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Trade Dynamics and Comparative Advantages

The agent-based simulation we are going to develop aims to reproduce some typical dynamics of international trade, such as impact of exchange-rate and comparative advantages. The idea is to transfer those dynamics into a microeconomic context (our NetLogo world) where there are two communities of agents that produce, consume and exchange two goods within the respective group and with the other one as well.

All agents produce two types of goods: wine and bread. Those from country A are best producers in absolute term of both goods (but not relatively), this in order to represent the comparative advantages that we observe in the world-trade context. Furthermore, at each time, agents have a fixed number of work hours, which are used to produce the goods. While the simulation is running, agents specialize in the production they are more skilled, increasing the quantity of output, and buy the other good from other agents.

In the model each agent initially produces its endowment, basing on the respective amounts of work hours dedicated to the goods and the wine/bread productivities. It also consumes a fraction of the goods produced proportional to its marginal propensity to consume.

The commerce mechanism is built upon the “desire” variable, which represents the agents' needs of the two goods aggregated. This is an essential characteristic of the model to point out. There is no distinction in terms of goods in the expectations of the agents because we do not want a pre-determined solution to the model. For this reason we deliberately did not create two different types of desire for wine and bread, but a unique one. In this way the comparative advantages, will come up as a property or result of the model, not being a feature set ex ante. The agents will naturally converge to the solution through their choices, assuring originality to the model.

Therefore, comparing its desire with the sum of bread and wine left after the consumption, the agent becomes a “potential seller”, in case of surplus of resources, or a “potential buyer”, in the other case. The potential buyer looks for a potential seller in order to trade. When it succeeds, the trade occurs from the seller to the buyer through the exchange amount, which is the difference between the desire and the two goods aggregated, as specified before. The exchange-amount increases the endowment of the good of the buyer that deficits more, while it reduces the good of the seller in abundance.

The commerce is both internal and external (international). The main differences are the presence of reserve/offer prices and the exchange-rate, which complicate further the international trade. On the other hand, instead, the internal trade is based exclusively on the work hours used to produce the goods.

Another vital feature of the model is the adaptive mechanism of the agents, that aims to reproduce the revision of their expectations and the specialization. We set a variable, called satisfaction, proper of each agent. If the satisfaction is too low after a certain length of time, the agents have the possibility to shift gradually the partition of the fixed amount of work hours between bread and wine. In this way we expect to have after a certain period a time agents more focused on the production of only one type of good.

For simplicity, at first the amount of work hours is partitioned equally between the two goods, and in order to evidence the comparative advantages, the agents cannot change their productivities, which are fixed. On the contrary, variables like the marginal propensity to consume, the total amount of work hours and the desire, together with the number of agents in the world, can be modified in the interface of NetLogo.

A more detailed comment about the code

The model is divided in three procedures:

- setup;
- work-hours endowment;
- production-consumption.

- **Setup**

We briefly comment the setup, reporting above the whole scrypt of the code, because it is not particularly challenging to understand and peculiar for our model.

```
“to setup
  ca
  ask patches with [pxcor >= 0 and pycor > 0 ]  [ set pcolor green ]
  ask patches with [ pxcor >= 0 and pycor <= 0 ]  [ set pcolor green ]
  create-Agents-of-A Agent-CountryA [ setxy random-normal 8 1  random-ycor ]
  create-Agents-of-B Agent-CountryB [ setxy random-normal -7 1 random-ycor ]
  ask turtles [ set shape "person" ]
  ask Agents-of-A [ set color blue set bread-productivity 1 + random-normal 0.5 0.5  set wine-productivity 0.8 + random-normal 0.3 0.3  ]
  ask Agents-of-B [ set color red set bread-productivity 0.3 + random-normal 0.1 0.1 set wine-productivity 0.6 + random-normal 0.2 0.2  ]
  reset-ticks
  set coll 0
  set sat 0.061
end”
```

To begin, we divide the NetLogo world in two countries, A the green one and B the black one, where the agents are supposed to be settled with a random position. However, regarding the number of agents created for each country, we put two sliders in the interface of NetLogo, with a minimum of 1 and a maximum of 50. In this way we can set a run with a different number of agents for each country.

As we have already mentioned before, the productivities are fixed because we are not interested in them. We focus on allocation of work hours. They are composed of a constant term and a random normal.

Finally, we set 0 the "coll" and the "sat" 0.061, which we are going to talk about later on.

- **Work-hours endowment**

This is an essential step for a correct running of the model. We created a button and two sliders (one for A and one for B) in the interface. Firstly the user has to decide the endowment of total work hours that each country will possess. The differentiation of the two sliders allows for different endowments for each country. After this decision, the user has to press the mentioned button in order to fix the amount of work hours.

This result is obtained through this scrypt:

"to work_hours_endowment

ask Agents-of-A [set work-hours-A work-hours-A-val set whours_w_A work-hours-A-val / 2 set whours_b_A work-hours-A-val / 2]

ask Agents-of-B [set work-hours-B work-hours-B-val set whours_w_B work-hours-B-val / 2 set whours_b_B work-hours-A-val / 2]

end"

Each country sets the amount of work hours on the specification of the respective slider, and successively divide the amount between bread and wine equally.

