UNIVERSITA' di TORINO

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UNIONS-FIRMS INTERACTION:
an agent-based model using genetic algorithms

Tesi di Laurea in Simulation Models for Economics

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1 Introduction

The researches about troubled relationship between unions and firms are quite frequent, but it can be anyway useful to take a deep look into them in a new perspective, by going into details for its effects on the labour market and its related employment rate.

There are many studies focused on unions – firms bargaining, based on how they behave to maximize their own utilities, the majority of these researches look at the internal functioning mechanism, that is how unions and firms act, by keeping them quite often separately. Our idea starts exactly from that point, we link this thesis with the common view of such a relationship; moreover, we try to add up a new element, we are interested in detecting the specific consequences of these bargains over the employment rate. Basically, we suppose a sort of causal effect between the nature of unions – firms relationships and the employment rate, our insight grounds exactly in this statement, we claim a strong relevance for the quality of those relations on the hiring rate.

We did not find out a new approach for the labour market at all, we have just tried to study its way of working (observable into the employment rate) as aftermath of the complicated relations between its two main agents: unions and firms. Let us be clearer by saying that we hypothesised to spot into this kind of relationships the key for the employment rate fluctuations.

We have decided to properly analyse this topic because of its key aftermaths over the economy functioning, since the labour market works through its own agents actions and not without any rule, we have in mind to try to convey you as much as we will able that there could be a feasible and implementable path to reach a better steady state.

The first reason for which we have opted for studying this item is the controversial game of blames, on average there is no part (like unions, employers and the State as intermediary) willing to admit if it was wrong; we move from a

system within which it is unlikely to find real development, it is due to hurdles in the dialogue. We are spur by a broader idea, we think the unions – firms relationship to be not well functioning, it could work more fluently thanks to more active agents, where these exploit their actions altogether and with a different aim.
From this point of view we have started our research, it has been developed with the use of two software, whose way of working is compulsory for the whole project: firstly with NetLogo we have figured out the settings for our simulation model, inside through all the commands emerges the overall principle that should regulate these kinds of relationships; secondly, with BehaviorSearch we have investigated how the best outcome can be achieved, given the NetLogo codes.
The major part of the thesis deals with the analysis of the relationships involving unions and firms, they are the main agents of the simulation model, there are even workers, but they do not have an active role, in fact they move accordingly to unions decisions. We could split the whole work in two areas:

1. *unions side*: we take a look into the choices of trade unions, we have spent many words on their role, how they currently act, what is their relative impact on the employment rate and we have proposed our view for fulfilling with their tasks;
2. *firms side*: we have analysed their decisions, how these are actually made and we have inserted our viewpoint on how they should behave.

We have compared how both agents behave nowadays, by quoting recent papers, and what is our idea of sane relation, mainly through our codes and results (obtained with NetLogo and BehaviorSearch) we have been able to let you notice the path that should be undertaken to reach the highest common goal: a greater employment rate.
Let us emphasize the mean benefit of those software: with NetLogo we have

defined the framework, that according to us can lead to the best scenario; with BehaviorSearch we have looked for the settings needed to achieve the best.
To say differently, with the agents based model and the support of genetic algorithms we have proposed an improvement for the labour market, we have highlighted which has to be the pattern and how its agents should act.
We have coped with these economic mechanisms by adopting a quite clear structure, let us state you in advance its pillars:

a) *literature section*, it stands for the longest part, inside it we have developed our own insight of those complicated links amongst companies and unions, both agents have been endowed with our view of their role and, above all, how they act to perform better. To let you make a basic idea of it we can tell you that: firms in this simulation model are asked at deciding for workers' involvement degree, innovation level, production amount and hiring-rate; on the other side, unions have to settle a flexibility value towards innovation. All those listed actions (represented in NetLogo with specific commands) overlap, that means they are taken in sequence and they affect with each other. Let us add that we did not so build up the model randomly, we have set it up in this way to constrain them, they are going to act by noticing what has been previously decided by the other agent; this kind of structure has enabled us to apply our main principle: both unions and firms must behave accordingly to a common purpose, if they want to get more from these labour market relationships they have to follow a precise path, inside which they are no more egoistic. Once more, the NetLogo software feature allowed us to perfectly work out our idea of economic links between those agents, they can obtain more for their own goals, but it can be done just by being altruistic, rational and competitive;
b) *NetLogo comments*, in this section you are going to find how

NetLogo works, in fact we have firstly described what the commands mean, that is we have described their meaning, secondly we have deepened why we have so built it up. All the codes are analysed according to their role, all of them belong either to firms or to unions and through these commands they interact; to better make you understand we have enriched the pure description with charts, where there is a broader view for the parameters flows. This second section has been thought to explain you how we have created it, that means what the codes stand for, and second via this description it can be easier conveyed you the essence of the model itself; all commands here described represent proper actions of both unions and agents, in fact all their moves can be gathered in our own agents codes;

c) *BehaviorSearch results with genetic algorithms*, while the previous section settled the framework within which the agents take action, in this third one we look at the learning. This concept is maybe the most engaging and outstanding side of the thesis: via a learning process of the model we have tried to know more about it, we were aiming at outlining the way in which it behaves. The software used here is BehaviorSearch, to make it purposeful for our research we have adopted the genetic algorithms, by them we have looked for the model functioning and in fact in this part we have performed searches on the simulation behaviour. Let us make it clearer, BehaviorSearch finds out the parameters optimal values to maximize an objective function (or a single parameter that we want to analyse, it will be called *measure*) given certain assumptions;

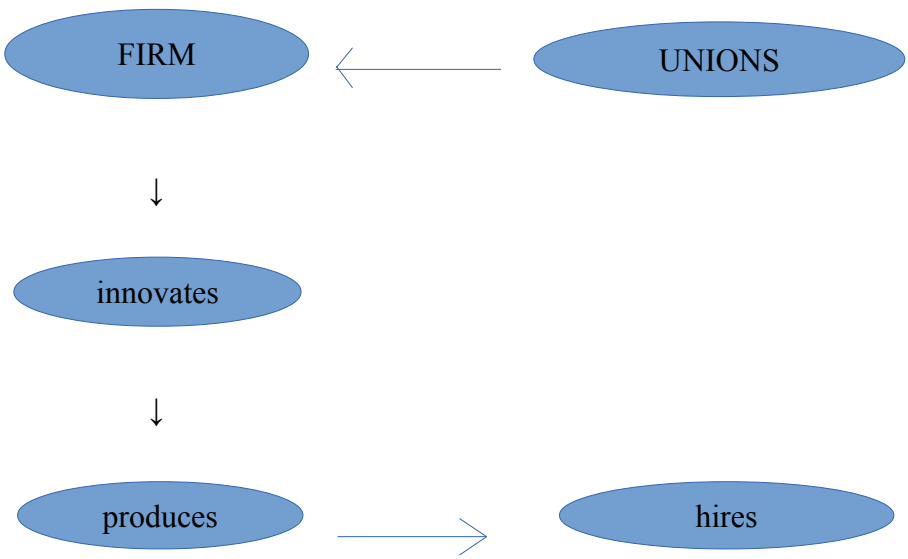
d) *model key points in results versus recent events*, in this part we have compared the current labour market, by quoting papers and other recent sources, with our proposal. All this section grounds on the gaps between how unions and firms interact nowadays and what improvement can be inserted to develop the market itself, this comes from our agent based simulation model and BehaviorSearch

outcomes. By noticing their difference and to make arise our items we have supported them with charts, they explain what is the path to achieve a richer functioning of the unions – firms relationship;

e) *appendix*, this is the last section of our thesis, we have commented broadly our results, from where we have started and what we have obtained. We have concluded the whole research by stating firmly our own ideas, according to which a better labour market is feasible and it can be implementable with more awareness. In the end we have proposed some future developments of this, that could make emerge other solutions to improve these relationships.

2 Preview

The main goal is to reproduce the system of relationships between firms and trade unions (deals and bargains). The ideal effect of this simulation is to get a continuous flow of positive interdependence between the two agents (unions and firms), as in the following representation:

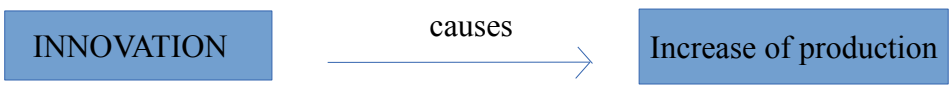


In the scheme above the sequence is: unions allow the firm to freely innovate, to increase production and as final outcome to hire more workers; this is the direction towards which we are going to lead the agents through the commands we are going to give them.

