

**UNIVERSITÀ
DEGLI STUDI
DI TORINO**
ALMA UNIVERSITAS
TAURINENSIS



UNIVERSITY OF TURIN
FACULTY OF ECONOMICS
SIMULATION MODELS FOR ECONOMICS
PROF. PIETRO TERNA
ACADEMIC YEAR. 2009/2010

***ESSAY ON NETLOGO SIMULATION:
“CONSUMPTION AND WORK-
LEISURE DECISIONS”***

SERENA CURRONE
ENRICO MULE’

THE MODEL.

This simulation aims to analyze the relationships among economic agents: firms on one side and people, both considered as workers and as consumers, on the other side. It is possible to divide the theoretical model, that is at the basis of our simulation, into several phases: starting from a basic structure, we complicate it in order to get, step by step, a better representation of the real world.

Phase 0:

We set in a space a certain number of firms and a certain number of people and we distribute them randomly.

As regard as firms, we assume that they have the same "well-behaved" production function (i.e. where labour is the only input into production), the same cost structure and that they all fix the same nominal wage. Moreover we assume that they operate in a "perfectly competitive" environment: there is no role for technological progress, the only good produced is homogeneous, the price is fixed and common to all firms (it is then possible to speak about price level). As a consequence, we end up with a unique level of the real wage.

As regard as people, we consider them as workers in search of an occupation: they decide where to work on the basis of the real wage that, assuming no informational asymmetry between firms and workers (so that workers, knowing exactly both the price level and the nominal wage, know exactly the real wage they perceive) and on the basis of how far they are from a firm. Being in this phase the real wage unique for all firms, workers accept to work in firms that are nearer to them, in order to have a minimum level of "travel costs". Contemporaneously, we consider people as consumers that move in search of the only good produced in our economy: they decide to buy where the good is less expensive. Being in this phase the price of the good equal for all firms, they purchase it at the nearest firm, in order to have minimum "research costs".

Phase 1:

Firms can arbitrarily fix different levels of nominal wage, whereas the price keeps on being common to all firms. To this purpose, we create three groups of firms and we associate to them three different nominal wages: we assume that firms offer high nominal wage if they are placed in the North of our world (since in the North labour force is more productive, due to infrastructural reasons), low nominal wage if they are placed in the South and "intermediate" nominal wage if they are placed in the Centre. We end up with three different levels of real wage, perfectly known by workers (no informational asymmetry).

Workers now fix a minimum level of real wage (that we call "reservation salary") and accept to work in firms that offer them a nominal wage greater or equal than that value. Nothing changes on consumption-decision side: being sell price still equal to all firms, consumers purchase the good at the nearest firm.

In the following two phases, we get out of a "perfectly competitive" environment.

Phase 2:

We now allow for technological progress and we assume that the cost structure isn't the same for all firms.

In particular, we specify the cost function as made of two components: fixed costs (i.e. the rental of the warehouse where the productive activity takes place, the rental of the machinery), that we set for simplicity to be common to all firms, and variable costs (i.e. the cost of the only input used, that is labour), that varies from firm to firm since it is directly related to the number of workers employed. This allows to know the unitary cost that each firm realizes and then to differentiate firms in terms of competitiveness: the lower is the unitary cost realized, the higher is the competitiveness. This reflects in the possibility that each firm fixes a different price, that is obtained adding a mark-up (again, for simplicity we set it equal to all firms) to the unitary cost realized. As a consequence, we end up with different levels of real wage, both depending on different nominal wages and on different prices (we make use of a medium price in order to have a measure of the real wage).

On work-leisure-decision side, workers decide to work where the wage that is offered (in real terms) is greater or equal than their reservation salary (discounted for the medium price). On consumption-decision side, consumers now fix a minimum price (that we call "reservation price") they are willing to pay and choose to purchase the good where the sell price is lower or equal than this value.

Phase 3:

As a further complication, we introduce on firms' side the very realistic idea of a competition based on quality: each worker produces less units of good since he concentrates himself on the production of just a unit. We end up with a higher quality of the good sold: this in turns increases the unitary cost and then the sell price.