- **Production-consumption**

First of all, we set the desire variable, which is shared by all the agents.

"ask turtles [set desire basic-needs + random-normal 1 0.5]"

The desire consists of two components: the basic needs, which are constant and have to be set in the interface through the dedicated slider, and a random normal.

Then there is the "production" of country A.

"set count_sellerA 0

set count_buyerA 0

*ask Agents-of-A [set work-hours-A work-hours-A-val set bread (bread-productivity) * (whours_b_A) set wine (wine-productivity) * (whours_w_A)]"*

The goods are computed by multiplying the amount of work hours dedicated by their respective productivities. We also set equal to zero the count_sellerA and count_buyerA, which will be fundamental in the next steps.

The same operation is done for country B.

Afterwards we introduce the consumption of the goods produced through the use of marginal propensity to consume.

*"ask Agents-of-A [set bread ((bread) - (bread) * (mpcb)) set wine ((wine) - (wine) * (mpcw))]*

*ask Agents-of-B [set bread ((bread) - (bread) * (mpcb)) set wine ((wine) - (wine) * (mpcw))]"*

The marginal propensity to consume is obviously distinguished between wine and bread, and can be determined at the beginning by means of two specific sliders.

Now we approach one of the most interesting part of the model: the internal trade. We are going to explain only the trade for country A, because the one for B has the same structure and operations.

First we have the separation of the agents between "potential seller" and "potential buyer", basing the distinction on the comparison "desire vs. wine + bread".

“ask Agents-of-A [ifelse desire < wine + bread [set status "potential-seller" set count_sellerA count_sellerA + 1] [if desire > wine + bread [set status "potential-buyer" set count_buyerA count_buyerA + 1]]]”

Secondly, an agent with status “potential buyer” looks for a “potential seller” and creates a link between them. In response to this link, the “potential seller” sets its own exchange-amount equal to the difference the sum of bread and wine, and the desire.

“if count_sellerA > 0 and count_buyerA > 0

[ask Agents-of-A with [status = "potential-buyer"] [create-link-to one-of Agents-of-A with [status = "potential-seller"]]]

if count_buyerA > 0 and count_sellerA > 0 and count links > 0

[ask Agents-of-A with [status = "potential-seller"] [set exchange-amount (bread + wine) - desire]]”

Then the “potential buyer” sets its exchange-amount on the “potential seller”'s one.

“if count_sellerA > 0 and count_buyerA > 0 and count links > 0 [ask one-of Agents-of-A with [status = "potential-buyer"] [set exchange-amount [exchange-amount] of [end2] of one-of links with [end1 = myself]] set count_sellerA count_sellerA - 1]”

In addition to this, the “potential buyer” sums its exchange-amount to the good he needs most.

“...ifelse wine < bread [set wine (wine) + exchange-amount][set bread (bread) + exchange-amount]]”

On the other hand, the “potential seller” subtracts the exchange-amount from the good he owns most.

“...ifelse wine > bread [ifelse wine > exchange-amount [set wine (wine) - exchange-amount] [set wine 0]][ifelse bread > exchange-amount [set bread (bread) - exchange-amount] [set bread 0]] set exchange-amount 0]”

One more thing to point out, if the exchange-amount is greater than the good from which is going to be deducted, this good will be set equal to zero in order not to have negative values.

Regarding the international trade, the structure of the code is similar but obviously the link is created between potential buyers from country A and potential seller of country B, and from potential buyers of country B and potential sellers of country A. Furthermore we implemented the code with the addition of the reserve and offer prices

The former are simply set in terms of work hours used plus a random normal, as it follows:

“ask Agents-of-A with [status = "potential-buyer"] [set reserve-price-A whours_w_A + random-normal 1 0.2”

“ask Agents-of-B with [status = "potential-buyer"] [set reserve-price-B whours_b_B + random-normal 1 0.2”

The latter are based on a formula that takes into account the sum of all reserve prices, the number of sellers and the work hours used, plus a random normal and other coefficients, in order to make them more realistic:

*“ask Agents-of-A with [status = "potential-seller"] [set offer-price-A 0.9902 * (totResP / (10 + CountsellerA)) - (whours_b_A * 0.001 + random-normal 0.8 0.1)”*

*“ask Agents-of-B with [status = "potential-seller"] [set offer-price-B 0.9902 * (totResP / (10 + CountsellerB)) - (whours_w_B * 0.001 + random-normal 0.8 0.1)”*

Here we report the scrypt for the international trade from country B to country A. The main differences interesting to notice are the *“if international trade”,* that refers to a switcher present in the interface from which the trade can be activated or de-activated, and the condition *“reserve prices > offer price”,* from which the trade is subordinated.