Let us begin from a system within which a union opposing to the innovation does not allow the firm to increase the production level and so of hiring more workers (or even "to fully exploit its own employees"). The lack of flexibility hinders development and employment growth; we cannot just blame the union, but, we should take into account even the firm fault: in a context in which the employees

are just seen as “inputs” the trade union has no interest to enable new investment projects, since the adoption of new technologies could have the outcome of making lose jobs and of enhancing the number of worked hours; an employee more involved (through bonuses, shares and executive decisions) gives the chance to the union (representing the worker) of being more willing of the innovation. If the worker is involved she has the possibility of assessing if the investment projects are “feasible” and so she can give her consent to the innovation changes.

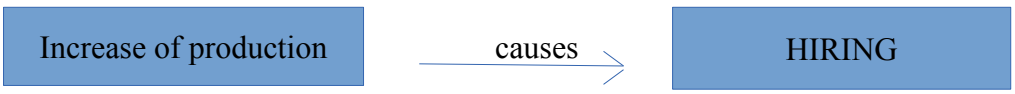
With innovation we refer to both productive process and of product: a platform equipped with the more innovative technologies grants to the firm of being competitive into the market with modern products complying with the request of consumers. The main outcome of an innovation change leads to more production; the effects chain that we try to represent for what concerns this intermediate step is: if the firm innovates its production line it can be more competitive by launching more technologically advanced products and by being more successful in terms of sales. That means the demand for that firm will be higher (thanks to the more desirable commodities) and it will be necessary to increase the production to fulfil the excess of demand by the customers. The causal effect is the following:



Where innovation takes place the production line keeps up with the new consumers' product requests, that means: firms adapt their factories with modern lines to be able to produce new products and in so doing to launch in the market new products. In this perspective we underline the causal effect between production process and product, the former causes the latter: innovation of commodities is possible just if an investment of production has been previously done.

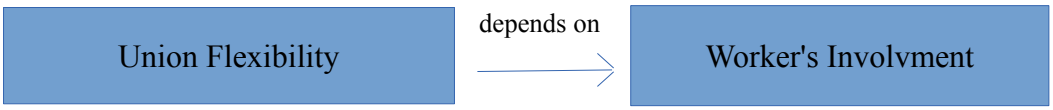
As a natural aftermath, more production would require more workers to be able to

produce that excess of products demand requested by the market; to this extent let us split between two possibilities: 1. the firm fully "exploits" its own employees by slumping to zero the number of hours of "wages guarantee fund", all workers will be engaged for the whole working day; 2. the firm needs to hire people out of the labour force since the current number of employees is not sufficient, by giving a contribute to the overall drop of the unemployment rate.
The relationship is given by:



This two causal effects are possible if and only if there is a collaborative trade union, that means a union signing all the deals; for the company it is possible to innovate, to produce more and to hire just if the union agrees with the innovation plans, otherwise there would be opposite effects: no innovation, less production more unemployed.
What we want to underline is the crucial role played by the union to make it possible; if the union is flexible to the implementation of such as changes all the previous passages are performed by the firm, the more the union is flexible the more innovation is worked out.
The degree of flexibility is not given by chance, but it is the aftermath of a precise behaviour of the firm: if the firm involves the employee in the daily life decisions of the company the worker feels to be part of the industrial activities and so the union (representing the worker) gives the consent to innovate.
The meaning of this sequential effect is: if the worker is involved she can oversee to the "feasibility" of the innovation projects and so to be convinced of their implementation, it makes the union glad of signing the agreement, it implies that a more involved worker will enhance the flexibility of the trade union.

Schematically:



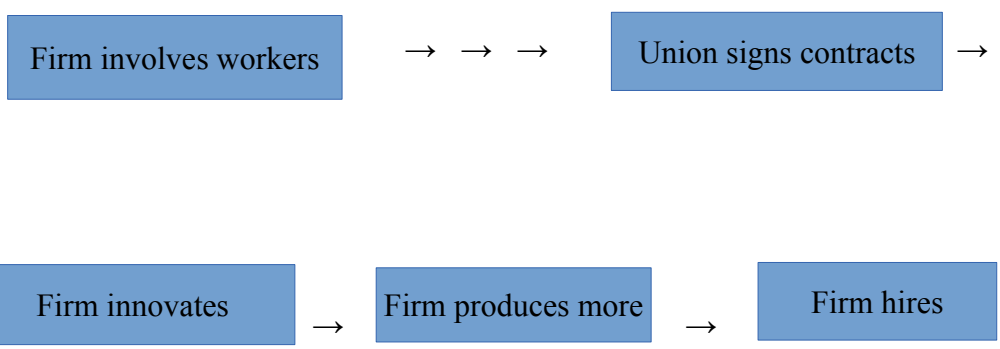
We are going to begin from a system within which nothing of the framework above happens, the starting point will be a “broken functioning” between union and firm, where the firm does not properly involve the worker and so the union disagrees over the innovation plans, the natural outcome is a block in the assumptions and an increase in the unemployment rate.

Essentially we start by representing the Italian labour market, the lack of a larger view from both sides (union and firm) does not enable for a development into the relationships between them.

Through a series of commands, in this simulation project, we are going to look for a representation of the relationship between trade unions and firm in an ideal context, where the goal is to get a company that hires and a union that “signs all the contracts” by guaranteeing innovation in the productive process.

A comparison can be done with the German labour market, where the workers are more active in running the company and the union are used to setting up “more collaborative dialogues” with the firm, for what regards innovation.

The chain of cause/effect that we are going to set out in the project, with agents interacting as a function of the others' movements, is:



The key outcome of these causal effects is a drop in the unemployment rate, if all the previous events take place there is the possibility for both the union and the firm to give a strong contribute to soar the number of workers in the labour market.

The purpose is to have unions that agree on all the investment projects and firms willing to hire; to achieve such an aim both the trade unions and the firms learn from their own mistakes: the union learns that if "it doesn't sign any agreement" the number of employed workers slumps (since there is no room for innovation); on the other side, the firm learns that if it does not try to involve more the workers into the company daily life they tend to be less attached to the firm context and the union does not give the consent for innovating.

Via a learning process, both the unions and the firm reach a situation inside which the request of the counterpart are always well accepted, in other words: the firm always involves the workers (since it has noticed that just in this way the unions are more flexible to innovation settings); the trade union always "subscribes" the contracts (because it has learnt that just in such a way the firm can innovate, produce and then hire).

A "border" situation would be represented by a company always involving its employees into the managerial decisions, so they play an active role inside and thus they choose to stay out from any union, they do not want to be labelled with any trade union association. In this framework the union would not have any role in the relationship "worker – firm"; here the company can innovate freely, with no constraints, soar the production and to hire who is unemployed, by giving evidence of an overall drop in the unemployment rate. The basic idea is that if workers are fairly treated by the firm ownership and executives (that means the employees are not deprived of any right, such as payroll, worked hours, work health conditions and so on) they do not feel the necessity of being associated with a trade union since they do not miss anything, the result is that unions are not needed in this context because the relationship between worker and employee works perfectly.

Let us stress this point more clearly, that situation requires that all the worker rights (and desires) are met by the firm; it means that the employee enjoys of:

bonuses linked with performance, a percentage of the company shares, to be part of the executive decisions. If these conditions are respected the employee has all what she wants to receive by the firm and so she doesn't need to be a member of the union: unions are “out of the firm”. Once again, this is just an extreme case, we are going to take into account even of this but, the core of the project will be another one: the focus is just on the involvement of the worker into the firm decisions.

It means that we put aside all the other rights, by concentrating just on that aspect, so even if the worker is altogether involved the union “will be still in the firm”; since there can be a lack of the other rights (such as bonuses and shares). For these reasons the firm is still needed by the worker.

A firm worker enrols in a union representation just to see fully applied her own rights, it implies that the firm is not fairly behaving with its employees, in our case the lack of the firm is the involvement of the workers in the executive decisions, perceived by the employee as a needed right, for this reason the worker decides to be part of a union to be much more taken into account by the company management.

Learning process resume

If the union does not sign the firm cannot innovate, it does not increase the production and it does not hire, rather, it is forced to fire the workers (or even to adopt “wages guarantee fund”).

The trade union notices this and it learns that it is necessary (and even useful) to stand up for new investment projects to avoid lay off and, instead, to make increase the employment level. The probability that the union is more flexible enhances with the reduction of the number of employed workers: the more the union realizes that the unemployment rate goes up (due to hurdles to innovation of union) the more it understands that it is necessary to bolster innovation.

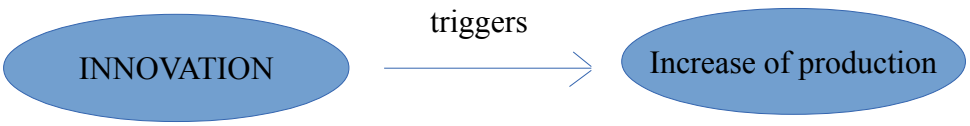
Likewise for the firms: the probability that the firm involves the workers into executive decisions gets higher with the decrease of union flexibility (that would grant more innovation, more production and so more profits); if the company notices that, with workers totally out of the firm management, the unions do not sign the deals, the innovation does not take place, the production goes down and the profits too, therefore the firm involves more the workers for having unions more flexible.