On consumption-decision side, consumers, that we endow for the possibility of being part of a community in which pieces of information about consumption experience are freely exchanged, perfectly know the quality level of the good sold and then are able to recognize in a higher price a higher level of quality. So they keep on choosing where to buy following the same criteria of the Phase 2.

THE PROGRAM.

PHASE 0.

All the agents of our model are *turtles*: we split them in two categories creating two *breeds*. `breed [frms frm]` (with "workers" we mean both

Firstly, we define the `breed [wrkers wrker]` workers and consumers)

global variables, that aren't linked to a specific breed but concern to the whole world: `globals [NomWage PriceLv] RealWage price]`

- price (in this phase fixed equal to all firms);
- price level (it is possible to speak about it in this phase of our model);
- nominal wage and real wage.

Secondly, we define the *variables that are connected to each specific breed*:

<code>wrkers-own</code>	[wage FirmNearw NumberOfSellers wealth work? buy? PiecesBought WhereIWork WhereIBuy LifePoints InitWealth MyFirmProduces]
<code>frms-own</code>	[NumWorkers Production produce? PiecesSold PiecesSoldNow buyers stocks]

We are going to explain some of these variables.

The variables that end with a question mark are binary: they can assume only the value of 1 if the condition is satisfied and 0 otherwise (for instance, the variable "work?" takes value of 0 if the worker is unemployed and 1 if he works). We use the prefix "num" to indicate "number": the workers' variable "FirmNearw" counts the number of firm that are in the searching-radius (we'll talk about it soon). The variable "lifePoints" is a measure of how long each worker can survive without working and consuming: to this purpose, we allow for the possibility that workers receive unemployment benefits from the government creating a switcher named "unemployment_benefits". The variables "WhereIWork" and "WhereIBuy" identify the specific firm in which a person respectively decides to work and to buy goods. Finally, the variable "stocks" is linked to the possibility for each firm to have a warehouse.

```
to setup
  clear-all
  create-world
end

to create-world
  create-wrkers workers
  create-frms firms
  ask wrkers [set shape "person"
              setxy random-xcor random-ycor
              set color red
              set InitWealth initial-wealth
              set wealth InitWealth
              set Lifepoints initial-lifepoints
              set size 1.3]
  ask frms [set shape "factory"
            setxy random-xcor random-ycor
            set color white
            set size 1.8
            set NomWage 20]
  set price 10
  set PriceLvl price
end
```

Then we create our world with the "setup" procedure. With "set shape" and "set color" we define how firms and workers have to look like. The *reporter command* "random-xcor random ycor" places in a random way all the agents in the space representing our world. We endow workers with an initial (i.e. before they start searching for a job)

level of wealth and an initial level of lifepoints that can be arbitrarily changed by the observer thanks to the presence of the corresponding sliders. Finally we can underline that, since in this phase of our model both price and nominal wage are fixed and equal to all firms, we define them in the "setup" procedure. We end up with a world like in the picture below:



Then we start our simulation with the “go” procedure.

```
to go
  search-for-job
  produce
  search-for-job-goods
  do-plots
end
```

Firstly we have to allow the production to start, then the world to operationally exist: we do this with the “search-for-job” procedure, in which no consumption decision is taken into account but it is just a simple rule (technically necessary) that allows workers to find an occupation.

Then the productive activity takes place and we define how it behaves with the “produce” procedure:

```
if NumWorkers > 0 [set production 6 * NumWorkers
  set produce? 1
  set color violet ]]
```

if there is at least one worker employed, a firm

starts producing (“produce? 1”) according to a well-behaved production function of the (arbitrarily chosen) form: $Y = 6 * L$ (with L representing the number of workers), and turns its color into violet.