“i*f count_sellerB > 0 and count_buyerA > 0 [* ***if international-trade*** *[ask Agents-of-A with [desire > wine + bread and status = "potential-buyer"] [create-link-to one-of Agents-of-B with [status = "potential-seller"]]]]*

if count_sellerB > 0 and count_buyerA > 0 and count links > 0 [ask one-of Agents-of-A with [desire > wine + bread and status = "potential-buyer"] [***if reserve-price-A > [offer-price-B]*** *of [end2] of one-of links with [end1 = myself] set exchange-amount (([exchange-amount] of [end2] of one-of links with [end1 = myself]) ** ***exchange-rate*** *) ask [end2] of one-of links with [end1 = myself] [set status "seller"]]]]*

In the international trade we also introduced the exchange rate, that can be manipulated in the interface through the appropriate slider in the range 0.1-2.0. It is expressed in terms of the currency of B, therefore for the country A the code will be:

*“if count_sellerA > 0 and count_buyerB > 0 and count links > 0 [ask one-of Agents-of-B with [desire > wine + bread and status = "potential-buyer"] [if reserve-price-B > [offer-price-A] of [end2] of one-of links with [end1 = myself] [set exchange-amount (([exchange-amount] of [end2] of one-of links with [end1 = myself]) ** ***(1 / exchange-rate)****) ask [end2] of one-of links with [end1 = myself] [set status "seller"]]]]”*

Regarding the addition and the subtraction of the exchange-amount, for the potential buyer the text is identical to the one of the internal trade, while for the potential seller it is slightly different, in particular for the presence of the exchange rate mentioned above.

*ask Agents-of-A with [status = "seller"] [set exchange-amount (exchange-amount ** ***(1 / exchange-rate)****) ifelse wine > bread [ifelse wine > exchange-amount [set wine (wine) - exchange-amount] [set wine 0]][ifelse bread > exchange-amount [set bread (bread) - exchange-amount] [set bread 0]]]* *ask Agents-of-B with [status = "seller"] [set exchange-amount (exchange-amount * **(exchange-rate**)) ifelse wine > bread [ifelse wine > exchange-amount [set wine (wine) - exchange-amount] [set wine 0]][ifelse bread > exchange-amount [set bread (bread) - exchange-amount] [set bread 0]]]*

As we are also interested in appreciating the effect of the exchange rate on the trend of the international trade, we created two plots in the interface, called "exchange-rate effect A" and "exchange-rate effect B", which sum all the exchange-amounts of the potential buyers of A and B separately.

Finally, there is the adaptive mechanism, which is essential in order to verify the theory of comparative advantages. Here is the mechanism of country A:

"ask Agents-of-A [ifelse wine + bread < desire [set satisfaction (satisfaction + 0.06)] [set satisfaction (satisfaction - 0.06)]]

*if ticks = 2000 [ask Agents-of-A with [satisfaction <= (ticks) * sat] [set whours_b_A whours_b_A + 1 set whours_w_A whours_w_A - 1]]*

*if ticks = 4000 [ask Agents-of-A with [satisfaction <= (ticks) * sat] [set whours_b_A whours_b_A + 1 set whours_w_A whours_w_A - 1]]*

*if ticks = 6000 [ask Agents-of-A with [satisfaction <= (ticks) * sat] [set whours_b_A whours_b_A + 1 set whours_w_A whours_w_A - 1]]*

*if ticks = 8000 [ask Agents-of-A with [satisfaction <= (ticks) * sat] [set whours_b_A whours_b_A + 1 set whours_w_A whours_w_A - 1]]*

*if ticks = 10000 [ask Agents-of-A with [satisfaction <= (ticks) * sat] [set whours_b_A whours_b_A + 1 set whours_w_A whours_w_A - 1]]"*

The mechanism is based on the variable "satisfaction". This variable, starting from the value zero, can decrease or increase, depending on the balance between the desire and the sum of bread and wine. If the desire is bigger than the two goods, the satisfaction rises, otherwise it falls. At predetermined numbers of ticks (2000, 4000, 6000, 8000, 10000), the turtles compares their satisfaction with a factor, that is the result of the product between the ticks and a coefficient called "sat". If the satisfaction is smaller, they are not happy; therefore they progressively adapt the division of their work hours depending on their preferences, shifting the use of work hours from one good to the other. In this way they specialize the production, and allow us to appreciate the comparative advantages.

First Experiment

In this experiment we are going to verify the theory of the comparative advantages in a challenging situation: in this case the country A has a better productivity in both goods compared to country B, therefore it has an advantage in absolute terms. On the other hand, the country B has a relative advantage in terms of one good with respect to A.

For this reason we set the productivities in the following way:

“ask Agents-of-A [set color blue set bread-productivity 1 + random-normal 0.5 0.5 set wine-productivity 0.8 + random-normal 0.3 0.3]”

“ask Agents-of-B [set color red set bread-productivity 0.3 + random-normal 0.1 0.1 set wine-productivity 0.6 + random-normal 0.2 0.2]”

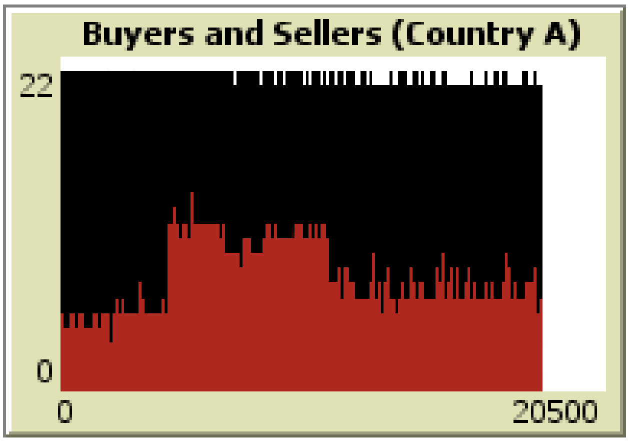
As we can notice, the relative advantage of country B is in the production of wine, because the ratio between the two productivities (0.6/0.3) is higher than for country A (0.8/1.0). Despite this, the country A has more efficient productivities, so in a closed economy, it will product more.