3 ANALYSIS: *literature part*

3.1 Section 1

Does innovation trigger production rises?

The first step that we are going to deepen regards the positive aftermath of innovation over the production level, that stands for the primary effect of innovation (then finishing with more hiring):



In the highly competitive markets firms decide to set up innovation plans to increase their own market share. With innovation we refer, first of all, of productive process: firms invest large slices of their profits to update their production lines, this occurs to produce new kinds of products. Firstly it is needed to change the structure of the factories, machineries have to be modified in order to create new goods.

An intermediate step for the relationship "innovation causing production increase" is the productivity: innovative products (coming from innovation of productive process) give the chance to the firm to be more competitive in the market; furthermore when the management of a company decides to update its factories it has in mind to widen the action ray over the customers. It stands for the will of the firm to reduce the costs and increase the power of its products.

Many authors have studied the link between innovation and productivity, in particular by using productivity as an innovation indicator as done by Hall (2011) in a recent publication "*Using productivity growth as an innovation indicator"*.

The scholar notices how the level of productivity for a firm can be measured by

the innovation changes implemented by the executive members. That means if a firm always tries to innovate and to adapt (to the new market challenges) its processes and its products there may be a clear and positive effect on the growth of productivity. Hall (2011) highlights that even if there is not a unique definition for both innovation and productivity, the link hypothesised is the following: the observable benefit of innovation projects results on increased prices, mainly due to a higher slice of the market. We always start with innovation in productive process, otherwise it would be impossible to build up new featured products; in this perspective commodities have been empowered with new qualitative characteristics satisfying more the final customer. The point here needs to be deeply understood: for a company is extremely necessary to innovate, because this is the only way to supply into the market new goods complying with the different tastes of individuals. Since people needs are inserted into an ongoing changing process the companies have the continuous urgency of moving together with these rapid changes.

Innovative products, answering to the "always – new" demands of customers, are seen by entrepreneurs as one of the few ways to grant themselves positive profits; since, these newly featured commodities, meeting the customer requirements, are more attractable and so sales may enhance; the consequence is a higher market share for the firm in the industry field in which it operates and even higher profits. As properly highlighted by Hall (2011) innovation of products guarantees to the firm of having a positive impact on both price and quantity, in other words, firms betting on innovative products enjoy of a double effect: they will sell their final commodity at a higher price and even a grater quantity. The former is justified by the qualities of these new created goods, since they are more highly featured they will have to be sold at a less competitive price; the latter comes from the satisfaction generated by these new products, mainly due to their level of components, closer to the final consumer, this will get more satisfaction by "more user-friendly goods". The overall outcome of innovation on productivity is positive according to Hall's analysis, even if he wants to claim a key distinction among innovations:

1. creation of entirely new goods;
2. improvements of already existing products.

With this gap Hall (2011) notices how it is impossible to have two equal innovations, to support his statement he gives us the example of the telephone and the telegraph: they are two amazing innovations having completely affected our own daily life, they are similar in a sort of way but they stay on different.
An interesting contribute on this topic has been recently released by "The Economist" in the article "Has the ideas machine broken down?" on the 12th of January 2013; the core of the item are the today innovations, totally deprived of the revolutionary connotation that we are used to giving them. Over the current role of the innovation many entrepreneurs have been interviewed, one of this is Peter Thiel, founder of PayPal, he pointed out the huge difference between the recent innovative products/services and the past ones (of the beginning of last century), he talked about the new technological discoveries as "something between dire straits and dead".
The article continues by reporting the general thought of several economists, agreeing on the remarkable gap between today innovations and past ones, where the former ones have been defined as pale with respect to the latter ones.
"The Economist" splits the concept of growth (ensured by innovation) in two categories:

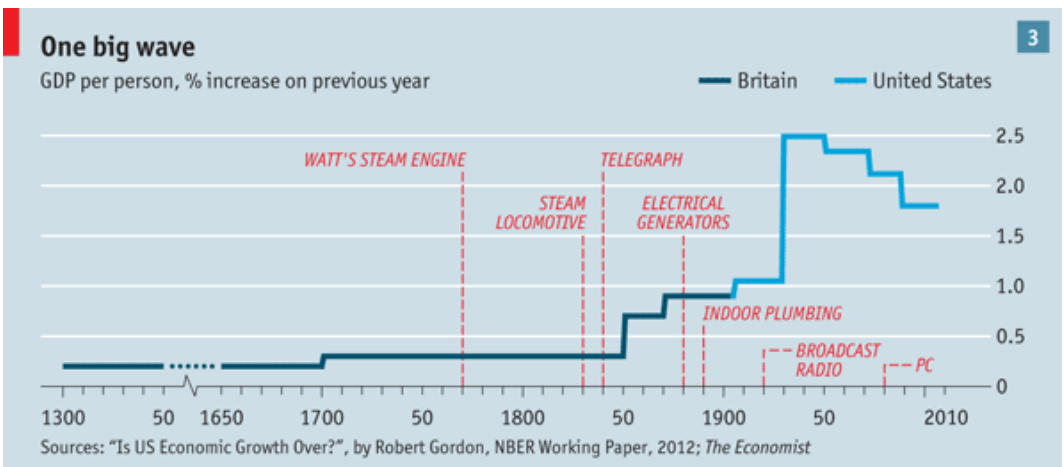
- extensive: this kind just adds something to labour, capital and resources;
- intensive: this type introduces better ways to use workers and resources.

We could label these two views of the growth with two eras: today is more featured by extensive growth, where innovations born every day but they just show us minimal improvements of past ideas; the past, instead, was closer to intensive growth, where some products had not origin from pre existing goods.
The period analysed by the economic journal goes from the 14th century until

today, the most prolific segment of time have been spotted between 1770 and 1980: Watt's steam engine (1770), steam locomotive (1830), telegraph (1840), electrical generators (1880), indoor plumbing (1890), broadcast radio (1920), pc (1980), just to quote some of them.

What "The Economist" outlined is the impossible comparison between the utility of certain current innovations, compared to the old ones; to briefly resume the content of the article we could say that what is built up (and so "invented") now is just a ramification of the initial brilliant ideas taken place in the past centuries.

Below the image of this evolutionary path:



There are some tracks of this line of reasoning even in Hall's researches, the author reports the main results of Acs and Audretsch (1990) by noticing that during 1982 the 85% of analysed innovations (acted by the companies of their sample) was just an improvement of existing products. This means that more than 8 firms over 10 preferred to further develop their current commodities instead of creating new ones.

At this point we would hint at both innovative production processes and of products, all those firms decided to bet on the goods already competing into the market (just by equipping them with new components/features) rather than

building something of new. This is the necessary bridge linking innovations of process and of product: if those companies had innovated their own productive lines they would have supplied innovative products too.
To be precise as possible let us convey such a stand point: according to the scholars mentioned above 8 firms over 10 improved just the existing products, this result underlines the lack of those entrepreneurs in investing, first of all, on the productive process (and as an aftermath on product).
To conclude this reasoning let us say that with the improvement of something already existing the firm ownership could exploit the same production process, that stands for the modifications of the factory are the basis over which the overall innovation is grounded.
Hall continues by looking into the innovation role even beyond, by agreeing over the "innovation measurement" with the current surveys, where it is measured in two ways:

1. whether the firm has innovated in the last three years, both of process and of product;
2. in what percentage the firm sales are directly due to those innovations.

Companies are listed over their propensity to innovate if and only if they applied such changes in the last three years (that means by taking into account just the short run) and if these newly added features are worth, so if they produced positive effect on the company market share.
This second characteristic given by Hall to the innovation lets us underpin a similar item deepened at the beginning of this section: one of the main goal towards which companies management wants to move is to get a higher market share to keep on ensuring themselves positive profits, new innovative goods are the key access for firms to generate more revenues, it lies even at the basis of Hall's thought.
To come back at the relationship "innovation – productivity" it is highly relevant to explain that link, to understand why more innovation sparks more productivity;

the 4th part of Hall's paper provides a microeconomic definition of that: productivity is the amount of output produced with a given level of inputs, by so knowing we can define the influence of innovation as the production of (the same level of) output with less inputs.

These few words clarify perfectly our notion of "innovation benefits" over the productivity level, if the company board opts for investing on innovation changes needed to hardly compete into the market the first emerging outcome is observable into the proportion "inputs – outputs". This last statement satisfies the core of the innovation definition: with updated factories the (same level of output) can be produced with less inputs, this would imply less costs for the firm; innovation would lead companies to a remarkable save of money, to purchase inputs, all guaranteed thanks to more productive processes (exploiting at most the margins of profits, essentially by lowering costs).

