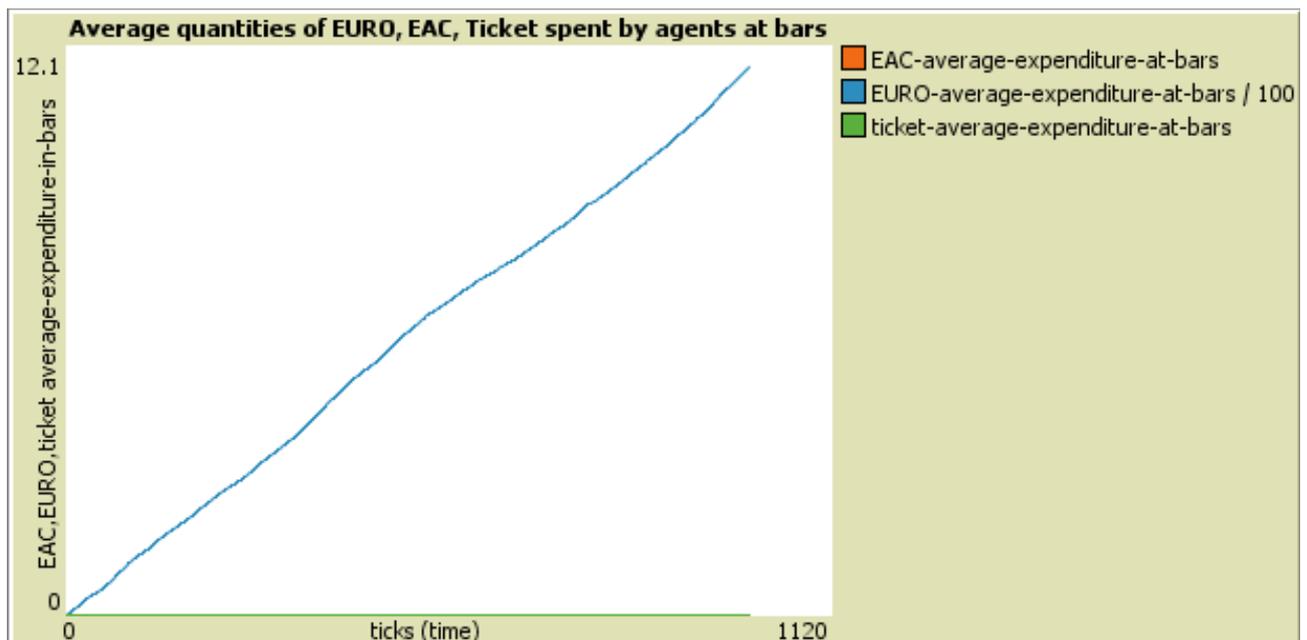
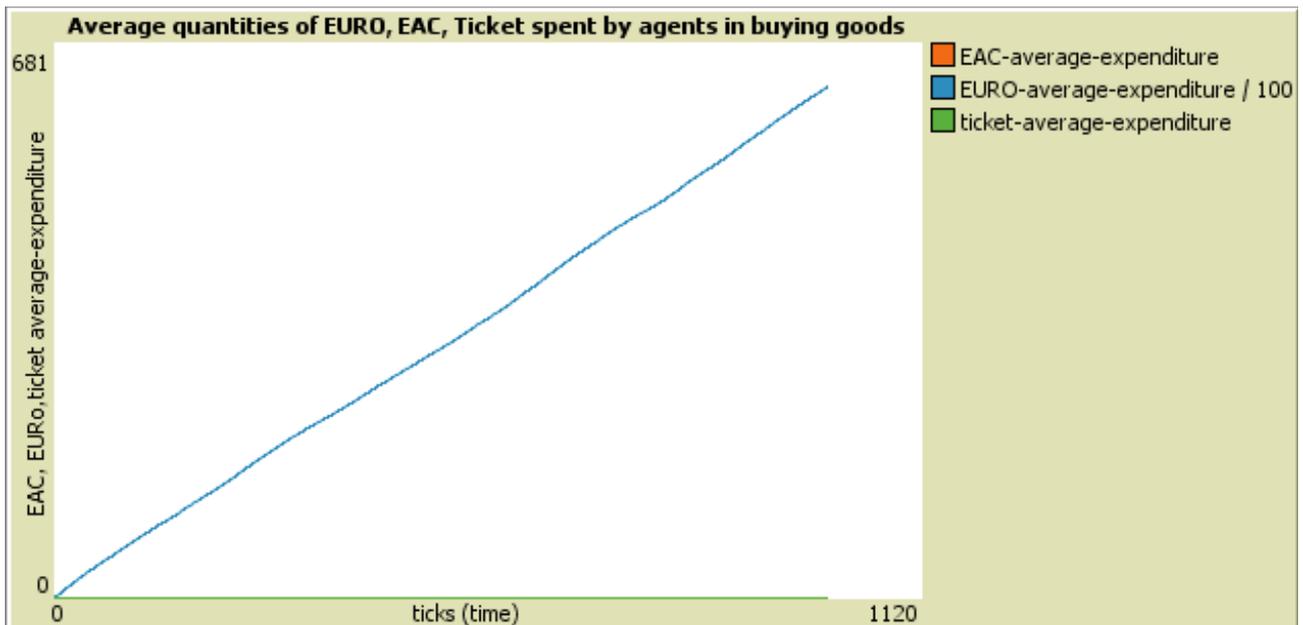
For what concerns the average level of Tickets-restaurant, we can notice that it increases exactly every 30 ticks by a random quantity that can range between 30 and 100. This is the case since each agent is provided, every 30 ticks (i.e. every month) with a random quantity of Tickets-restaurant that can range between 30 and 100. As we have already said in the beginning of this work, this is due to the fact that we assume that the salary that agents receive is paid in EURO and, for a small percentage, in Tickets-restaurant.

It is notable the fact that the final quantity of EURO owned on average by agents, is less than in the previous case, since they could not use the EAC and the Tickets-restaurant to repay debts and to pay goods bought at shops and bars, but they are obliged to use the EURO. The graph of the average level of each of the three currencies owned by agents, is the following:



- For what concerns the other results, it is not surprising the fact that the credits and the debts are, respectively, received and paid only in EURO, and that the same is true for the purchases both at shops and at bars. Moreover, it is important to notice that the quantity of EURO used to repay debts and used to buy goods both at shops and at bars, is higher than in the previous case (experiment 1), clearly, because agents can only use EURO for these transactions. The plots for these average quantities are the following:





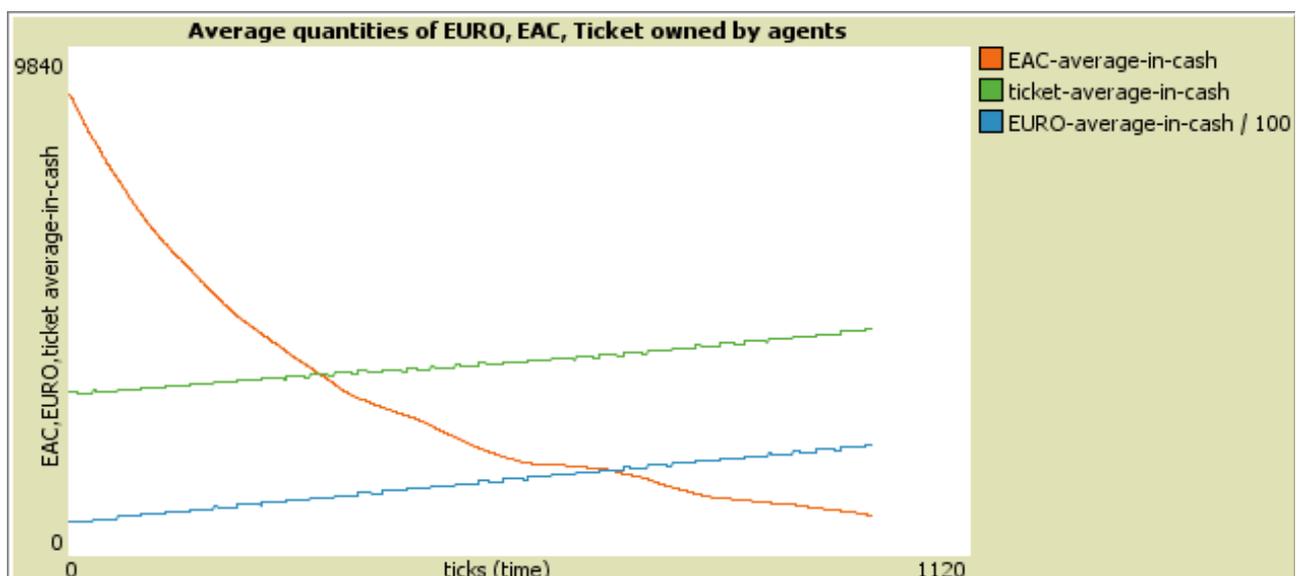
### EXPERIMENT 3.