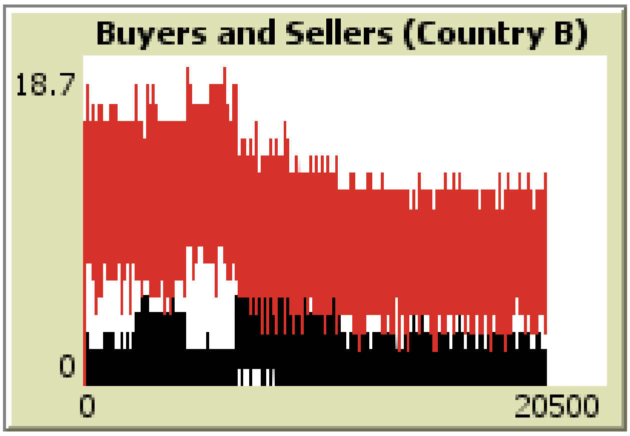
1.First Setting

We report the first set of conditions of the model:

- number of agents per country: 21;
- work hours endowment per country: 10;
- marginal propensity to consume equal to 0.7 for both goods;
- basic needs set at 1.0;
- exchange-rate at 1.0.

Here follow the plots of buyers and sellers of both countries after having started the simulation (the sellers are black colored and the buyers red colored):





We can see that in country A there is an imbalance between the number of sellers and the number of buyers. This is not surprising, since its productivities are far higher than the ones of country B, leading to a surplus which is traded on the international market. In fact, on the other side, in country B there are significantly more buyers than sellers, confirming that the surplus of A is bought by B.

After 2000 ticks, the adaptive mechanism starts affecting the simulation, clearly showed by the second plot (country B) where the number of potential buyers starts decreasing thanks to a higher number of potential sellers or agents with status “sazio” (satisfied). For A we denote a temporary shock in the number of potential buyers that disappears after roughly 2000 ticks.

Country A has a big advantage with respect to country B and so has a less incentive to specialize its production.

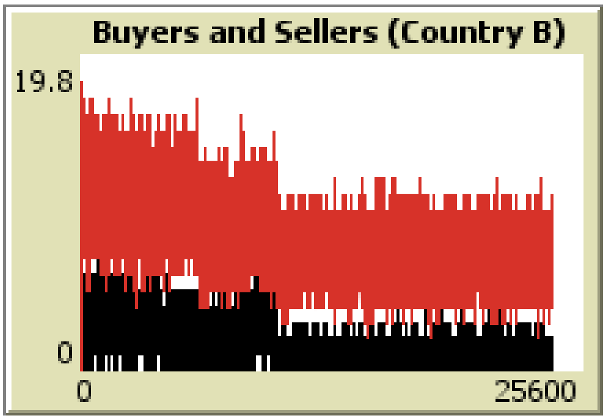
1.2 Second Setting

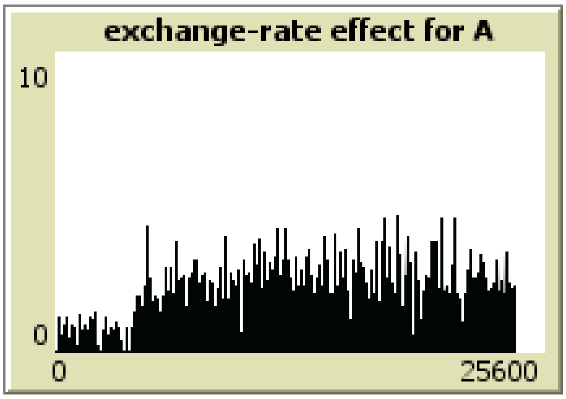
These are the second conditions set in the model:

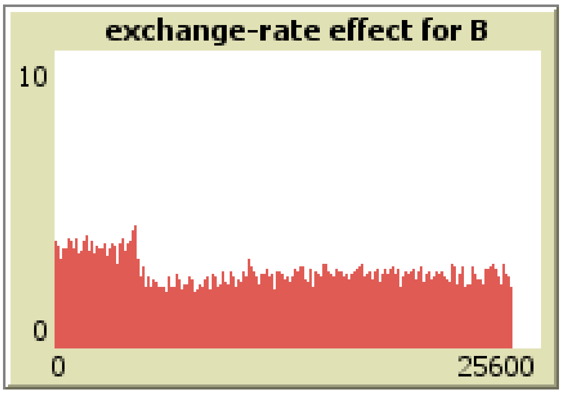
- number of agents per country: 21;
- work hours endowment per country: 10;
- marginal propensity to consume equal to 0.7 for both goods;
- basic needs set at 0.6;
- exchange rate firstly at 1.0, after 4000 boosted to 1.8.