Now that our economy works, it is possible to analyze both contemporaneous work leisure and consumption decisions and we do this by means of the “search-for-job-goods” procedure:

```
ask wrkers [set FirmNearw count frms in-radius searching-radiusW
  set WhereIWork one-of frms in-radius searching-radiusW
  set NumberOfSellers count frms with [produce? = 1] in-radius searching-radiusC]
```

we set a radius that simulates workers’ vision capacity and we call it “searching-radiusW”: each worker chooses randomly (“one-of”) to work in one of the firms in that radius (i.e. “FirmNearw”), that are assumed to be the nearest one and then that are associated to null travel costs. At the same time, each person is endowed with another radius that simulates consumers’

vision capacity (we call it "searching-radius"¹) and can see how many firms producing goods there are in that radius: all these are associated to null research costs. Then, making use of the "ifelse" structure we specify how people take their decisions: `ifelse FirmNearw > 0 [ifelse NumberOfSellers > 0` there is at least one firm in the radius and it produces, then worker starts to work turning his color into green: by working, he perceives the nominal wage increasing his wealth. Contemporaneously he chooses randomly one of the firms that are in the radius and, if his wealth is greater or equal than the price of the good, then he purchases it becoming bigger. Otherwise:

```
[right random 360 forward 1
set color red
set wealth (wealth - ResearchCosts)
set LifePoints LifePoints - 1]]
[right random 360 forward 1
set color red
set wealth (wealth - TravelCosts)
set LifePoints LifePoints - 1]]
```

he picks a random whole number from 0 to 359 and turns right this number of degrees². Then he moves forward one step: each movement causes the loss of one lifepoint and the decrease of his wealth of an amount equal to the travel/research³ costs supported (that keep on increasing step by step). To make our world as closer as possible to the real world, we assume that both firms and workers get out of the market if some conditions aren't satisfied.

```
ifelse unemployment_benefit [if work? = 0 [set wage (0.5 * NomWage)
ifelse ticks < 1 [set wealth (InitWealth + Wage)] [set wealth (wealth + Wage)]
if LifePoints < (- 5) [die]]]
[if LifePoints < 1 [die]]]
```

On workers' side, we allow for the possibility of receiving unemployment benefits from the government: if this is the case then each unemployed person receives half of the salary he would have received if he worked and "dies" later on (operationally, we reach this result allowing negative values of lifepoints), otherwise he dies as soon as his lifepoints reach the zero value. On firms' side, the same reasoning is applied and we talk about firm subvention that (if activated by means of the corresponding slider) can allow a

¹ we assume it to be lower than the workers' one (in particular, we suppose that generally people compute their work-leisure decisions "more easily" than the consumption one since an occupation allows to gain money, without which it would be impossible to consume)

² This is a reporter command.

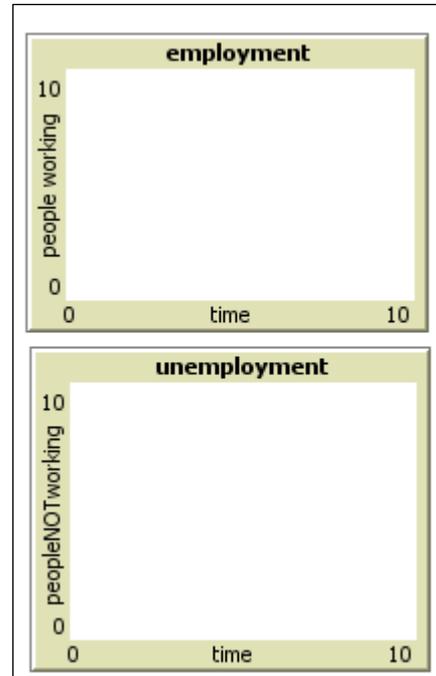
³ We assume them to be equal in our simulation but we allow for the possibility to change them arbitrarily thanks to the presence of the two corresponding sliders.

firm to survive for 12 ticks even if it doesn't sell any unit of goos to the public.

Finally, in order to have a graphical representation of how employment/unemployment behave along time, we make use of the “do-plots” procedure getting the following plots:

we realize graphs by counting how many people are unemployed (i.e. with work? 0) and how many people are regular work (i.e. with work? 1).