In the third experiment we will consider another extreme situation: in fact, we suppose that the creditors want to receive their payments both in EURO and in EAC and to an equal extent and that the shop owners have the same preference of the creditors in terms of the means of payment used by their clients; for what concerns the bar

owners, we assume that they accept only Tickets-restaurant. As usual, the values of the nine parameters we have chosen are summarized in the table at the end of this paragraph. Let us consider the main results coming from this setting of the economy.

- The first evident outcome is that the average level of EAC owned by agents after 1000 ticks, is much lower than in the previous cases we have considered. This is due to the fact that agents are asked to repay their debts and their purchases of goods and services at shops with a pretty high (relative) quantity of EAC.

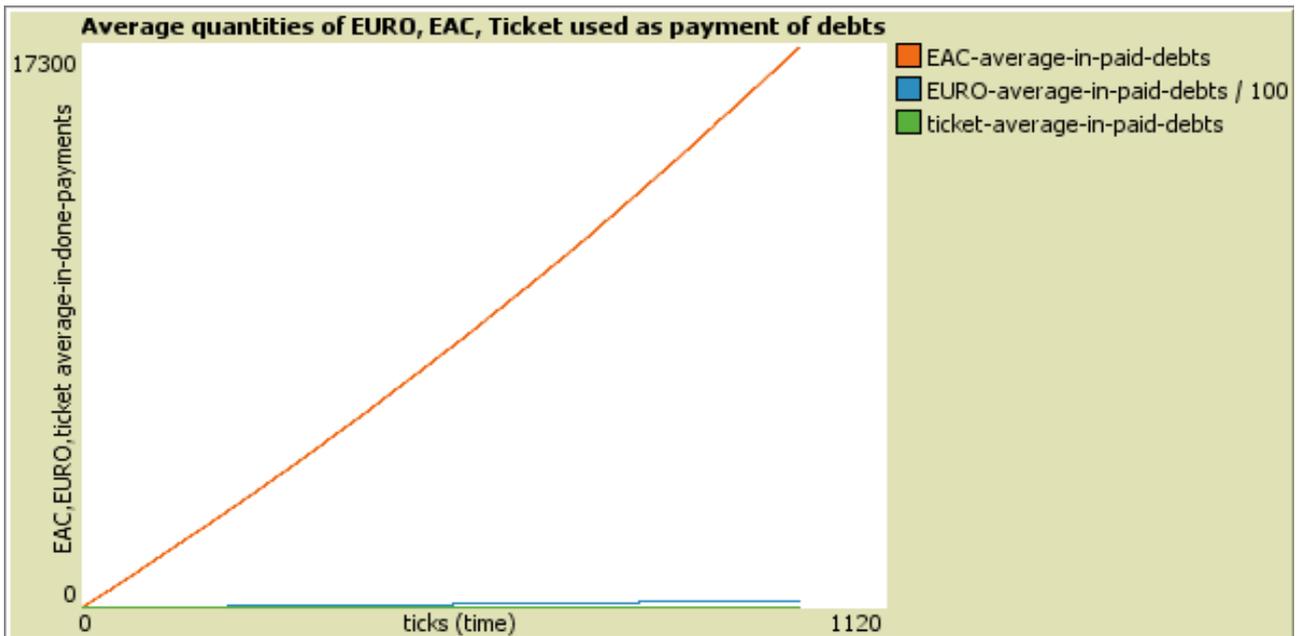
It could also be noticed how the final quantity of Tickets-restaurant owned on average by agents is higher than in the first experiment we have set. This is due to the fact that, even if now agents have to pay their expenditure at bars entirely with Tickets-restaurant, they could not use them to repay debts as well as to pay their purchases at shops. Now, since the expenditure for purchases at bars is much more lower than the expenditure for purchases at shops and for repaying debts, it comes out that the Tickets-restaurant are used less than they were in the first experiment. Here is the plot referring to the average quantity of each of the three currencies owned by agents.



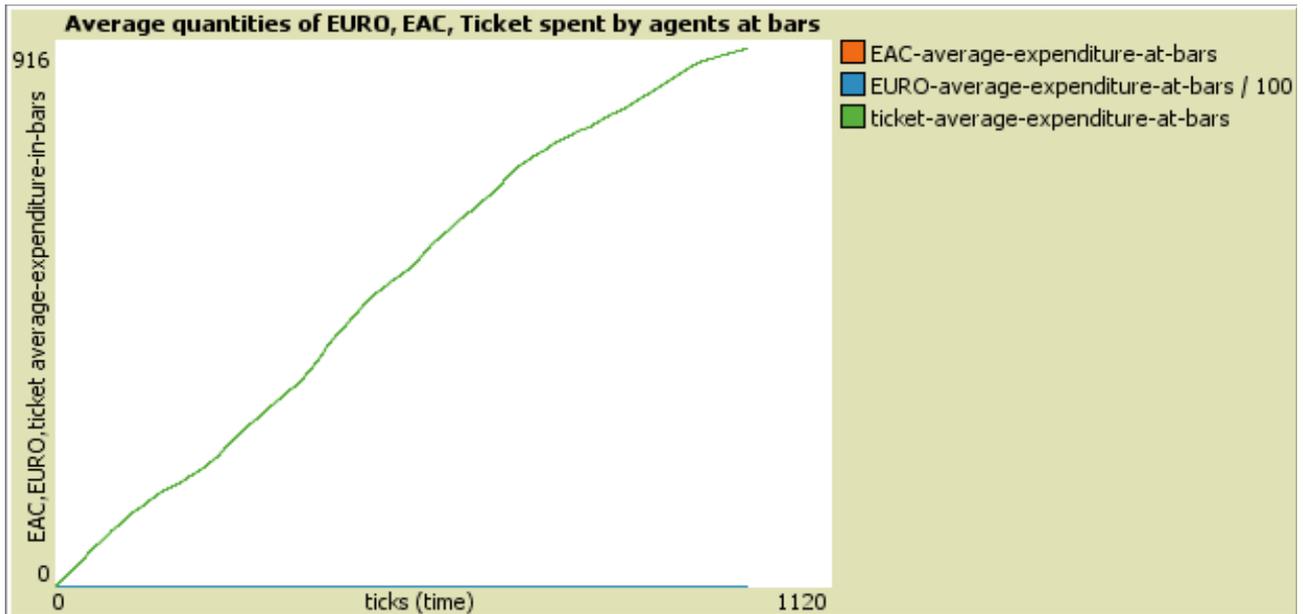
- For what concerns the evolution over time of the average quantity of each of the three means of payment used to repay debts, it can be immediately seen that the EAC are used at a greater extent than in the first and second experiment, consequently to the fact that we have chosen the value of the parameter “desired-percentage-of-EAC-in-received-payments” to be 50%.