Now we are going to test a depreciation of the currency of B (we remind that the exchange rate in expressed in the currency of B). For this reason we leave the other parameters unchanged but the basic needs, in order to demonstrate that the model works indifferently with whatever value we choose.

Here are the plots of buyers and sellers once we have started the simulation. The time series in the plots are similar to the ones of the previous case, therefore no particularly interesting so far. Now we increase the exchange rate to 1.8 and see what happens.







As you can easily notice in the top left side plot. The depreciation has clearly increased the purchasing power of A towards B, and this is confirmed by the left side plot, showing the exchange-amount time series of A.

However, the depreciation does not disprove the Ricardo's law. The agents keep shifting their work hours endowment starting from the 2000 ticks. This shock has only changed the entity of the exchange-amount.

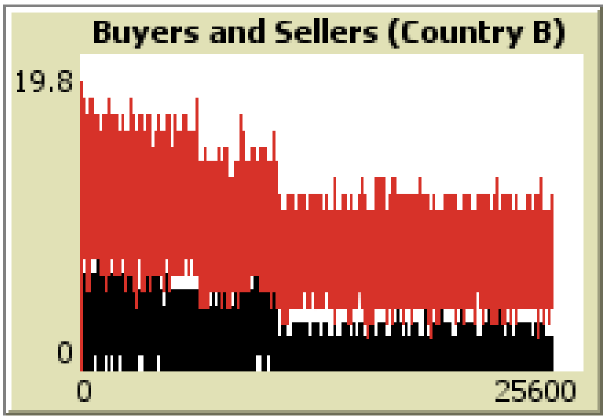
1.3 Third Setting

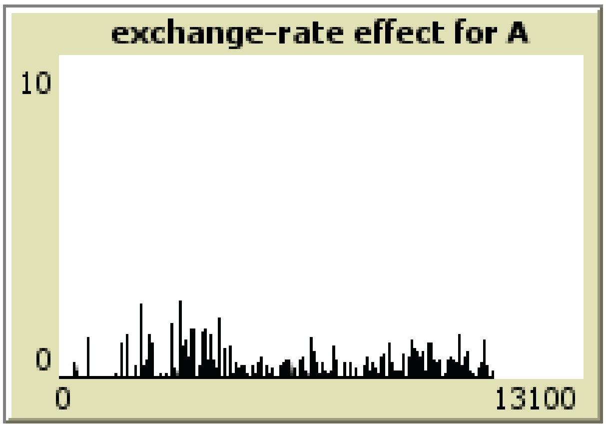
The third set of settings:

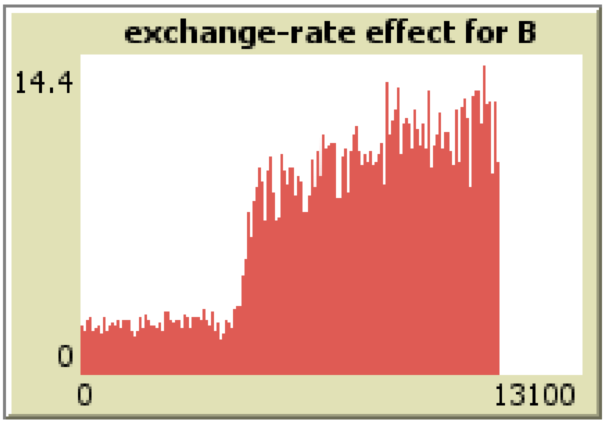
- number of agents per country: 21;
- work hours endowment per country: 10;
- marginal propensity to consume equal to 0.7 for both goods;
- basic needs set at 0.6;
- exchange-rate firstly at 1.5, successively decreased to 0.5 (after 4000 ticks).

Now we experiment the following shock: an appreciation.

Here the the usual plots:







When the appreciation occurs, the purchases of B boost and the entity of the exchange-amounts in the international trade surges, as we can notice from the bottom right side plot. On the other hand, the drop of the exchange rate disadvantages A, even if the consequence in terms of sales are less clear.

The depreciation has also increased the number of sellers in country B, therefore thanks to this shock B copes with its less efficient productivities.

Second Experiment

2.Starting

In this section we focus our attention on a situation different from the previous one where one country had absolute advantages in both production. In this second experiment we want to test the hypothesis that country A is best-skilled in producing bread while country B is best-skilled in producing wine. A similar situation led David Ricardo to formulate the law of comparative advantages, an aspect that we are interested to underline as well in our model.

In order to go further with the experiment we modify the values of productivities in the set up procedure of the code, we report here the particular;

"ask Agents-of-A [set color blue set bread-productivity 1 + random-normal 0.5 0.5 set wine-productivity 0.8 + random-normal 0.1 0.1]

ask Agents-of-B [set color red set bread-productivity 0.3 + random-normal 0.1 0.1 set wine-productivity 1 + random-normal 0.1 0.1]"

We have set values for the two productivities that make each country best producer in one of the traded goods. Other parameters of the experiment are not changed (such as work-hours) and only the modifying of sliders value will enter in the observation.