Moreover, in order to associate to each firm a label showing each tick how many workers are employed, we ask to each firm to create a label counting the number of workers that are exactly in the same position of the firm (in other terms, that have the same coordinates). We do this at the end of the “search-for-job-goods” procedure.



```
ask frms [set label count wrkers with [pxcor = [pxcor] of myself and pycor = [pycor] of myself]]
```

PHASE 1.

We introduce the diversification of firms in terms of the fixation of different nominal wages by adding the following “ask” in the “setup” procedure:

```
ask frms [if ycor >= 28 [set NomWage NomWageNORTH]
         if ycor < 28 [if ycor >= 14 [set NomWage NomWageCENTER]]
         if ycor < 14 [set NomWage NomWageSOUTH]]
```

We create three groups of firms,

North, Centre and South with different values of nominal wage (that can be changed arbitrarily during the simulation, thanks to the presence of the corresponding sliders), by using an “if” structure related to the y-coordinate of each firm.

In turns, we modify work-leisure decision:

```
ask wrkers [set FirmNearw count frms in-radius searching-radiusW with [NomWage >= [ReservSalary]of myself]
           set WhereIWork one-of frms in-radius searching-radiusW with [NomWage >= [ReservSalary]of myself]
           set NumberOfSellers count frms with [produce? = 1] in-radius searching-radiusC
```

each worker now chooses randomly one of the firms in his searching radius that offers a nominal wage greater or equal to their reservation salary⁴, that we set to be a random integer number between 5 and 29. Since here just nominal wage changes from firm to firm, this doesn't requires us to modify consumers' decision mechanism.

PHASE 2.

In order to introduce the technological progress, we proceed by adding the following "ask" to the "setup" procedure:

```
ask frms [set KNORTH random 25 if KNORTH < 15 [set KNORTH 15]
         set KCENTER random 15 if KCENTER < 10 [set KCENTER 10]
         set KSOUTH random 10 if KSOUTH = 0 [set KSOUTH 1 ]
         set N random-float 0.9]
```

"K" is a random constant which represents the technology. The higher it is, the better is the technology involved in the production: in particular we assume it to be high in the North of our world, lower in the South and at an intermediate level in the Centre. This modifies the production function that becomes: $Y = K * 6 * L$ and that now will change from firm to firm.

Worth of note is the construction of the cost function: we need it for the determination of price that now changes from firm to firm: We assume it to be of the following form: $TC = FC + (L*W)$,with the fixed component set for semplicity equal to 3 for all firms.

```
ask frms [if ycor >= 28 [set costs ( 3 + NomWageNORTH * count wrkers with [pxcor = [pxcor] of myself and pycor = [pycor] of myself] )]
         if ycor < 28 [if ycor >= 14 [set costs ( 3 + NomWageCENTER * count wrkers with [pxcor = [pxcor] of myself and pycor = [pycor] of myself] )]]
         if ycor < 14 [set costs ( 3 + NomWageSOUTH * count wrkers with [pxcor = [pxcor] of myself and pycor = [pycor] of myself] )]
```

Unit costs are calculated simply dividing total costs by the amount of units of good produced. It is then possible to reach our goal: each firm fixed its own price adding a mark-up, that we set for semplicity to be equal to all firms (with the possibility for the observer to change it throught the use of the corresponding slider), to the unitary cost supported.

In turns, wee need to modify both work-leisure and consumption decision mechanism:

4 We maintain this random way of computing choices in order to **avoid determinism** in our simulation.

```

ask wrkers [ifelse ticks < 1 [set FirmWearw count firms in-radius searching-radiusW with [NomWage >= [ReservSalary] of myself]
[set FirmWearw count firms in-radius searching-radiusW with [RealWage >= ([ReservSalary] of myself / MediumPrice)]]
ifelse ticks < 1 [set WhereIWork one-of firms in-radius searching-radiusW with [NomWage >= [ReservSalary] of myself]
[set WhereIWork one-of firms in-radius searching-radiusW with [RealWage >= ([ReservSalary] of myself / MediumPrice)]]]
ask wrkers [set IfICanBuy count firms in-radius searching-radiusC with [(price <= [wealth] of myself) and (price <= [ReservPrice] of myself) and (produce? = 1) or (stocks > 0)]
set WhereIBuy one-of firms in-radius searching-radiusC with [(price <= [wealth] of myself) and (price <= [ReservPrice] of myself) and (produce? = 1) or (stocks > 0)]]