Another thing that deserves to be noticed is that, even if the value of the parameters “desired-percentage-of-EAC-in-received-payments” and “desired-percentage-of-EURO-in-received-payments” are set at an equal level (fifty percent), the final average amount of total debt paid in EURO is different from the final average amount of total debt paid in EAC, as it logically should be. This apparent anomaly comes from the fact that, in the procedure “paying-debts” it is ordered that if the amount of one of the three currencies that an agent has to pay is greater than how much he owns in this currency, he will use *all that* money to repay the debt, clearly besides what he has to pay in the other two currencies. So this means that, some agents in the system, at a certain point, did have no more EAC to repay their debts, causing the fact that they could pay them only partially.

The same reasoning is true for the purchases at shops; in this case, however, agents simply would not buy all the *desired* amount of goods, but less than it. It is then possible to conclude that in this setting the whole economy would like to have more EAC at their disposal, which is not possible in our model since we suppose that the EAC is given to agents one-off at the beginning of the “game”, without the possibility of an increase in the supply of EAC. It is therefore logical to say that in this setting we have an excess of demand for EAC and correspondingly a shortage in the supply of EAC. The two graphs of interest are the following:



- The last result to mention concerns the expenditure for purchases at bars. Since in this setting, the bar owners accept only Tickets-restaurant, it is not surprising that these transaction are only in Tickets-restaurant, so that the total average expenditure at bars in EURO and EAC is zero. The plot is the following:

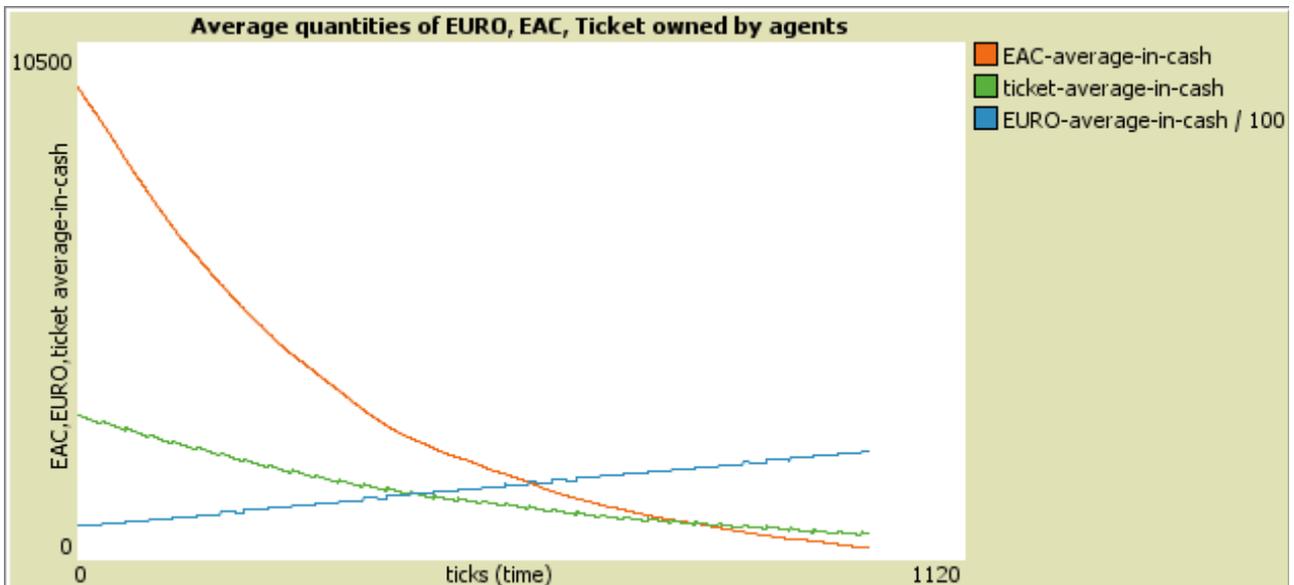


#### EXPERIMENT 4.

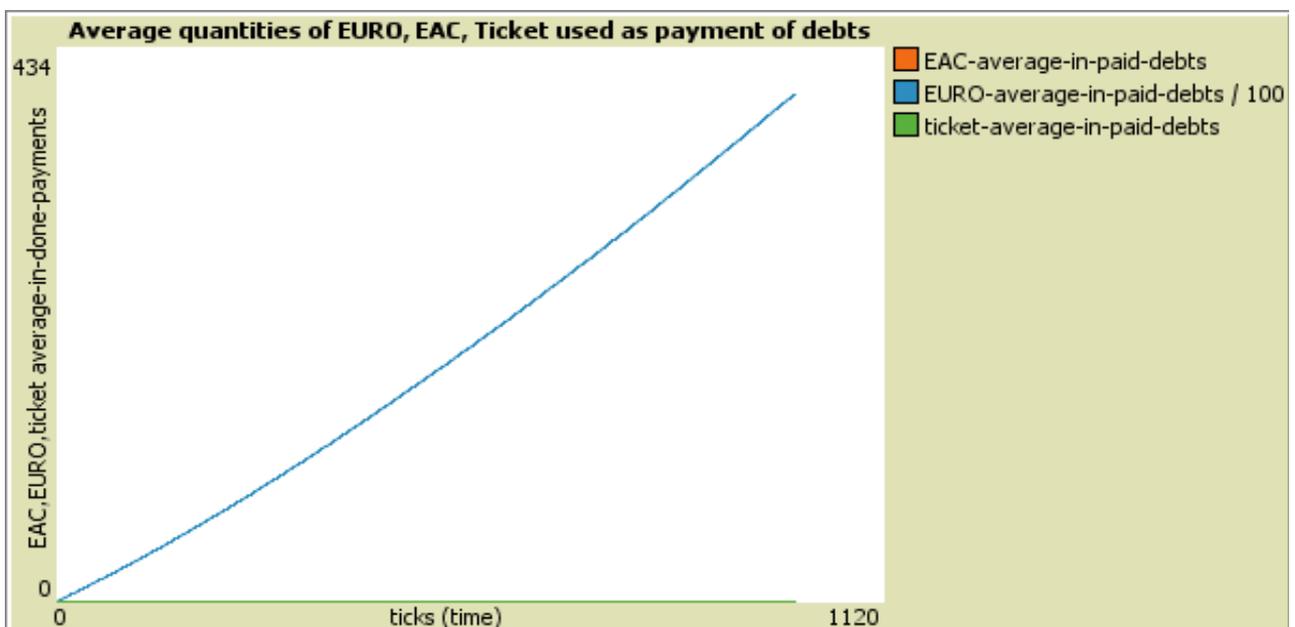
Let us now consider a situation in which the level of acceptance of creditors of the three means of payment is completely different from that of shops and bars owners. In particular, we want to analyze the the outcomes of a setting in which the creditors accept only EURO and the shop and bar owners accept all the three currencies, even if at a different extent. We can think of this situation as one in which the creditors do not trust in the alternative means of payment, and therefore want to be paid in EURO, whereas the shop and bar owners are more willing to accept these new currencies, at least in order to sell more. The values of the nine parameters are summarized in the usual table at the end of this paragraph. Let us examine what are the most significant outcomes.