Hall finishes this section dedicated to "innovation – productivity" relationship by observing the same topic under a microeconomics perspective, that is the production function of a generic company:

$$Q = A\, C^{\alpha}\, L^{\beta}$$

where Q is the output produced by the firm, C is the capital level, L measures the labour force and A is the productivity level (varying throughout the firms). As usual, output level depends upon capital and labour; it could be quite restrictive to analyse just the impact of two inputs over the output, but in this analysis Burt rules out all the other possible inputs, like for instance the human capital (that is the core of the analysis for economic sociologist).

It is remarkable to point out how companies with the same levels of C and L could have different levels of output because of diverse levels of productivity. This remark is outstanding from our point of view, it underlines the potential effect of the productivity over the output, the causal relationship is strictly positive: a company more productive than its direct rivals will be able to produce more output at the same quantity levels of labour and capital stock. That would mean to be able to supply more output into the market by making larger the overall sales.

We can fully converge towards one of the main positive outcomes of productivity (that is empirically explained by the production function of above): the gap in output can be easily noticed even in the same firm context, it means that if we are willing to suppose that A > 0, at parity level of inputs a firm featured by more productivity would increase its output with respect to the condition in which it had not enhanced its productive level. This is the strongest result since with productivity at the next level a firm can get more with the same expenditure efforts. Moreover, if we deal with technological companies we will notice a drop in the costs too, so we would have a doubly positive aftermath.
To further show up this positive effect Hall's improves the production function of above by inserting the innovation variable:

$$Q = A\, C^{\alpha}\, L^{\beta}\, K^{\gamma}$$

where K captures the innovation ability of the firm; by letting us put together all what noticed so far we may argue that:

" the production function of a company does not strongly depend only on the usual inputs, such capital stock and labour force, but even on the productivity level and innovation changes"

We could update Hall's point of view with a light difference, in which we can try to link implicitly *A* and *K,* in particular let us put in these terms:

$$Q = f\,(A(K^{\gamma})\, C^{\alpha}, A(K^{\gamma})\, L^{\beta}, K^{\gamma})$$

We have added up the following modifications:

- both C and L levels can be increased by more productivity, we might have higher performances in terms of capital use and labourers if there is more productivity; we do not just look into C and L as fixed variables, rather, as variables whose levels can be

directly increased/decreased by more /less productivity;

- A, the productivity level, depends on the innovation changes, that means higher levels of productivity are ensured just if innovative plans are set up; otherwise with no new platforms it is unlikely to enhance the productivity of the firm and no updates would be followed by less productivity directly impacting on inputs levels;
- K, the innovation capability, is the root of the changes in the production function; all the increases and drops begin from the innovation.

The main core of this equality is represented by the influence of innovation over the output level of the firm.

What done by Hall is fully consistent with the influence of the innovation over the production level (by passing through productivity), but we may add up one more feature, characterising the ***evolution*** of this positive impact, since these two variables (operating into the production function of the firm) evolve over the time. What we modify with respect to the Hall's production function is to get in the "time" variable, by attaching all the variables with their changes year by year:

$$Q_t = f(A_t(K^{\gamma}_{t-1})\, C^{\alpha},\, A_t(K^{\gamma}_{t-1})\; L^{\beta},\, K^{\gamma}_{t-1})$$

Remarks:

- yearly level of output strongly depends upon the levels of innovation and productivity; upon the level of innovation made the year before and upon the productivity of the current year, at its turn deriving from the innovation of $t - 1$;
- we suppose a gap of 1 year between the implementation of the innovation changes both in platforms structure and of new products with the "observable" results in terms of productivity; it is evident in this

intermediate passage how innovation improvements affect output level via optimization of the productivity; it may seem reductive just 1 year of distance between works to update factories/products and immediate effects on productivity, since in the reality before seeing these outcomes it takes several years;

- we have maintained the yearly effect of productivity over inputs C and L, the enhanced productivity (once again due to innovations) produces positive influence over labour and capital within the same year; in this setting we have taken C and L as <u>exogenous</u>, we are not interested in varying them, we just focus on how they are affected by more/less productivity, their level may change just because of different levels of productivity and not due to their own internal changes (of C and L);
- to distinguish we have split the effect of innovation on production in <u>direct</u> and <u>indirect</u>, since it enables us to switch off the two kinds of innovation:

1. <u>direct</u>: K_{t-1} modifies the output level thanks to innovation of product, new goods go to affect sales directly;
2. <u>indirect:</u> K_{t-1} makes vary output through changes in C and L productivity, here we can include innovation of process, like machineries and labour conditions.

One more detail over the complete functioning between A and K is needed, let us tackle separately with what happens for capital, firstly, and for labour, secondly:

1. $A_t (K^{\gamma}_{t-1}) C^{\alpha}$ stands for the whole impact of capital over the output level, let us say something more about its way of working; everything begins with K^{γ}_{t-1} that means innovations affecting just the

capital component inside the firm. In this field we can refer to new production lines, new factories or new engines. All these updates make increase the productivity of the capital within the firm because of more efficient way of producing (compatible with the market evolution, requiring more efficiency at least to survive). Higher innovation and higher productivity will give us a positive $A_t\ (K^{\gamma}_{t-1})$ that multiplied for C (taken as exogenous) will impact positively on the output. What we want to stress is the core of such a positive aftermath over the output, we hint at the role of new way of building up the products, that means to be more productive under the capital point of view is needed a continuous improvement of the lines; it is the only way to guarantee in the end an increase of the amount of production;

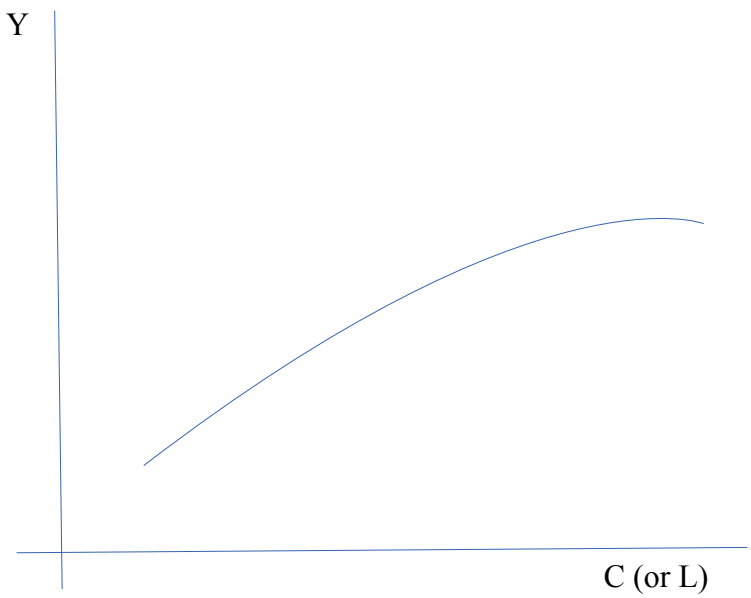
2. $A_t\ (K^{\gamma}_{t-1})\ \ L^{\beta}$ represents the overall influence of labour over the firm output, let us be clearer about the cause/effect chain; even here, as we have said for the capital, the key starting point is given by the K level. In this case innovations in terms of labour are less flexible than what we figured out for capital levels since less changes can be implemented for the workers with respect to the machineries. With labour conditions innovations we speak of new contracts, in which the way of working (and behaving) of the worker inside the company would change dramatically the productivity of themselves. We think about a positive labour condition as a mix of two combined contractual decisions: a) a drop of the "spare time" of the worker, she has less time to have lunch/dinner in the firm (let us suppose a reduction of the break from 40 minutes to 30 minutes); b) those 10 minutes "stolen" to the workers are financially compensated, as an increase in the monthly payroll. We have opted for this balance to convey more efficiently the sense of "a higher productivity of the labour"; we claim that it can be done just by making work more the employees and by paying them for this extra

effort. To resume, $A_t (K^{\gamma}_{t-1})$ will be positive (thanks to those new contracts) and multiplied for L (exogenous) we will get a positive impact over the output.

To explain as clearly as we can let us draw a simple chart.
Inside it you will find the positive correlation between C and L with Y (output); we are going to depict a production function with these First Ordinary Condition and Second Ordinary Condition:

$$f'(Y) > 0 \qquad \text{and} \qquad f''(Y) < 0$$

That means the output will always increase, but at a decreasing rate. Here the chart:



The chart above testifies the positive impact of capital and labour over the output: a higher C (or L) will give us a greater amount of output. This occurs thanks to the shape of the production function (positively sloped) even if that increase of Y due to higher C (or L) will be less remarkable for greater levels of capital (or labour).
As final comment to this microeconomic section we have decided to make play a

primary role to the *evolutionary mechanism* of production, innovation and productivity since they cannot be thought as fixed levels that are modified sometimes, they have to be taken in mind continuously; company executives and ownership have to constantly revise and stress themselves to understand what innovations may or may not push up productivity and consequently production. Nowadays, because of rapid evolution of the market (leading to more globalization) companies cannot afford to avoid innovating, it gives them the possibility of satisfying the customers' requests inserted into an ongoing modification process; just by continuously adding new features (before to plants and resulting into products) they can survive, and it has to be done ever. This explains why we got into the production function the inter temporal link between innovation - productivity and above all why we leaved a 1 year gap: if a firm innovates in the year *t - 1* it will get results in productivity immediately in the next year *t*; more productivity multiplied for the (exogenous) levels of C and L will make go up output level directly within the same year *t*. With our assumption of "1 – year gap" we can notice that an increase in production is ensured constantly (here every year) thanks to innovations made yearly; if companies invest a slice of profits for innovation plans every year they can enjoy of higher levels of production ever, this stands for why we mainly focused on the "time" variable in a production function.