```

workers choose randomly one of the firms in their radius that offer a real wage greater or equal to their reservation salary divided by the medium price and, all at once, they take their consumption decisions by choosing randomly one of the firms that are in the smaller consumer-searching-radius that produce or have available stocks and that sell the good (that has the same quality everywhere) at a price that is lower or equal than their wealth and in particular lower or equal than their reservation price (that we assume to be a random integer number from 5 to 39). This happens after the first tick since, to determine unitary cost (and then price), it is necessary to calculate the number of workers employed and it is possible only after having run the simulation once, with just the complication of different Nominal Wages taken into account, like in phase 1.

PHASE 3.

We create a *switcher* named "quality", in order to endow the observer with the power of introducing the further diversification of firms in terms of the quality of the good sold, by modifying the "produce" procedure in the following way:

```

ifelse quality [if ycor >= 28 [set production N * 6 * KNORTH * NumWorkers]
if ycor < 28 [if ycor >= 14 [set production N * 6 * KCENTER * NumWorkers]]
if ycor < 14 [set production N * 6 * KSOUTH * NumWorkers]]
[if ycor >= 28 [set production 6 * KNORTH * NumWorkers]
if ycor < 28 [if ycor >= 14 [set production 1 * KCENTER * NumWorkers]]
if ycor < 14 [set production 6 * KSOUTH * NumWorkers]]]

```

N is a random floating number between 0.1 and 0.8 and it represents quality: the closer it is to 0.1, the higher is the quality provided.

In order to take into account our assumption that consumers are perfectly informed about the level of quality of the good purchased, we discount (in the consumption-choice procedure) the reservation price for quality indicator.

THE RESULTS.

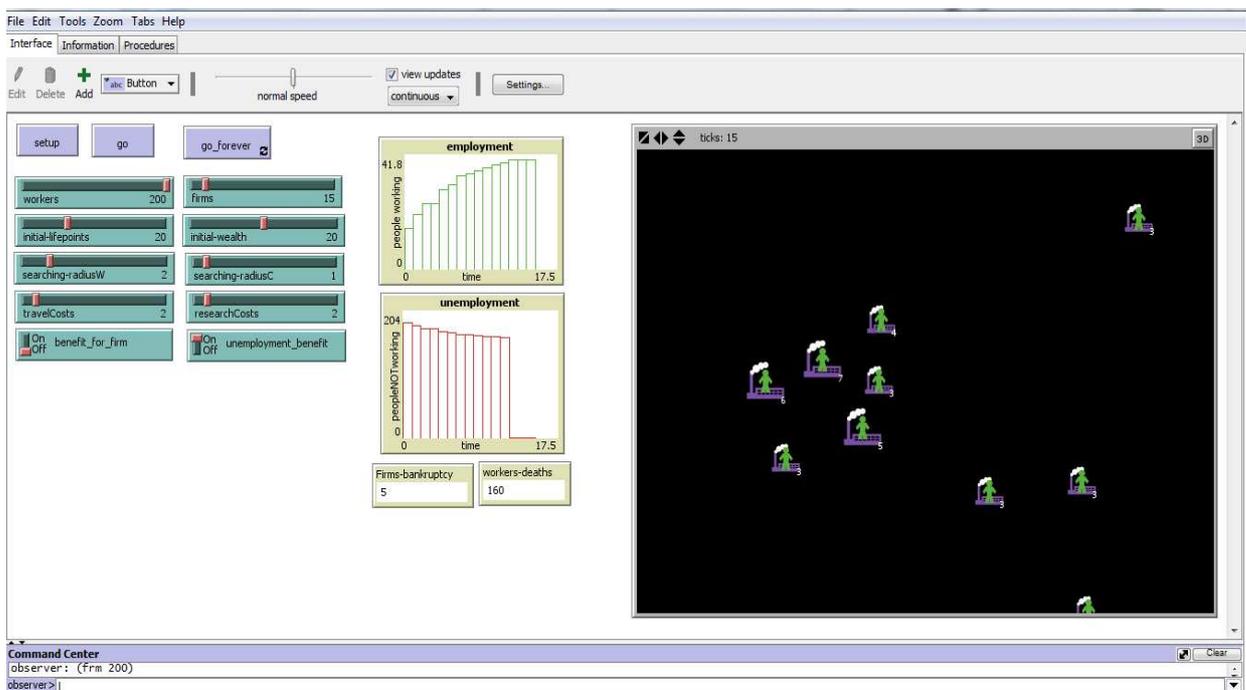
Running the simulation several times, each with different combinations of the main variables of interest, it is possible to make some observation over each phase of our model and then to make a comparison between all the observations collected.