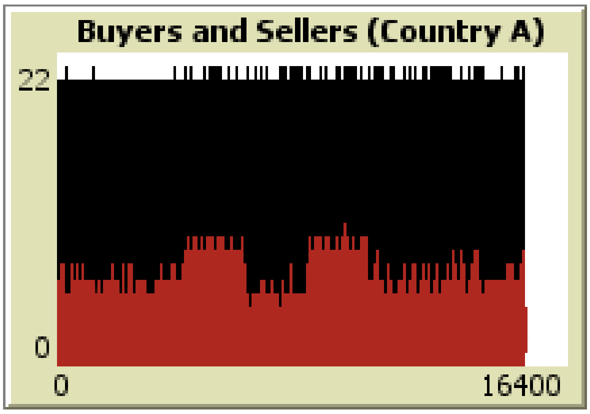
2.1 First Setting

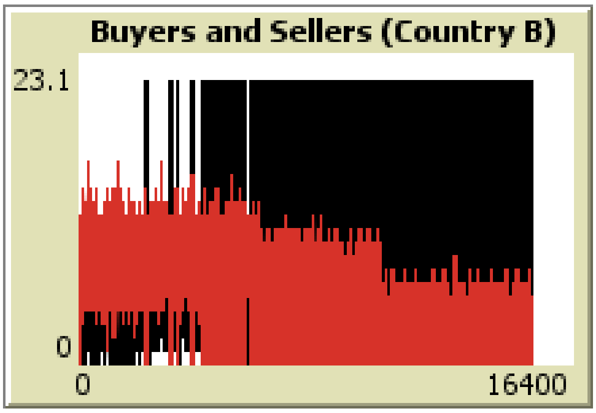
We run our model with the following set of conditions:

- work-hours endowment set at 10 for both countries
- Marginal propension to consume set at 0.7 for both goods
- Number of agents set at 21 in each country
- Basic needs set at 1.0
- Exchange-rate fixed at 1

With the last point we underline the fact that competitiveness is made only by productivity level. When we will change the values of the exchange-rate slider, one country will gain an extra advantage or disadvantage since values showed here have to be interpreted as a ratio between two currency values, in particular, our exchange-rate is expressed in terms of the currency of B. It comes clear that higher values we set in the slider, the more the currency of B will be depreciated.

After starting the simulation we denote the following behavior of our plots

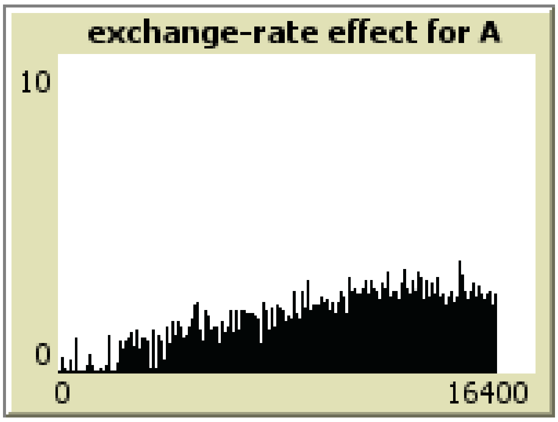


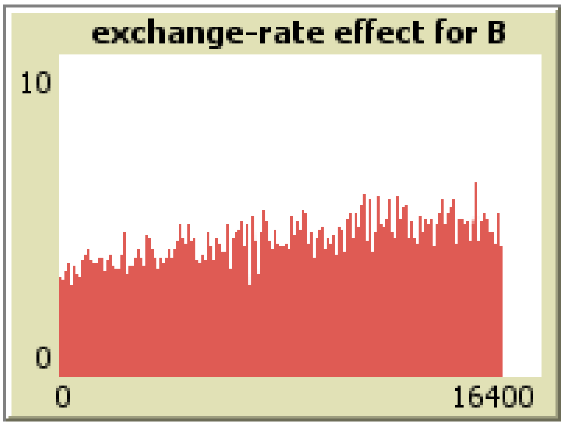


In country A we clearly see from the beginning that sellers are always more than buyers so in country A there will be significant trade surplus. The time series of number of is almost stable but jumps up (and down) when there are changes in work our division, in the case of A there will be a shifting of hours from wine production towards bread production.

In country B we denote a number of buyers higher than sellers for the first 2000-3000 ticks and then the series starts a declining path that is associated with the progressive shifting in production (this time from bread to wine). From the declining number of buyers in B we can state that agents have specialized through time and more of them are satisfied (i.e. desire < wine+bread)

What is the effect of the exchange rate?