After having analysed the microeconomics effects of such a link ("innovation – productivity - production"), it becomes relevant to let you know how it might happen from an entrepreneurial point of view, in other words, who is empowered of deciding whether to innovate or not, or who is the main author/authors of these so – relevant changes.

Let us deepen this other side of the coin, we are now interested in knowing where the innovation decision plans come from, since, from a business perspective it plays a key role. In this field the researches of the US sociologist Ronald Burt give a strong contribute to know more about this influence.

First of all, it gets necessary to define a couple of common lines shared inside the business community, as stated by the CEO of Fiat and Chrysler Sergio Marchionne (2011), if someone has the privilege of imagining something it

becomes his/her own responsibility to do the best to achieve that aim. These few words allow us to understand what is the role of an executive or of an entrepreneur nowadays (according to Marchionne's thought), they have the duty of making realize all the innovative projects. We would add that they have to pursue this goal continuously, since they play a primary role in the firm which they run, but even in the society if dealing with big businesses, they are firmly supposed to implement (always) changes aiming at improving the company performances.

Burt (2004) goes beyond, by keeping the attention on the social impact and structure of the firm; at the beginning of his paper he emphasizes the role of entrepreneurs in exploiting the whole holes of business. That means, he is not able to eschew from outlining the merit of some entrepreneurs.

Essentially he states that the majority of innovative changes are guaranteed by ideas of people managing the companies (like owners, CEOs and executive members); according to the sociologist all these business people are able to find, to exploit ant to make profitable holes not still discovered. He refers to that slice of the business always involved into an ongoing change process, within which there will be always the possibility for firms to grow up.

If we put in this way it gets perfect to embed a popular statement of Steve Jobs, during his speech (2005) issued towards the Stanford University graduates where he said that in technology field there are no dogmas. We would interpret those words as “no limits to get bigger”; as claimed by Steve Jobs and as academically proved by Ron Burt in all industrial sectors there is always for companies the possibility to keep up with new technologies, letting them to gain market shares and to soar profits too.

The point here is the following: firms to be competitive (and at least to survive) need to exploit all the holes of the demand, they have the continuous purpose of getting as first where others will arrive later. Let us take as example the car industry, that is one of the sectors in which innovation is the key element enabling companies to sell, just through new products they can meet the customer requirements. To be precise as possible, it urges to say that with requirements we hint at the worldwide ones, multinational companies compete in several markets

throughout the international markets since they know, especially nowadays, it gets relevant to open them up to clients of the whole world.

It is no more sufficient to produce and to sell within national borders, otherwise the brink of bankruptcy could get closer; as recently released by the ACEA association (it gathers all the European car makers) (2012) these companies are able to do not plunge their overall profits by offsetting them in all the markets in which they operate. The publication notices how all European auto makers have been slumping sales inside Europe, but, on the other side, they make huge profits in US, South America and BRICs countries in general. Once more detail gave us by this press release is the amount of money for R&D of all European car makers, it is of €26 billion annually. This data is extremely relevant, it tells us how much these companies bet on innovation, it grants them to be continuously in touch with customer's tastes.

This is the same concept that Burt tackles with, he states that there is always for firms the room for those “hidden chances”, of exploiting customers' wishes more deeply; he talks about a social structure in which we play our game at different positions, and it affects the success of the operation, even in business.

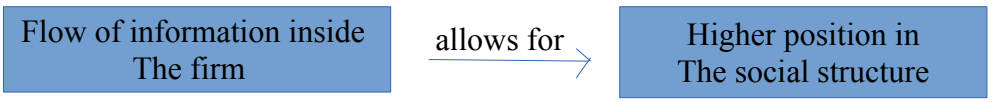
Let us say more about this: the idea of social structure is inside the broader item of business organization, the author notes that people standing close to holes (in that social structure) are more likely to have good ideas. Ideas leading them to be “temporary revolutionary”, it means they can arrive as first competitor where nobody else had thought to get.

Inside the social structure Burt fills in the social capital, it exists where people (executives) have an advantage because of their location in the social structure itself.

Normally, we can enjoy of a higher position thanks to the information that we own, (in our frame) information belonging to the business we took over and we want it to be successful, Burt adds that flow of information (compulsory to get the goal) move better inside the group rather than between groups (of different firms).

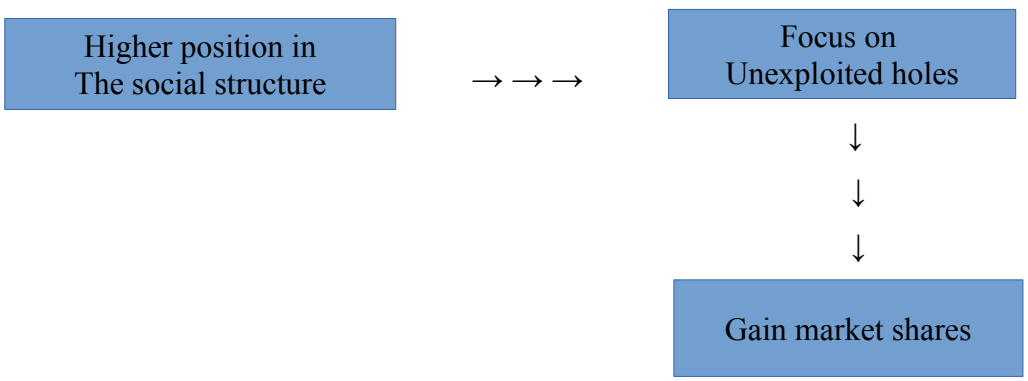
What Burt wants to convey is the importance of finding out unexploited business opportunities, that is more likely if information flow among people (involved in that business) without hurdles; that means clear and continuous information would

entail more knowledge to enter in new markets. It can be resumed schematically in the chart below:



Burt strongly endorses the necessity for people managing international businesses to find the best way to interlink all the information circulating inside the company. It gets of primary importance since if information arrive at disposal of the management of the company they can use them to reach areas of the market before direct competitors.

The next step of the relationship is:



Burt keeps on speaking of the leadership role as fundamental for these achievements. The social structure position strongly depends upon the ownership decisions, they affect business strategies and the following results. In Burt's paper some scholars' point of view over this topic have been reported, the main ones:

- Schumpter (1914), entrepreneurial leaders are those business professional figures bringing together elements from separate production spheres, by joining them in innovative ways;

- Merton (1949), Katz and Lazersfled (1955) speak about the diffusion of new tastes through cosmopolitan leaders, whose relationships bridge the gaps between social worlds.

If we were asked at (briefly) summing up their view of the entrepreneurial contribute to successful businesses we would depict an ideal entrepreneur so endowed: a long – term thinking owner should hire executives extremely flexible in linking sectors far among themselves and to able to adopt an international vision of the run business. That stands for the capability of simplifying the general structure (the social one) of the hierarchy inside the company to let information flow, freely.

The effects chain of Burt tries to represent in his work both sociological and business skills of owner. If there was a lack of one of them the purpose would not be achieved any more. Burt tells us how much good ideas have strongly had an impact on big innovations in the past, he talks about good ideas as insights; those are the skills making the difference among executives, if they are leaded by their intuition they can reach profitable improvements. Let us take Tim Cook's example, CEO of Apple Inc. and successor of Steve Jobs, he is used to saying that the biggest stake of his decisions come from his insight sense, it allows to be leaded by what he feels, but, furthermore, he does not exclude experience, through what he learnt during his career he can afford to follow the instinct.

Burt studies deeply this topic and he quotes the philosopher Collins (1998), who says " creativity is the friction of the attention space". It results relevant the creativity even by the Collins' words, it stands for the driving element, it is compared with a friction, that means it enables to change our pace to achieve higher levels of productivity. To jump a the next level a firm needs this featuring element, it needs to bet on creative innovations and ideas leading to the "next step". According to Burt this can be done by the entrepreneurs, they might have these good ideas allowing for innovation and productivity.

3.2 Section 2

Does production increases cause hiring rate rises?

In this second section of the literature part we are going to tackle with the relationship linking production and hiring, even if we are going to take into account even a broader perspective starting with innovation changes and ending up with hiring rate increases (in this analysis we will go beyond the intermediate passage of production rises).