PHASE 0.

Situation A: 200 workers and 15 firms.

1) searching-radius $W=2$; searching-radius $C=1$; firms don't receive any subvention.

It is possible to note that our economy reaches an equilibrium at the tick n°12, with just 5 firms that fall in bankruptcy (and that are then forced stop their business exiting the market) and a very high number of workers (more or less $\frac{3}{4}$ of the total amount) that "die" despite the unemployment benefits: this can be due to the very high number of people available and in search of an occupation and of a good to purchase with respect to the number of firms. If at the beginning of the simulation someone is far from all firms it takes to him many steps before reaching them: then travel/research costs increase and lifepoints decrease, though causing his "death". Moreover, we can note that in equilibrium we have clusters of big firms (this reminds us the concept of "industrial district"): this can be explained by the fact that being closer to other firm is a big advantage in a situation in which the searching-radius aren't so big since who works in another firm can choose to buy from my firm and viceversa, creating a continuous exchange of workers/consumers between the firms belonging to the district. Finally, by looking at the plots it is possible to note how employment increases gradually till stabilizing when equilibrium is reached.



2) searching-radiusW=10, searching-radiusC=9; firms receive subventions.

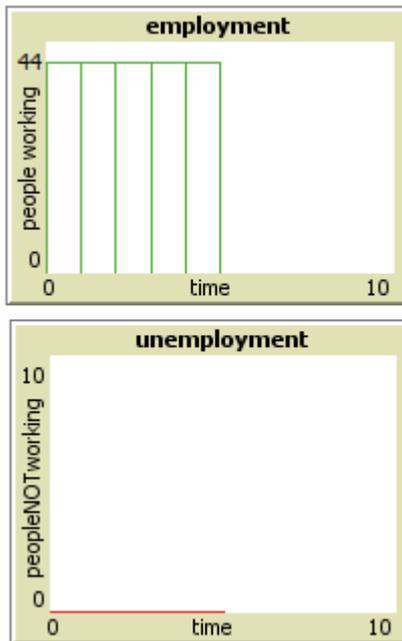
We can observe an equilibrium situation in which any firm doesn't fail and only 7 over 200 people "die": on firms side, this can be explained by the presence of subventions from the government that, buying goods from firms that don't sell to the market till tick n°12 (in which equilibrium is reached), prevents several firms from the bankruptcy. On people's side, this can be explained by the presence of a very large searching-radius: since it captures a high number of firms, it will be more easy for a person to find a firm in the radius that satisfies at the same time both work-leisure and consumption conditions. Another observation worth of attention is the fact that in equilibrium we've very big firms (signal of a high number of pieces sold) with many workers⁵ employed that are placed all around the space (no clusters are formed): this can depend on the fact that with a searching-radius very large, firms don't need to be close one to another to gain advantage from the exchange of workers/consumers since they can have a very big business just relying upon the number of workers employed (very high), that in turns corresponds to the number of customers. Finally, by looking at the plots it is possible to note how employment increases gradually till stabilizing when equilibrium is reached.