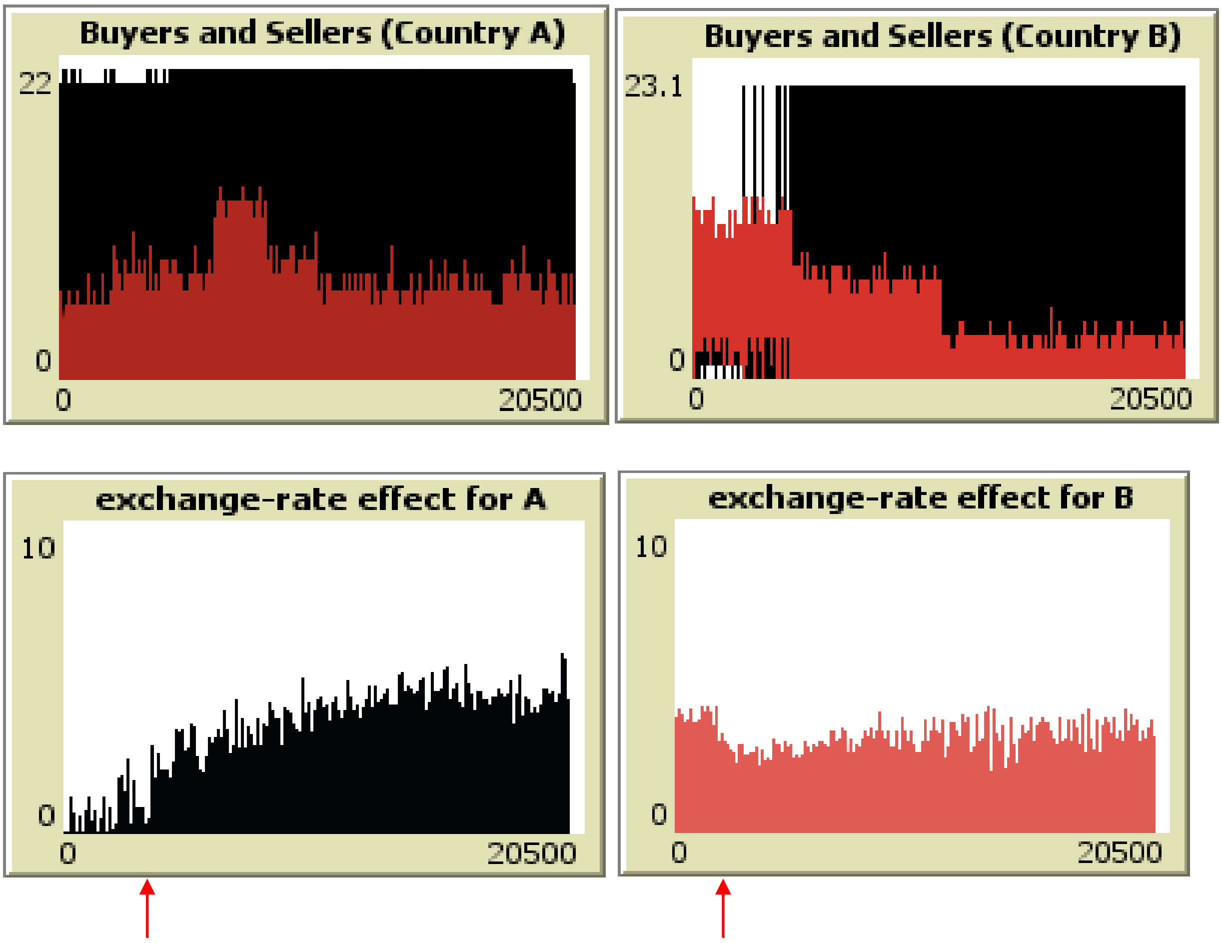
As the two plots reported here show the aggregate exchange amount of the Agents in A and B with status potential buyer, we can get from here the perception of the impact of the exchange rate on traded goods. Here clearly nothing relevant happens since exchange rate is set equal to 1 and the two series are almost stationary.

2.2 Second Setting

We run our model with the following set of conditions:

- work-hours endowment set at 10 for both countries
- Marginal propension to consume set at 0.7 for both goods
- Number of agents set at 21 in each country
- Basic needs set at 1.0
- Exchange-rate fixed at 1.8 (after 2000 ticks)

Here we want to test what is the reaction of the model to a depreciation of the currency of B



We starts the simulation with an exchange-rate value of 1 and after 2000 ticks we improved it at 1.8 that means a depreciation of the currency of B. The first two plots show a trend similar to the one observed in the previous observation with jumps (up and down) due to shift of hours between each production. The interesting part is perhaps the one concerning exchange rates; here we see that after the shock in the exchange rate (indicated by the red arrow) the traded goods acquired by the buyers of A (exchange-amount variable) increases significantly and this is clearly the effect of the improved purchasing power of country A with respect to country B.