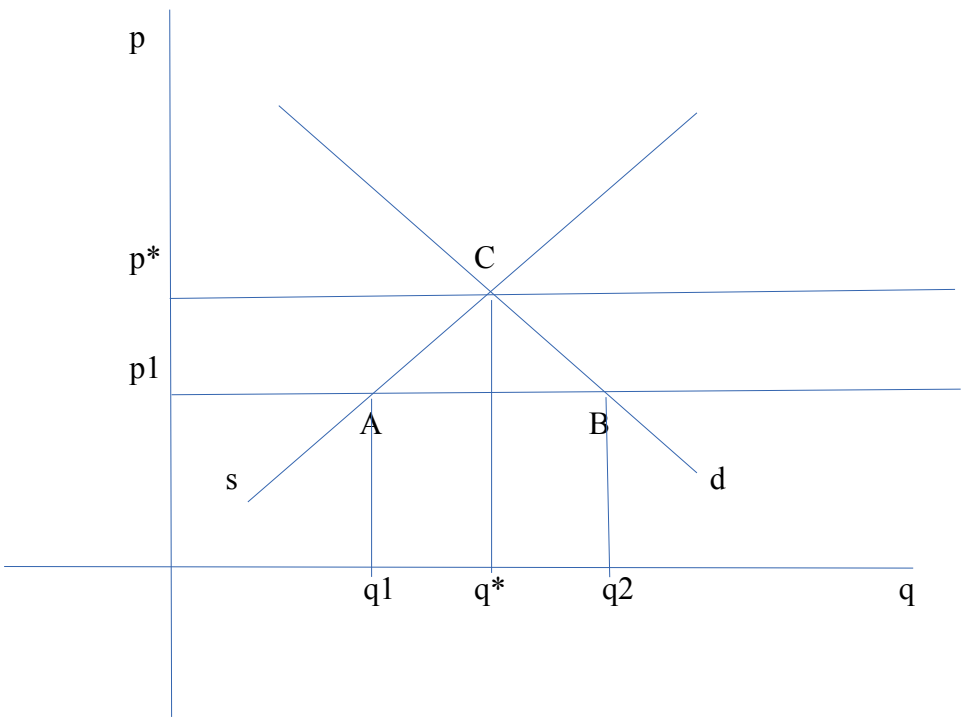
Before going into more details a brief link with the previous part is needed: we have closed section 1 by claiming the positive influence of innovation plans upon the production level. The interpretation of such a causal effect can be resumed as follows: firms and trade unions reach an agreement over the new contractual clauses (regarding the workers' involvement degree), it turns out the possibility for firms to set up innovation projects; the first part of these changes consists in updating the currently existing platforms, to adapt them to new building processes. Consequently, these more performing establishments are ready to bring out new goods, in fact through new production systems it is possible to supply more competitive products. These last sentences are securely tied up, this means innovative products can be built up just via more modern production lines, and vice versa, new lines have the natural aftermath of equipping the company with more efficient commodities. The first observable outcome of these innovations is reflected into sales, since these new goods comply with "the-always-changing-requests" of the consumers: to be more innovative stands for providing new ways of satisfying the customers' needs. More sales will make arising the firm profits and as well as its supply of product, it will get necessary to enhance the production of their own goods to satisfy the (higher) demand.

After having recapped the starting point we can deepen the core of this second section: if production soars, the firm is obliged to hire new workers to satisfy the new demand (or, the firm can exploit fully its workforce if some of them have

been employed just part-time).

Let us be clear as much as possible, all these sections are extremely linked each other, that means a different initial level of innovation would spark a chain of negative effects; in other words, we are just looking at positive scenarios, within which there are no variables slumping down, all of them are towards positive patterns, but it has to be clear that we are going to try to achieve developments of the labour market just with a common awareness of being more flexible. A too rigid attitude either of the firm or of the union would cause drops into these variables values.

By coming back at the relationship between production and hiring let us start with a chart, inside it we are going to plot the first evident effect of innovation: <u>excess of demand:</u>



In the graph above it is represented the excess of demand, at a price of p = p1 there is a demand of product higher than the supply. The price is so low because

of innovation gains, thanks to R&D findings the price has slumped below the equilibrium level. When the company notices this excess into the market, it immediately starts minding it by producing more. To produce more means to fill this gap between the demand curve and the supply one: the production increases from q1 to q*, it is performed to comply with a part of the excess of demand when p = p1. This is not the full story, by producing more the firm starts asking a higher price for its commodities, it is mainly due to these more "skilled" products, since they are equipped with more sophisticated components. The price rises up from p1 to p* (it is the equilibrium price too), this increase is not completely appreciated by the consumers willing to buy when p was settled at p1, in fact at p = p* just half of the demand excess purchases the product. More production has two sides of the same coin:

- positive: by producing more there are more sales and the precise is higher, because of more qualitative goods, the overall sales are greater than before;
- negative: to require a higher price makes lose clients to the firm, since it gets more expensive to buy these new products; the more the price goes up the less the number of interested customers will be.

The management of the company could have avoided enhancing the price and keep it at p1, it would have entailed a downward shift of the supply curve, where the excess of demand would have been completely minded and the quantity would have increased until q2.

We did not work out a shift of the supply curve essentially because we have been truly interested in (positively) assessing the surplus of the innovation. We would like to convey you the relevance of the benefits due to innovation, to really appreciate and consider them we have opted to compensate these gains with a higher price. This means, quality is paid more, customers can enjoy of a friendly-

product by paying the equivalent price (they cannot purchase them at the same level of price of less skilled goods, it would not embed in a competitive setting).

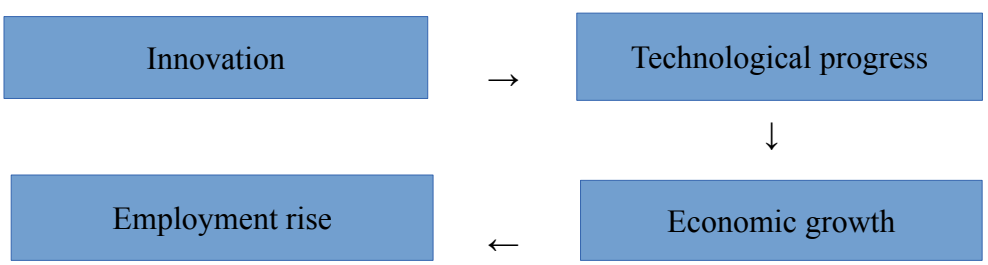
Let us concentrate on the production rise, it has passed from q1 to q*; this difference was not planed by the management before the innovation projects, after having settled these changes the executives cope a trouble: they have to hire new workers to fill this demand excess, the current labour force is not sufficient to produce this new amount. An alternative interpretation, as pointed out at the beginning of this section, is to fully use its own work force, to "exploit" all the employees that were in "redundancy fund". The key feature of this way of reasoning is the outstanding benefit of the demand excess, it grants to require more workers, otherwise this new demand could not be satisfied by the firm and the rivals may grab it.

From our point of view there are just positive consequences deriving from the increased production, we could not be leaded towards a negative framework; the same item has been studied by Pianta (2005), he tried to answer the question "Does innovation create or destroy jobs?".

Pianta handles with three different topics related to the innovation role:

- diverse types of innovation conduct to several effects upon employment;
- the aftermaths on the quantity of employment vary at the firm, industry and macroeconomic levels;
- focus on changes of quality of employment.