Situation B: 40 workers and 120 firms.

⁵ By looking at the command centre it is possible to know which is the firm that employees more and, by detaching it, it is possible to know how many workers are actually employed.

Searching-radius $W=10$, searching-radius $C=9$; firms receive subventions.

It is possible to note two main differences with respect to the analogous case in situation A: unemployment goes to zero immediately (and then, the equilibrium is immediately reached) and we can observe the formation of clusters of firms.



On unemployment side, this can be explained with the low number of workers compared with the number of firms in the market: it is reasonable to think that each person has several firms in his large searching-radius at the beginning of the simulation and that then, as soon as the simulation starts, they immediately find where to work and where to purchase. As regard as the presence of clusters, we can justify it with the low number of workers in the market: each firm takes advantage from being part of an industrial district since it needs to participate to the exchange activity in order

to employ more (then to produce more) and to sell more, increasing its business and then its size.

PHASE 1.

Situation A: 200 workers and 15 firms.

1) searching-radius $W=2$; searching-radius $C=1$; firms receive subventions.

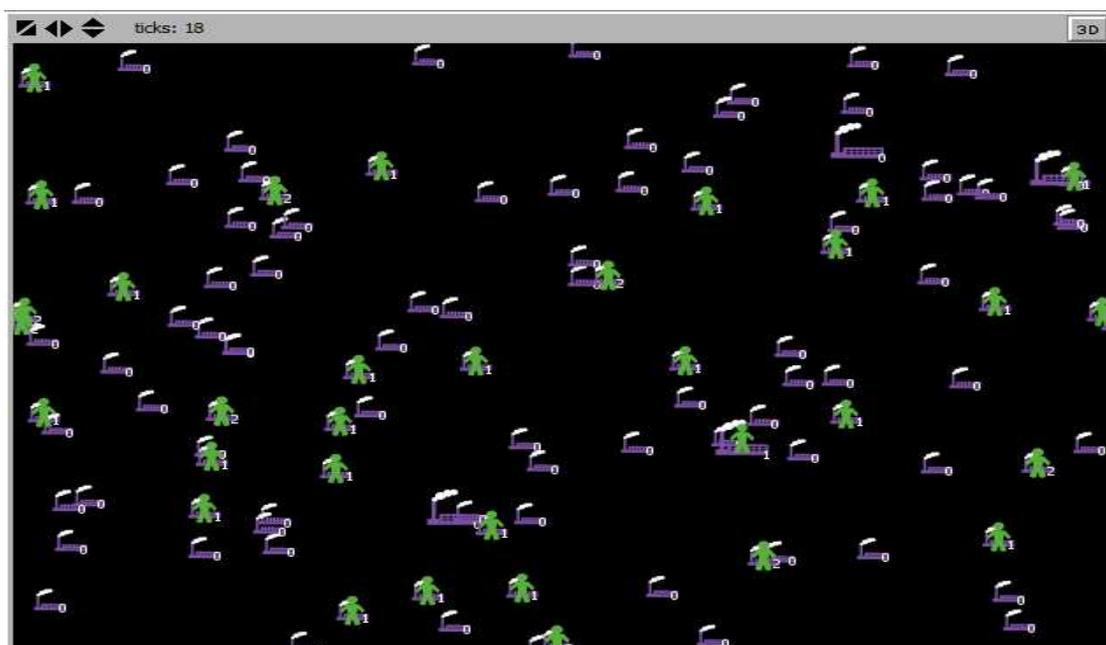
It is possible to note that the addition of the complication of different nominal wages delays the achievement of the equilibrium, that is reached at the tick n°26: this can be due to the presence of a reservation salary that complicates work-leisure decision mechanism. Moreover, it can be interesting to note that we end up with an equilibrium situation in which the biggest firms are in the South of our world: this is an unexpected result that can be explained by the fact that the majority of workers are in the South at the beginning of the simulation and have a reservation salary (remember: it is randomly determined) compatible with the nominal wage offered by the firms belonging to the South of our economy. They choose to work here even

if the nominal wage offered in the North is much higher because moving from the South to the North would be too costly.