- With respect to the evolution over time of the average quantity of each of the three currencies owned by agents, it is evident how the average level of EAC decreases quite fast over time until the thousandth tick, when it stops at a very low level. It is also evident how the level of Tickets-restaurant decreases over time, even though each month, as we have said, agents receive a random quantity of them as a component of the salary. From this fact, it can be argued that

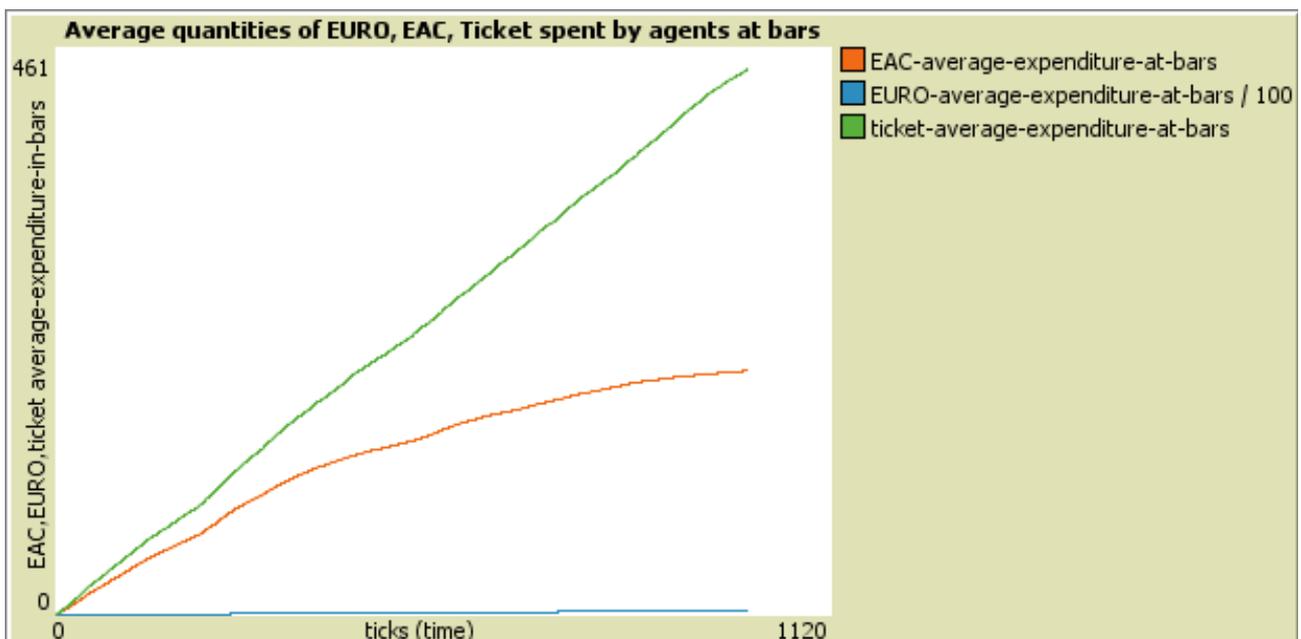
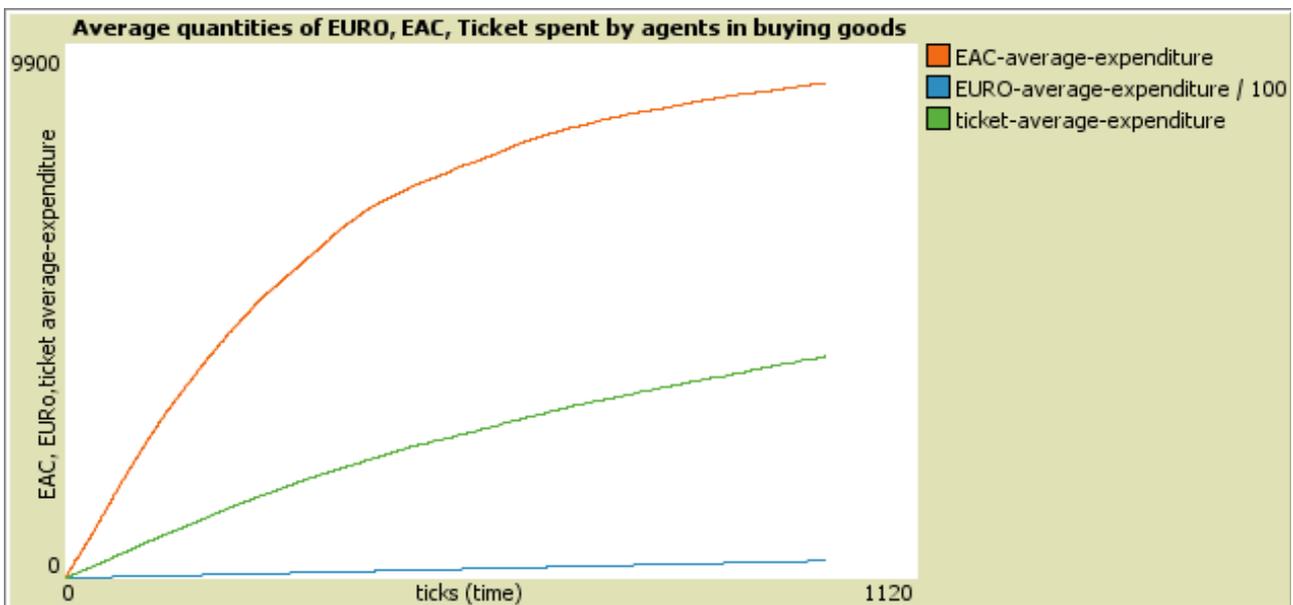
in this situation agents do not save Tickets-restaurant, but use them at a quite high extent to buy goods at shops and bars. The relative plot is the following:



- With respect to the payments of debts, they are only in EURO, clearly, since we have set that the creditors accept only EURO. The average level of debt paid in EURO is therefore higher than it was in the first and the third experiment; whereas the average level of debt paid in EAC and Tickets-restaurant is clearly equal to zero. The graph is this:



- With regard to the purchases of goods both at bars and at shops, it can be noticed that the EAC and the Tickets-restaurant are used at a quite large extent; in particular, for the purchases at shops the EAC is more used than the Tickets-restaurant, and the opposite occurs for the purchases at bars, this according to the parameters that we have set. The graphs representing the average quantity of each of the three currencies spent by agents at shops and at bars, are the following:



## EXPERIMENT 5.

The last experiment we will do in this section examines a situation which is opposite to the one depicted in the previous experiment. Here, in fact, the level of acceptance of the two alternative means of payment of creditors differs much from that of shop and bar owners, as in the previous experiment. What changes now, is that the creditors are quite willing to receive payments both in EAC and in Tickets-restaurant, whereas the shop owners do not accept payments neither in EAC nor in Tickets-restaurant and the bar owners do not accept payments in EAC, while accept payments in Tickets-restaurant (we can assume that they are obliged to accept them because of the signature of a contract with the firms supplying these). Summarizing, this is a situation in which the creditors trust in the two alternative currencies, maybe because they think that in the future the whole economic system will accept them, and where the shop and bar owners do not trust in them at all, for some reason<sup>18</sup>. As usual the values of the nine parameters can be seen in the table at the end of the paragraph. Now, let us comment the principal outcomes coming from this setting.

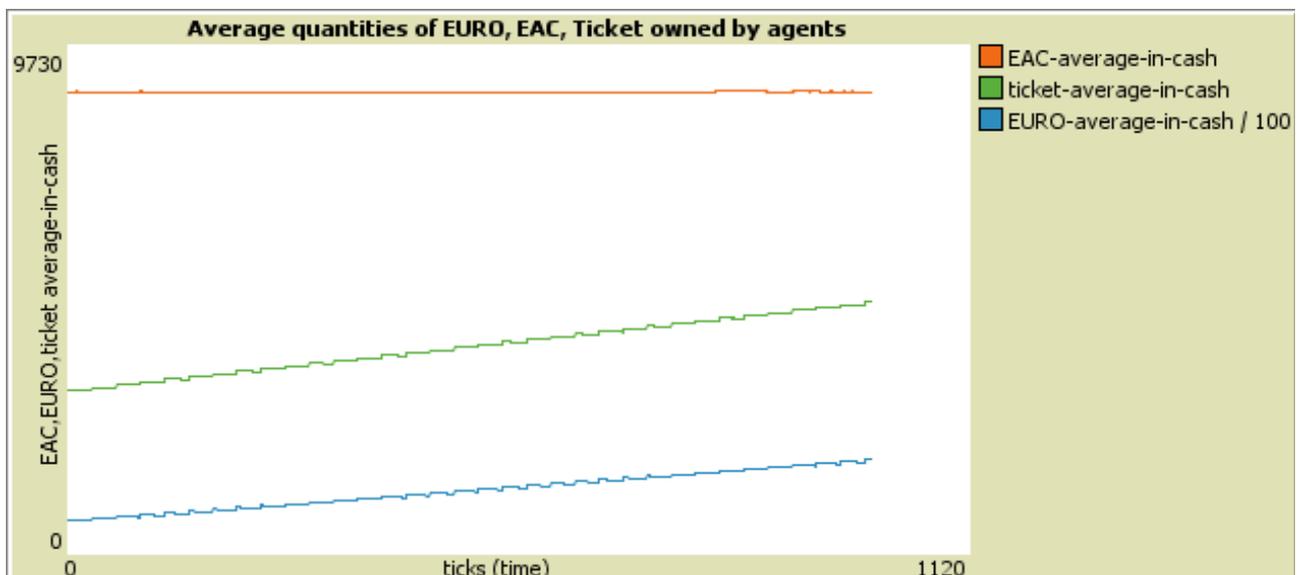
- With regard to the average quantity of each currency owned by agents, the first thing that catches the attention is that the average quantity of EAC owned by agents is almost constant (if we exclude some very little oscillations). This is due to the fact that, agents could not use the EAC for purchases at shops as well as at bars, whereas they can use it to pay debt. A logical question could be: why does it stay constant if it can be used to repay debts? The answer is the following: the payment of debts occurs contextually to the credit collection, and this *on average*, makes the quantity of EAC owned by agents constant<sup>19</sup>.