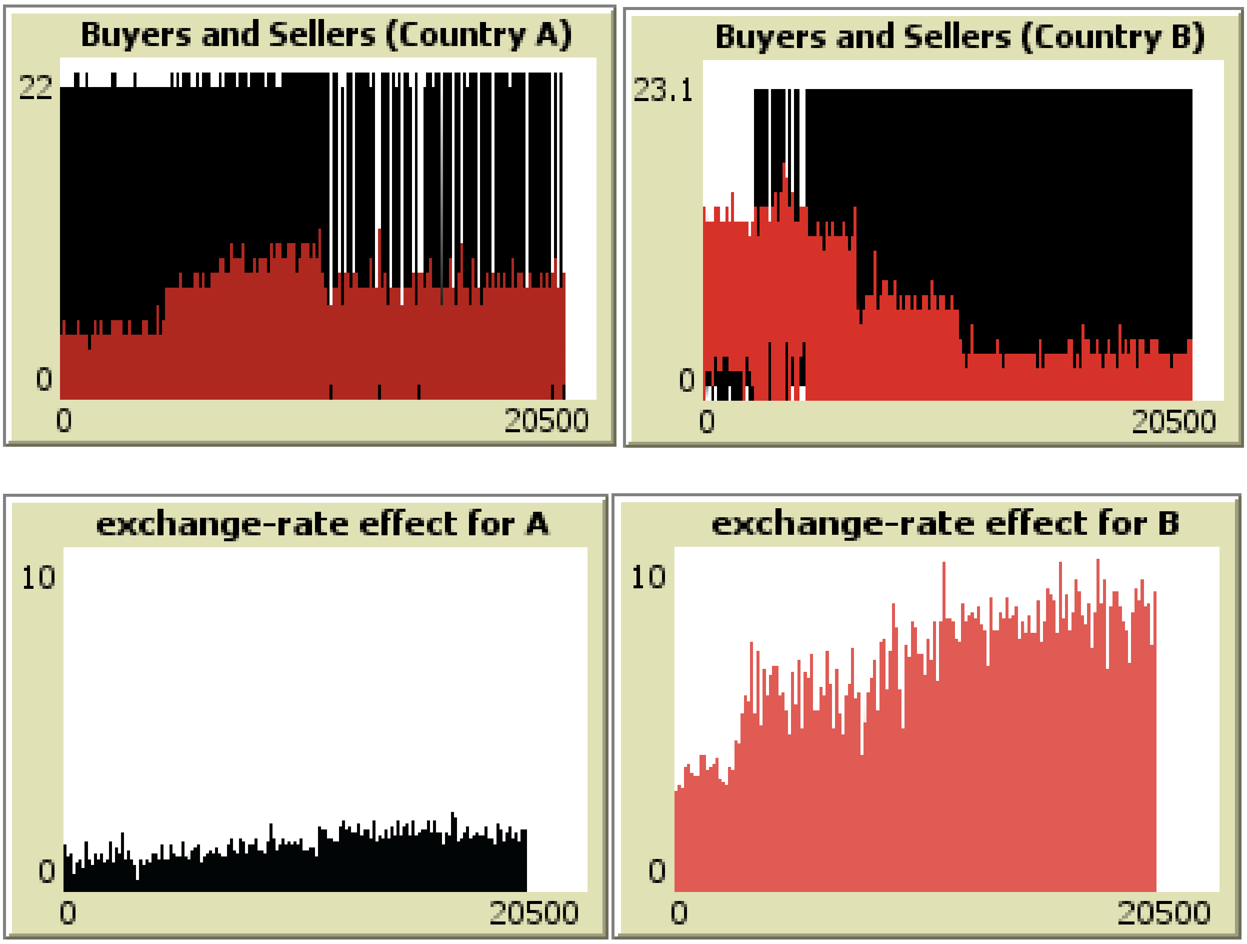
On the contrary we observe the opposite dynamic for country B, that after the shock in exchange rates shows a drop in the long-run mean of the exchange-amount series; this is loosely speaking the effect of a drop in purchasing power.

2.3 Third Setting

We run our model with the following set of conditions:

- work-hours endowment set at 10 for both countries
- Marginal propension to consume set at 0.7 for both goods
- Number of agents set at 21 in each country
- Basic needs set at 1.0
- Exchange-rate fixed at 0.7 (after 2000 ticks)

Here we want to test what is the reaction of the model to a depreciation of the currency of A



As in the previous observation, the first two plots show the same trend (see above) while the exchange-rate effect makes us observe (as expected) the opposite dynamic of the one in observation 2 but this time with a strong difference in the magnitude of the effect.

This case refers to a depreciation in the currency of A and of course we denote a jump in the exchange-amount acquired by agents of B due to the increasing purchasing power. The same dynamic was observed in the previous observation but here the magnitude is at first sight significantly bigger while in the plot of A we do not observe notable effect due to the exchange rate shock. We can intuitively say (we will discuss better in the conclusions) that country B is more sensible to international-trade shocks (such as the exchange rate) than country A.

From the outcomes of the present experiment we have observed that the country that has absolute advantages in bread production (A) is less subject to shocks due to the oscillating exchange-rate.(the exchange-amount series has a lower long-run mean and lower variance). This means also that they are less dependent from international trade since they manage to reach an equilibrium between resources owned and desires before the international trade starts.

Some final considerations

From the plots showing the amount of buyers and sellers in both countries we clearly see the specialization mechanism especially for country B (the country that is more dependent from international trade), here we observe the number of buyers declining through time since agents shift their work-hours to more efficient production (wine) and this determines a bigger surplus that can satisfy agents and transform them into potential-sellers. From this observation comes out indeed the specialization process (heart of Ricardo's theorem) that is obviously stronger in the country that results more dependent from international trade (B). This result comes out in both experiments.

The reason why one country is more dependent must be found in the setup. Both countries have a comparative advantage but since the terms of trade are supposed to be 1:1 and country A has a bread productivity advantage higher than the advantage of B in wine productivity, it comes out that A will need international trade less than B and B will be forced to follow a stronger specialization process in order to face its higher dependence from international trade.