Situation B: 40 workers and 120 firms.

Searching-radius $W=10$, searching-radius $C=9$; firms receive subventions.

It is possible to note two main differences with respect to the analogous case in phase 0. Firstly, unemployment goes to zero gradually: this can be explained by the fact that in this phase, with nominal wage that varies from firm to firm, work-leisure decision mechanism is complicated by the presence of the reservation salary and then, despite the large searching-radius, it takes more time to workers to find firms that satisfy at the same time both their work-leisure and consumption conditions. Secondly, in equilibrium we don't observe clusters of firms: in particular we can note how the firms that sell more and employ more are placed in the North of our economy. This is an expected result (differently from what we have found in the situation above) that can be linked to the higher nominal wages offered in this region. Moreover, we can observe the presence of several firms with zero workers but with a high number of pieces sold (again, we can verify it by looking at their dimensions): this can be related to the creation of a great warehouse (that allows to sell units of goods even if in that particular moment the production is null) and to the fact that, since searching radius are so big that embrace many firms and then people keep on moving from a firm to another in the radius, sooner or later some worker will choose to work in the mentioned firms allowing the production to start again.



PHASE 2.

Situation B: 40 workers and 120 firms; Searching-radius $W=2$, searching-radius $C=1$;

1) firms receive subventions.

It is possible to note that our economy reaches an equilibrium at the tick n°43, with an unexpected high number of failed firms (in particular 94 over 120 firms): this can be explained by the presence of a reservation salary divided by a medium price that further complicates work-leisure decision mechanism and by the presence of a reservation price that complicates consumption decision mechanism. Moreover, it can be observed an equilibrium situation balanced between the North and the South of the world and with industrial districts (again, this can be explained with the advantage deriving from the continuous exchange of workers/consumers from firms belonging to the same group) but all composed by firms that sell less than 3 pieces: again, this can be linked to the presence of the reservation price.

2) firms don't receive any subvention.

It can be observed an equilibrium economy with no clusters.

Moreover, by looking at the behaviour of employment over time, we can surprisingly note that at tick n°38 it reaches its highest pick and then drops down immediately: this can be linked to the fact that in that particular moment despite some workers are employed, they may not find any firm in the radius to which they are willing to buy goods (since prices are re-set tick by tick, it's possible that in this particular tick all firms in the radius fix a price that's greater than consumers' reservation price) and then they have to move in search for a new occupation, becoming (hopefully temporarily) unemployed.

PHASE 3.

Situation A: 200 workers and 15 firms; searching-radius $W=2$; searching-radius $C=1$; firms receive subventions.

It is possible to observe an equilibrium situation with no clusters of firms. In particular, the first firm with the higher number of workers employed and of pieces sold is placed in the North of our world, the second in the Centre but they produce goods with low quality: this can be explained by the fact that, despite consumers well know the level of quality offered by each firm, maybe

it isn't convenient for them to support further research costs in order to seek for a firm which sells goods with higher quality since the value associated to the extra quality they would get is lower than the value associated to the extra costs they would have to face. In other terms, in a situation with small searching-radius the quality factor seems not to strongly affect consumers decision mechanism.

Situation B: 40 workers and 120 firms.

Searching-radius $W=10$, searching-radius $C=9$; firms don't receive any subvention.

It is possible to observe an equilibrium situation in which there are no industrial districts. In particular, the firms with the highest number of workers employed and of pieces sold are again placed in the North of our world but, differently from the situation above, this firms produces goods with high quality: this can be explained by the fact that, having a large searching-radius that embraces many firms, consumers can easily choose to purchase goods with high quality without having to support any research cost. In other terms, the presence of large searching-radius favours the research of quality.