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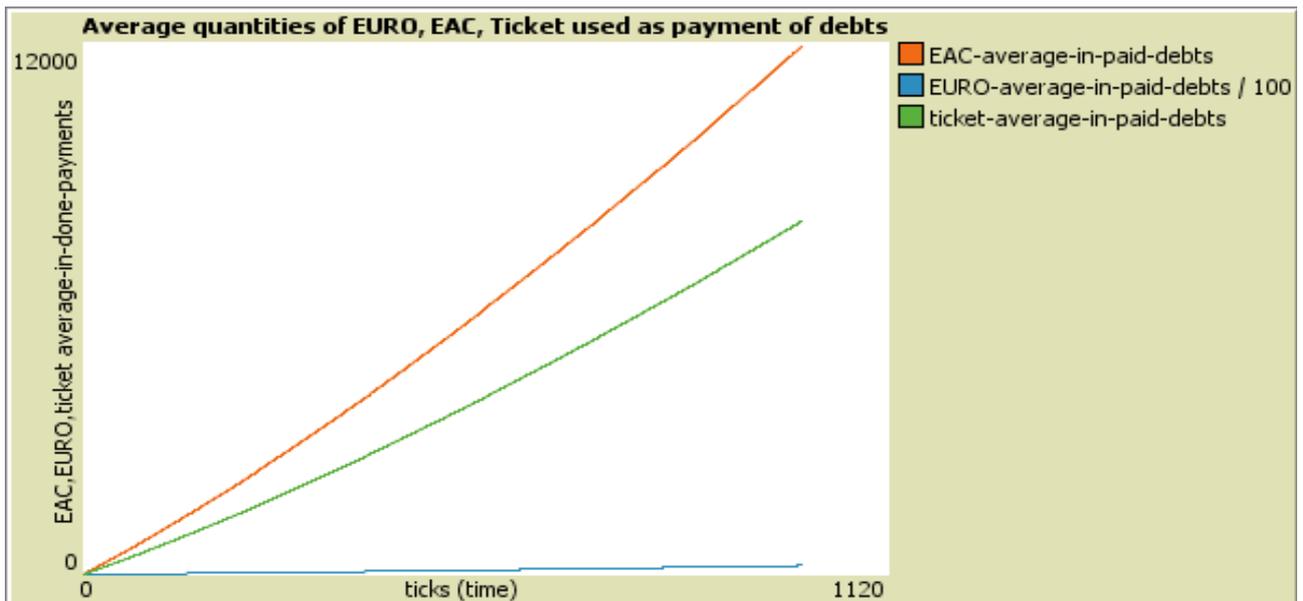
18 It is important to underline that here we suppose that the bar owners are obliged to accept Tickets-restaurant because of the signature of a contract and that they do not believe that the Tickets-restaurant will spread in the economy as a mean of payment.

19 It can be helpful to remind that the collection of the credits and the repayment of debts, when it is possible, is respectively received and paid according to the parameters called “desired-percentage-of-*currency*-in-received-payments”.

Then it can be noticed how the level of both Tickets-restaurant and EURO owned by agents increases over time and how the last quantity stops at a lower level than in the previous experiment. This is due to the fact that, differently from before, now agents can use neither EAC nor Tickets-restaurant for the purchases at shops, and, even if they can use the last ones for the purchases at bars, there they can not pay with EAC. For these reasons, agents have to use more EURO to pay their purchases, and therefore can save less of them during the lifetime. The graph relative to these quantities is the following:

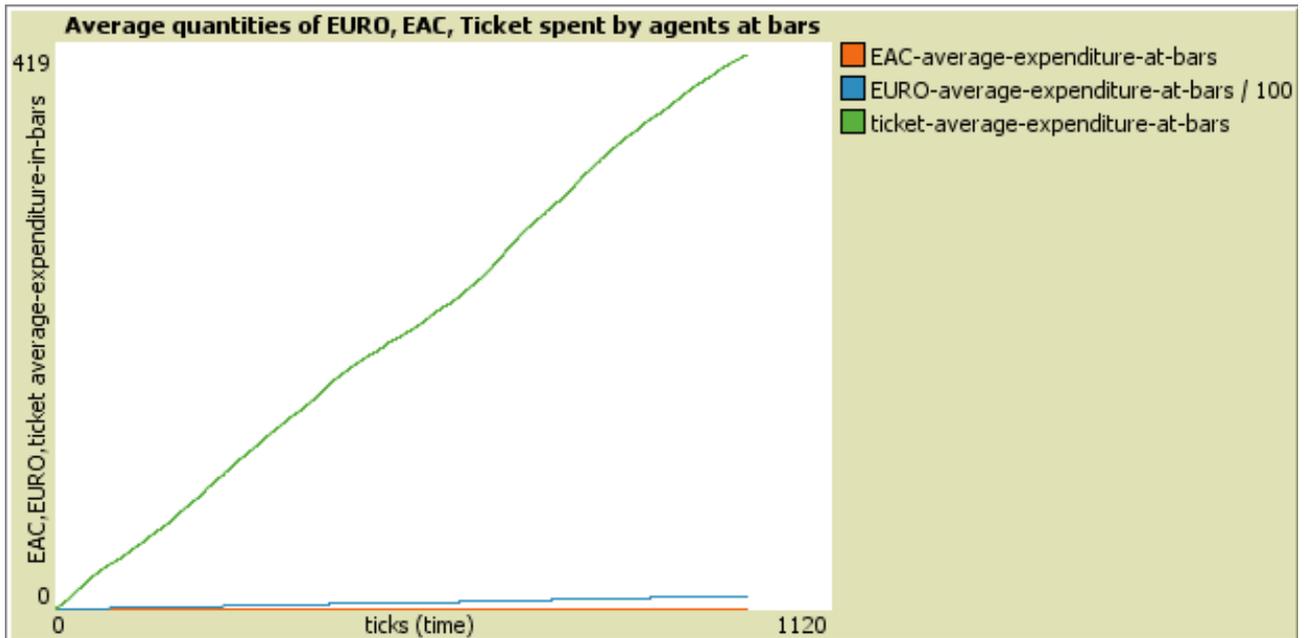


- For what concerns the payment of debts (and, in a parallel way, the collection of credits) it can be noticed how the EAC and the Tickets-restaurant are used at a relatively large extent, in correspondence with the chosen level of the parameters that rule the degree of acceptance of the creditors. The relative plot is the following:



- The last two graphs represent the average quantity of each of the three currencies spent for purchases at shops and at bars. It can be noticed how in both cases the average quantity of EAC spent by agents is zero, since neither shops nor bars accept it; and how for the case of shops also the average quantity of Tickets-restaurant spent by agents is zero, whereas in the case of bars it is positive and quite considerable. The plots relative to these quantities are the following:





**Table of the parameters:**

Number of experiment	desired-percentage-of-euro-in-received-payments	desired-percentage-of-eac-in-received-payments	desired-percentage-of-ticket-in-received-payments	desired-percentage-of-euro-in-payments-of-goods	desired-percentage-of-eac-in-payments-of-goods	desired-percentage-of-ticket-in-payments-of-goods	desired-percentage-of-euro-in-payments-at-bars	desired-percentage-of-eac-in-payments-at-bars	desired-percentage-of-ticket-in-payments-at-bars
1	93,00%	5,00%	2,00%	87,00%	10,00%	3,00%	45,00%	5,00%	50,00%
2	100,00%	0,00%	0,00%	100,00%	0,00%	0,00%	100,00%	0,00%	0,00%
3	50,00%	50,00%	0,00%	50,00%	50,00%	0,00%	0,00%	0,00%	100,00%
4	100,00%	0,00%	0,00%	50,00%	40,00%	10,00%	30,00%	30,00%	40,00%
5	50,00%	30,00%	20,00%	100,00%	0,00%	0,00%	70,00%	0,00%	30,00%

### 1.3) Analyzing the diffusion of the EAC and the Tickets-restaurant in the economy

As we can see from the previous experiments, there are some cases in which the alternative currencies (i.e. the EAC and the Tickets-restaurants) spread over and affect the whole economy. With respect to this issue, we will analyze in term of the economics behind them, three of the experiments done in the previous paragraph.

#### ECONOMIC ANALYSIS OF EXPERIMENT 3.

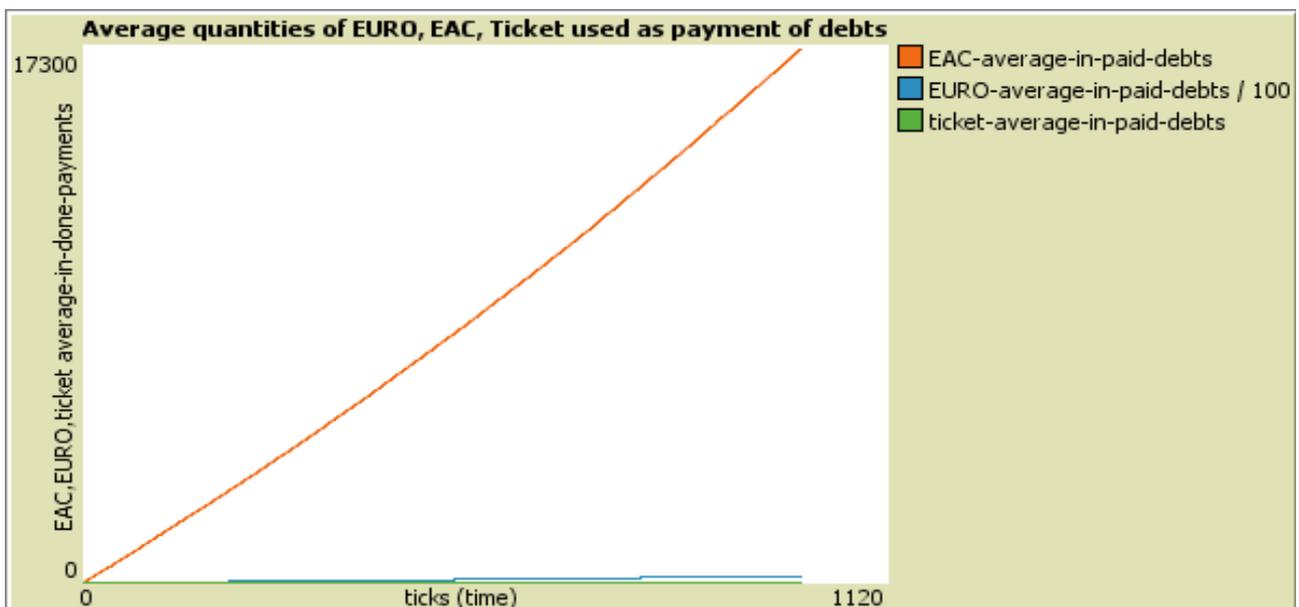
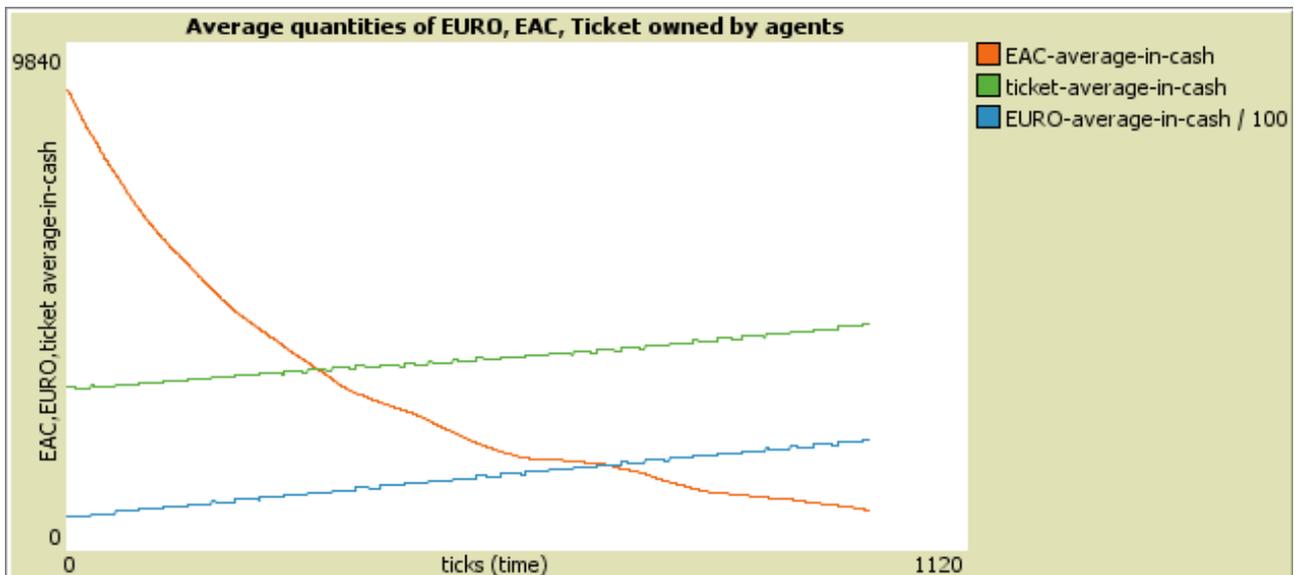
In the third experiment we assigned the value of the desired percentage of receiving payment in EAC to be fifty percent both for creditors and for shop owners. The principal outcome was that the final level of EAC owned on average by agents is much lower than in the first, second and fifth experiment, this because the agents pay the debts and purchase goods and services at shops using a greater amount of EAC than in the that experiments we have just mentioned.

It can be strongly believed that, if the desired percentage EAC in receiving payment increased above the value of fifty percent, then we would assist to a gradual substitution of the current predominant currency, the EURO, with the EAC; since also at the bars, which accept only the Tickets-restaurant, the EURO cannot be used anymore. Therefore, in a very extreme situation, EURO would become useless.

Moreover, we can notice that the final amount of Tickets-restaurant owned on average is pretty high. The reason in simply that the agents can only use Tickets-restaurant as a mean of payment to the bars, but not at all to repay debt and to purchase goods to the shops.

In conclusion, the main currency that rises from this settings is, without doubts, the

EAC, that is used to repay debts, to receive credits and to purchase goods and services at shops. As the two plots describe, is the EAC the real “surprise” for the economy.