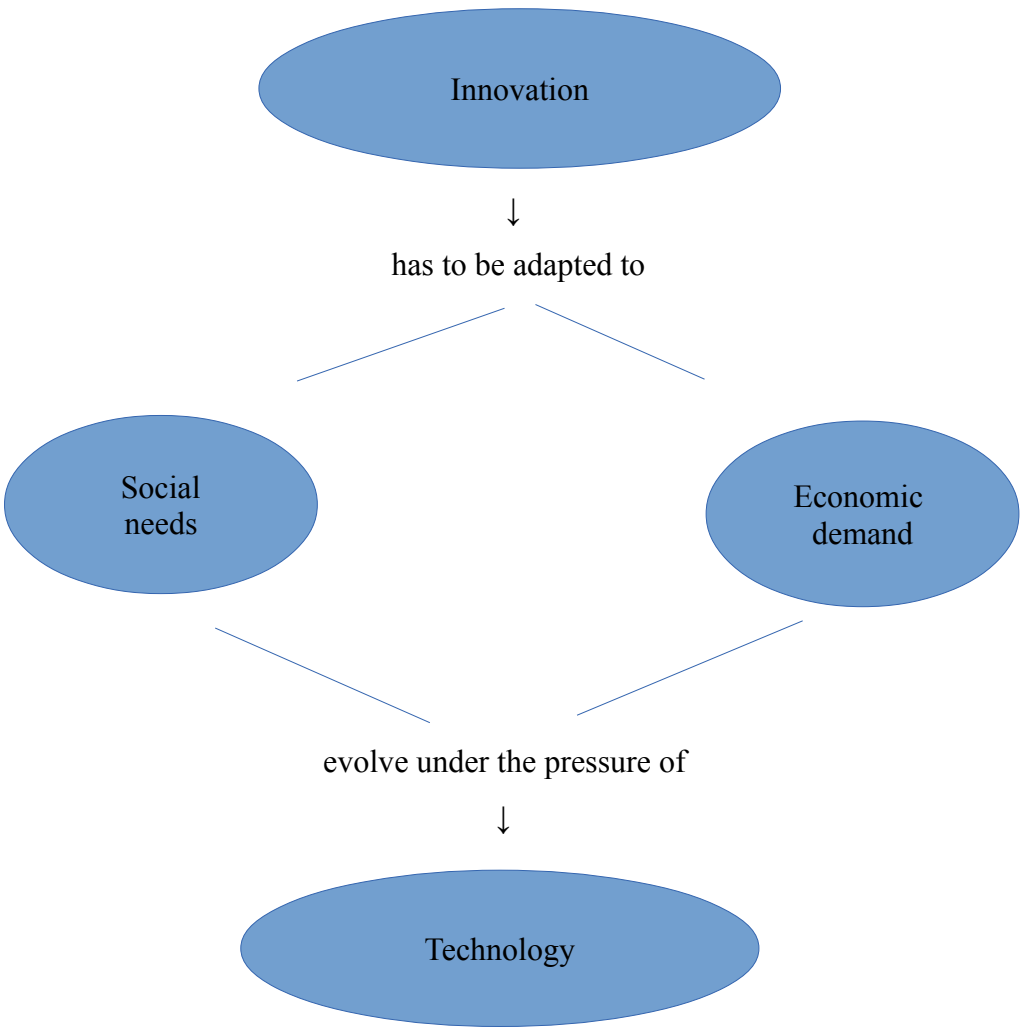
Pianta underlines the mainstream approach of the economic literature, according to which technological progresses lead to more employment:



It is relevant to point you out the third step, the one in which Pianta refers to Economic growth; he spots as first consequence of technological development (due to innovation) the growth of the economy.

Innovation is the main component for endogenous growth, Pianta highlights how, in the majority of growth analysis, labour economists just focus on production processes updates and they leave aside the improvements in terms of new products.

By referring to the relationship involving technological progress and economic growth Pianta stresses the social aspect of such a line of thinking; he notices what the social implications of innovation are, they can be so represented:



The scheme of the previous page has to be analysed in two parts:

1. innovation projects cannot be set up randomly or just by aiming at the economic interest, there is something more that belongs to the sphere of social responsibility, at which all firms have to comply with; in many cases the bargain with unions make firms to apply this criteria, since representative unions fight for seeing respected the social vision of the job. On the other side, firms manage innovation projects in an economic perspective, in fact it is not enough to be socially interested, if a company wants to survive it has continue filling the demand (we have spoken of this item at the beginning of the section). This first task of innovation, according to Pianta, is quite complex for companies, since they have to be aware to fulfil both social duties and economic ones;
2. social needs and the structure of the economic demand are not fixed at all, once a change is made up by some firms operating into the market, the desires, aims and requests of consumers are no more as before. This way of thinking implies a continuous change of what is asked by the society and the basic parameters of the economic demand. Moreover these new (social and economic) needs are deeply affected by those technological progresses.

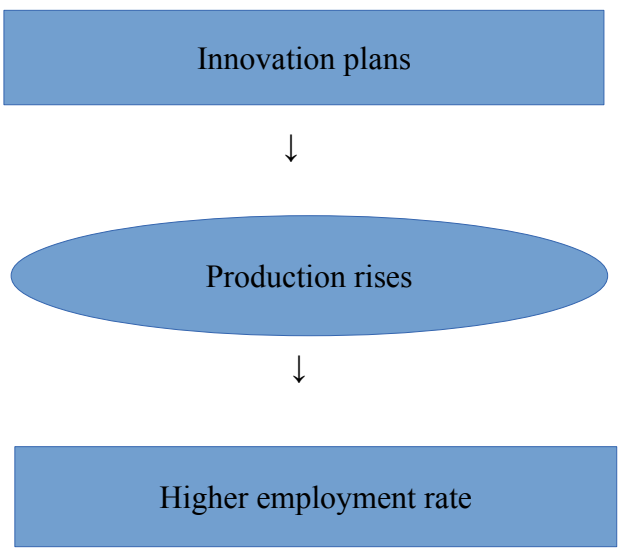
This distinction is meaningful and it perfectly embeds into our analysis; the technological innovation is the origin and the end of the cycle, innovation has to bear in mind the social impact and economic changes, but at their turn they are affected by innovation itself.

Pianta adds up that even if social and economic demands spur different levels of innovation, this latter might take several years before generating the first results.

Let us say a couple of words more upon the social influence over innovation projects: first of all it is necessary to be clear with “social”, from our point of view it would mean the needs of the society, what the people belonging to the society want to get from firms products.

Furthermore, it would be too reductive to label the adjective social with that previous statement, it is much more powerful to name this word with a social-cultural meaning. It is hidden behind it the importance of the corporate responsibility of a company, it cannot just think in terms of profits without considering the social impact of the produced goods; they have to be supplied even with a liable purpose, firms executives have to aim at *really* satisfying the customers' desires, without undermining their health, wealth and suctions.

Let us jump to the key element of our analysis, we are referring to the effect of innovation into employment rate; in this framework we are just looking into the direct effect of technological progresses in enhancing the number of employed workers, by (implicitly) passing through an increased production:



Pianta talks about the positive link between the first and the third element of the scheme, he gives us some data to better understand it: he notices the economic relevance of innovation to the employment performances (with which he hints at average annual rate of change) of 20 manufacturing industries in four EU countries (Italy, France, the Netherlands and the UK). By analysing the data for the share of new products on sales there is a variability of influence according to

the industry field, in sectors like office computing and telecommunications there is a more evident positive signal; but, overall, the relationship between product innovation and employment in European countries is positively sloped.

Pianta continues by stating that firms that innovate in products and processes can grow faster (than rivals) and they are more likely to widen their size of employed workers than non innovative firms.

The scholar also highlights a converse flow, from employment size to innovation: in the long run perspective of firm development, rapid growth of hiring rate might be interpreted as the main determinant of innovation, it takes place as the firm innovates to face the rigidity production processes and increasing wages.

To support Pianta's thought we introduce even the researches of Harrison et al. (2008); they remind ourselves how innovation is widely considered to be a primary source of growth.

The authors agree upon the long run effects of innovation on employment, this means that an extended period of innovation could lead the employment rate to be positive.

Furthermore Harrison et al. (2008) claim the remarkable role of innovation in triggering the demand for a firm product, even if they noticed that it happened in the past situations in which innovation wiped out jobs, it is still unclear how it occurred.

A part from this ambiguous interpretation of a secondary effect of innovation, the authors tell us what was the impact of innovation in last decades, on average we had not a drop in the employment rate.

Let us adopt a broader vision of this topic: it is extremely relevant to understand the positivism generated by innovation, it turns into more jobs created and it allows families to account upon a fixed revenue.

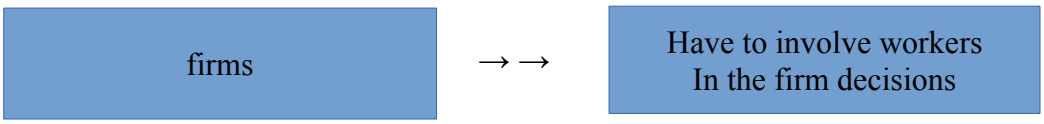
At this point it gets primary the function of the unions, (in our simulation) it is up to them if there is innovation support or not, trade unions and firms have jointly the responsibility of guaranteeing better conditions of lifestyle; if these two parts converge towards acceptable conditions (at least so judged by the counterpart) there is room for innovation plans and consequently rises in production and employment rate.

All of these causal effects have a common root: the bargain between firms and unions. This is the main reason for which we have decided to constrain both agents: we are aware of the liability in which they are asked to operate and for this we have opted for equally involving them.

Both firms and unions are supposed to reasonable going towards the most convenient behaviour for their own goals: firms act with an economic purpose; unions claim their protected workers' rights.

If it were so no deal would be reached, since both parts would be just fixed in their own positions, without taking care of the likely consequences of certain attitudes; this explains why we have introduced a double clause, counting differently for both groups:

1.