#### ECONOMIC ANALYSIS OF EXPERIMENT 4.

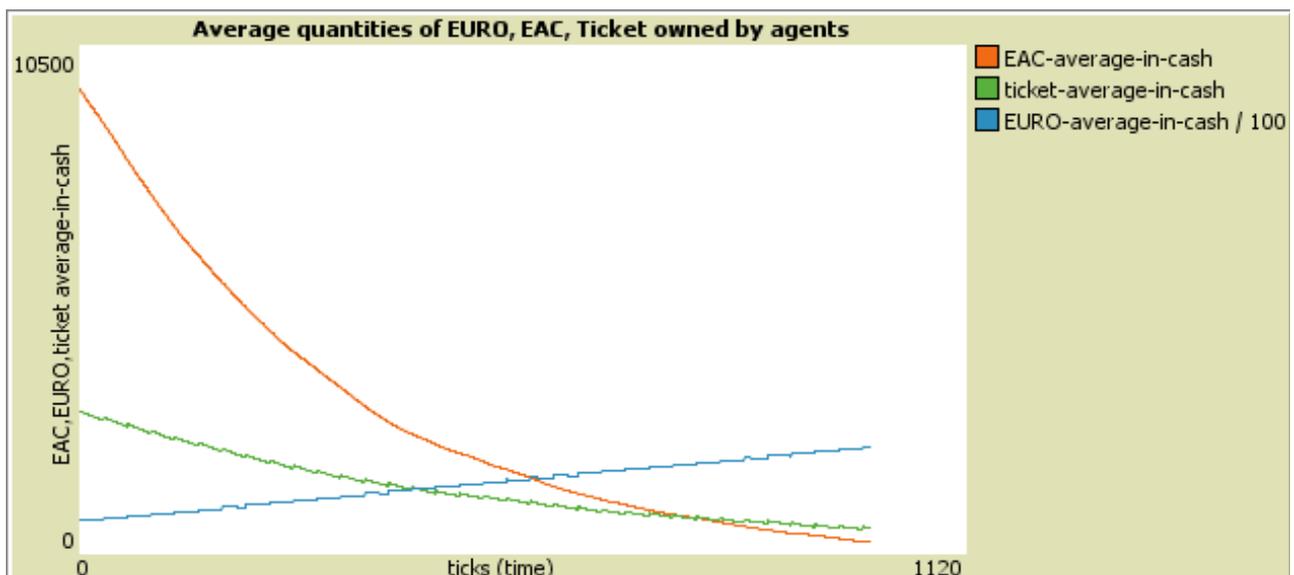
We can observe from the fourth experiment that, assuming a situation in which creditors accept only EURO, whereas shops and bars accept all the three currencies (to a

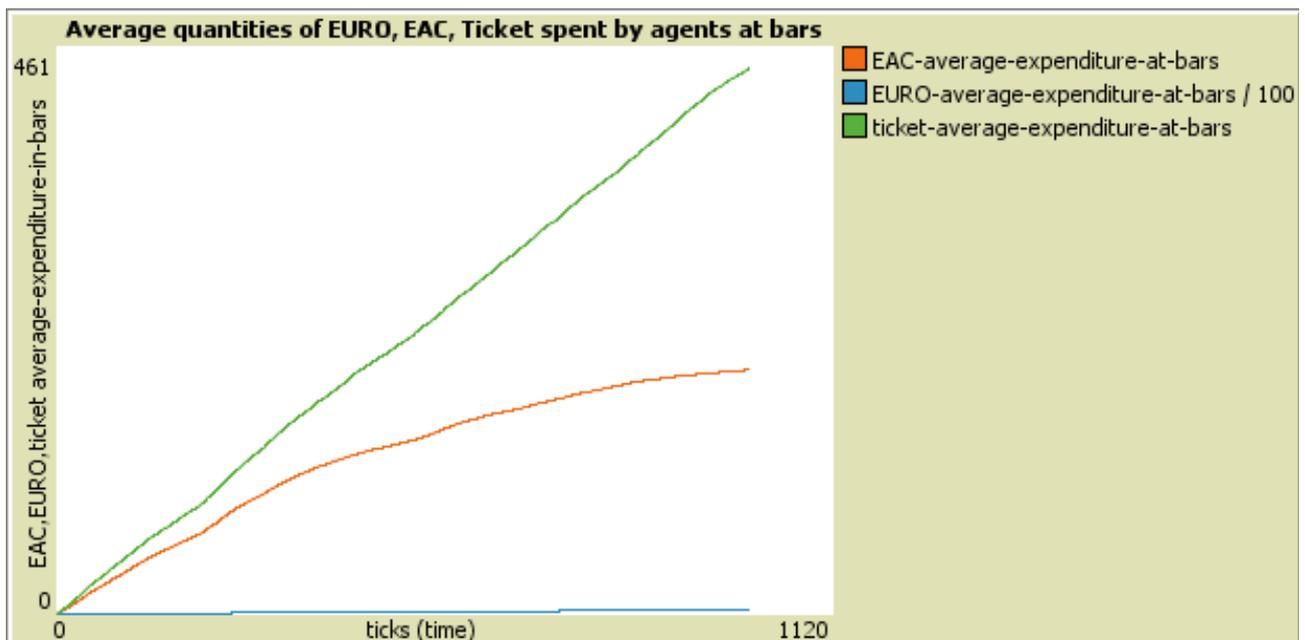
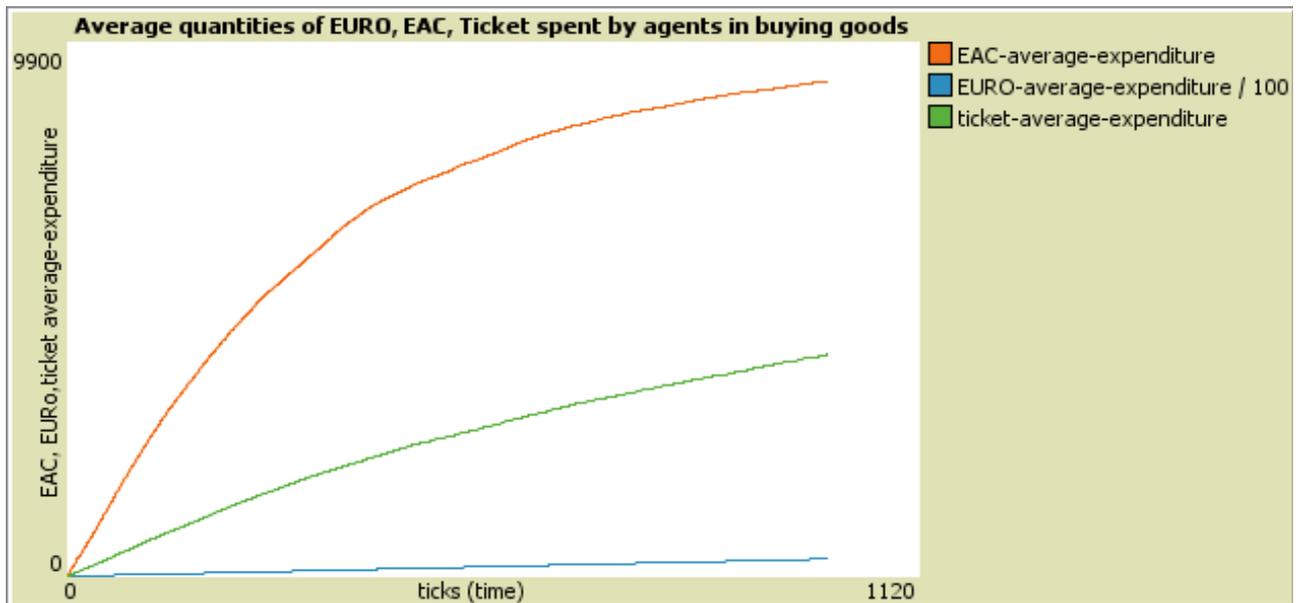
quite equal extent), the level of EAC owned on average by agents decreases dramatically, stopping at a very low level. In this situation, as we have already mentioned, also the level of Tickets-restaurant decreases, even if agents receive monthly an amount of them as part of their salary.

In a situation like this, we can reasonably claim that the creditors do not trust, for a variety of reasons, in the new alternative currencies as a mean of payments, and therefore they accept only EURO for the collection of receivables.

At the same time, the shops and bars are more inclined to accept the new currencies, in order to sell more goods and services, and therefore in order to make more money; however this is not enough to compensate the behavior of creditors characterized by the absence of trust in the new currencies. and then both levels of EAC and Tickets-restaurant drop, as it appears in the graphs below.

As the three plots describe, the fact that both shops and bars are quite willing to accept the two alternative means of payments causes a real “boom” of the use of them in the economy; and this happens nevertheless the creditors do not trust in them at all.





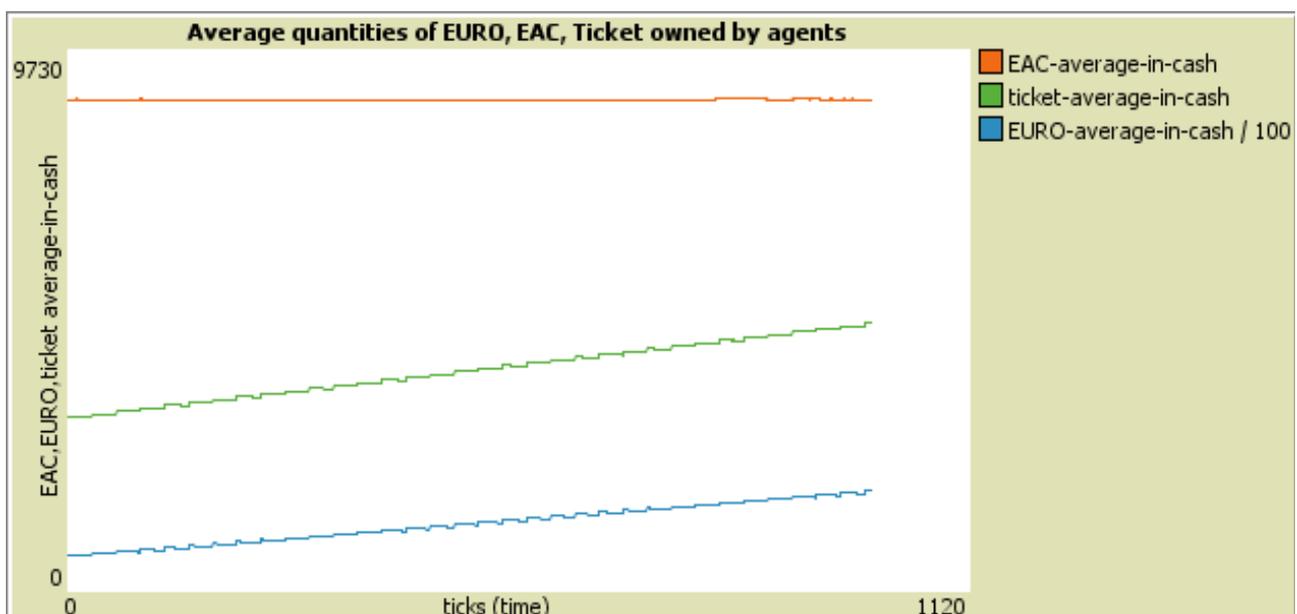
*ECONOMIC ANALYSIS OF THE EXPERIMENT 5.*

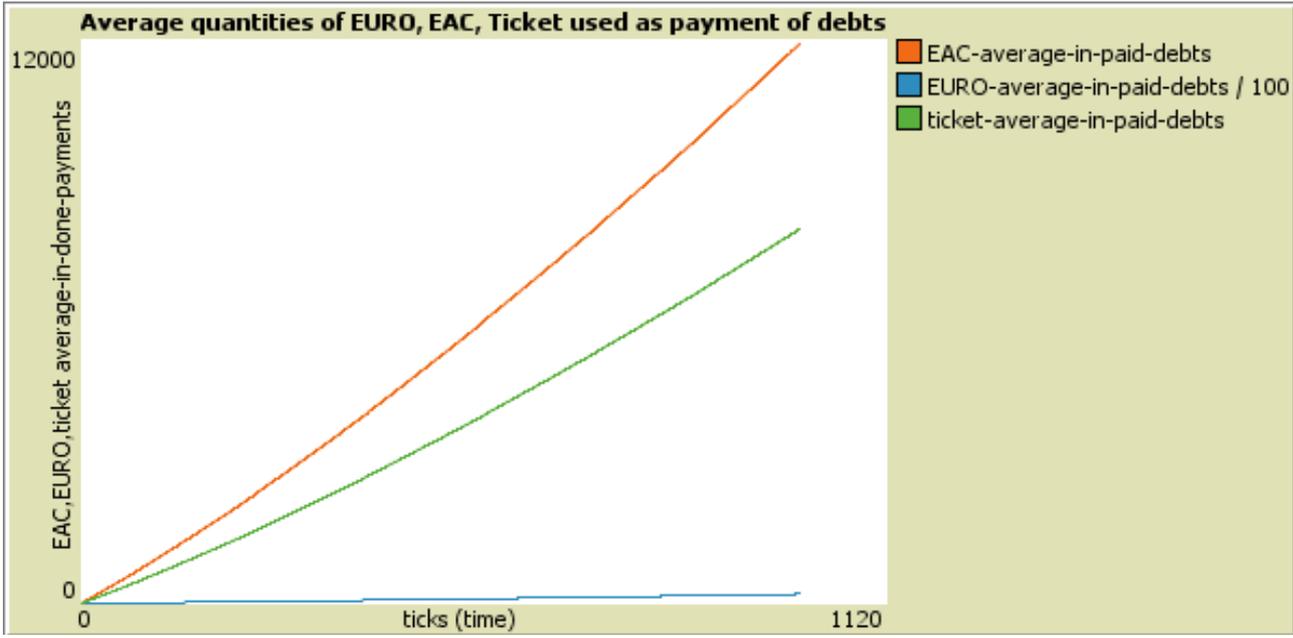
In the last experiment we have proposed, we have supposed that the setting was the opposite of the one of the fourth experiment; that is a setting in which the creditors are more inclined to receive payments both in EAC and in Tickets-restaurant, while

the shops owners do not accept payments neither in EAC nor in Tickets-restaurant. Although the bars do not accept payments in EAC, we have assumed that they are forced to accept them in Tickets-restaurant, because of the agreement that they stipulated with the Tickets-restaurant provider and the firm giving them to its employees.

Analyzing the outcomes of this experiment, we noticed that EAC owned by agents is almost constant, for the fact that the agents could not use it to buy goods neither at shops nor at bars, but they can use it only to repay debts, together with Tickets-restaurant, that increases, because of the monthly payment of salary given, as we know, in Tickets-restaurant for a small part.

Therefore, in this setting agents must use more EURO to pay goods and services, saving less of it. In this situation we can claim that the creditors trust in the two alternative new currencies, as a result of their faith that both EAC and Ticket-restaurant will be a safe mean of payment. The confidence that the creditors give to the new currencies leads to the opportunity that they become more used in whole economy.





## Section 4

### Conclusions

After having considered the two different types of experiments, it is clear the twofold purpose of this simulation model for economics.

On one hand it permits to analyze the outcomes coming from different setting, that is, coming from the choice of different level of the acceptance parameters. In this case it can help the economist to form predictions about the future diffusion of alternative means of payments, starting from the analysis of the present situation.

On the other hand, it permits to better understand the mechanism of diffusion of a certain currency in the economy. In this case it can help the economist in the comprehension of the way in which a certain type of alternative currency spreads in the economy (the case of the EAC), as well as in the comprehension of the way in which something that is created exclusively to buy a determined good (the case of the Tickets-restaurant), starts to be used to buy other goods and services or to repay debts.

So, we can say that this simulation is useful both for predictive purposes and for theoretical ones.