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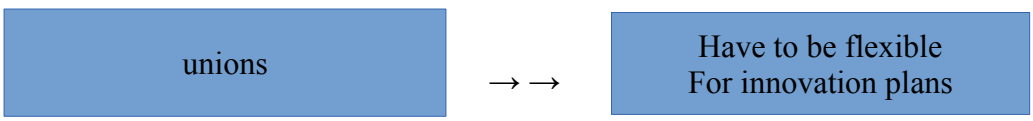


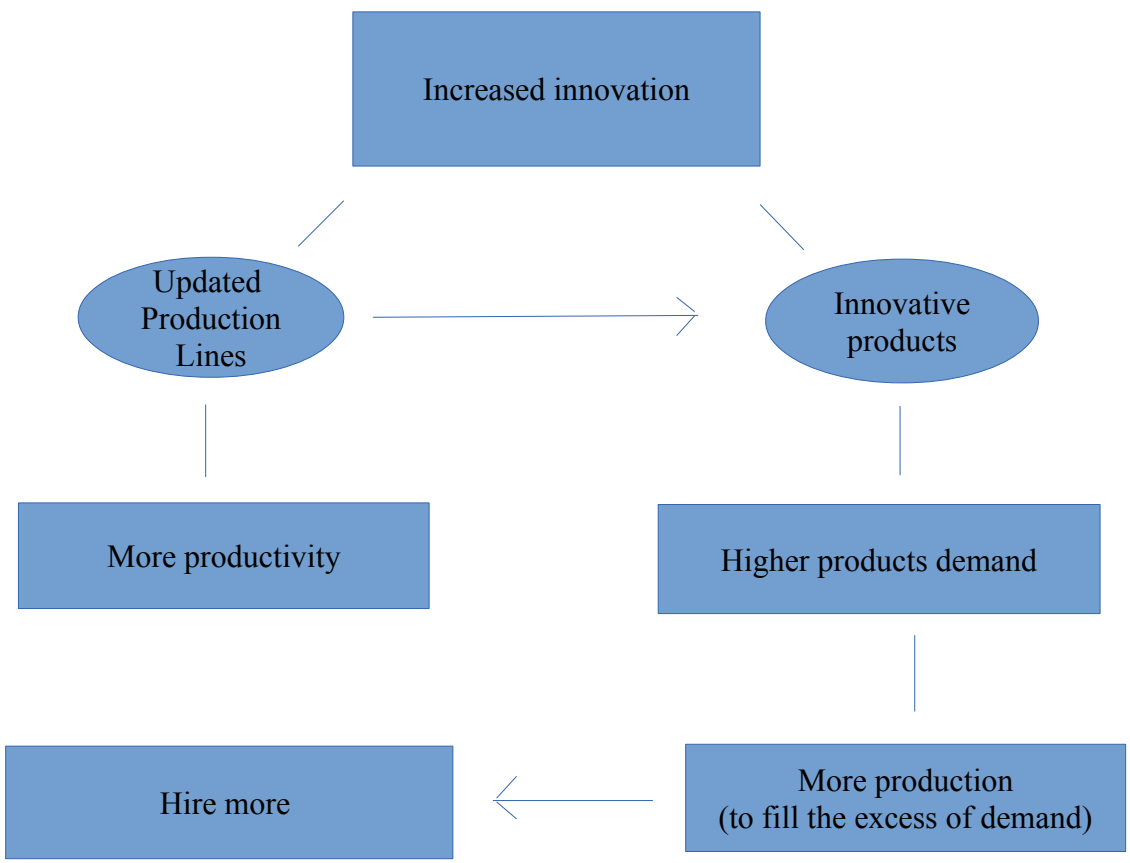
These two conditions have to be fulfilled simultaneously if we want to achieve the result of a higher hiring rate, it is highly likely in our project to increase the size of employed workers but it is bind to these constrains, if one of them drops all the positive chain effects do not take place any more.

Once again, we want to be clear in the double liable role for both parts, it is possible to reach a more wealth situation in the economy, only if all the agents play their (socially) aware function.

3.3 Section 3

Are trade unions more flexible if workers are more involved into managerial decisions by the firm?

From this section onwards we are going to deal with the unions side, that means we observe what its liabilities are; until section 2 we have tried to deepen, as much clearly as we could, all the actions of the firm that lead to increase hiring.
Section 3 (and Section 4 too) looks at the impact of the union decisions on innovation, production and hire; even if we have to state in advance that at the origin we will find once more the firm role.
Before going into details, let us resume with a scheme the chain involving the firm:



A remark is needed: as specified into NetLogo codes description, the increase of employed workers (due to produce more) is not proportional to the production rise, since by gaining productivity (with innovation plans) the single worker can be more productive and *contribute* to the whole production process more than before innovating.
The previous chart belongs to firm side, what the steps to employ more people are. Let us switch to unions, in our simulation model we have assumed to assign it a double role:

1. if workers are more involved into firm executive decisions the union will enhance its flexibility for innovation projects;
2. if unions flexibility gets bigger, innovation level will soar more.

If we had to be more precise we should say that there is a unique liability for unions in this relationship, since the only decision up to them is the flexibility degree with which they allow for increasing innovation. This function is embedded in two *sub-relationships*, in fact its level depends upon the involvement of the workers into firm decisions and (at its turn) it affects the innovation support.
In this third section we focus on the chain: workers' involvement – unions flexibility; instead, unions flexibility – innovation increase will be item for the next section.
The insight of this link was born from the general idea of more satisfied unions, to say it better: within the firms that involve more their own employees, the trade unions are more willing to support innovation projects set up by the firms.
By saying “to involve more” we refer to the degree with which workers participate into managerial decisions, where they do count for the final outcome, some cases can be: approval of new investment plans, bargain over the revenue

changes, decide for the opening/closing of factories, purchase other companies shares, increase the hours of work.

We acknowledge that there is already a similar role played by the unions, they deal with the firm to converge towards a common point for both parts.

However, in our simulation we assume a slightly different setting, where workers act directly with the management to stand up for their weight into the firm they work for; it is diverse compared to the unions function, in fact the latter ones have the duty to represent workers under the contractual point of view, that means for their salary rights.

Instead, in our framework, we claim a key power for employees to make hear their voice just for what concerns the decisions taken by the executive.

We have so thought because of the need to introduce the workers to more important choices, our claim comes from a general liability into the firm, we suggest for a "more spread responsibility" throughout all levels employees. If workers take part to these critical decisions they might have a clearer vision of the huge importance in running the company they work with; this involvement would have an educational role (we hint just at the job relationship), since all the employees would get aware of the relevance degree in undertaking the best pattern. Furthermore, it would be economically grateful as well, if we assumed that one of the way to involve more them is to cease shares of the company itself to the workers, they would have an economic return every year.

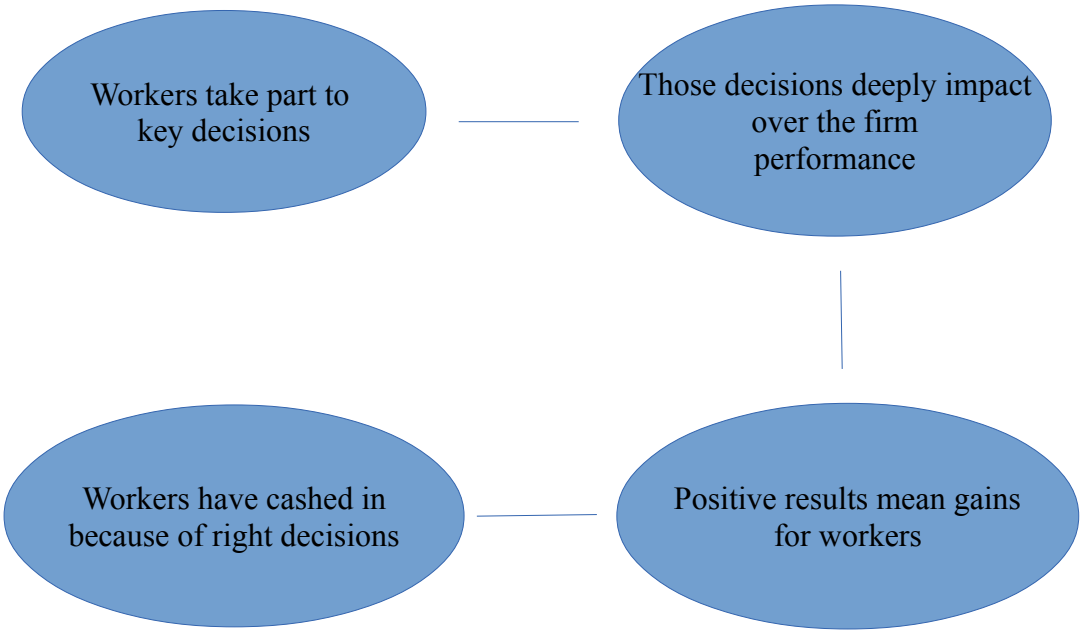
The last event would occur if the decisions have been taken properly, such as correct investments, opening of new factories (for instance), even in opting for these we would have workers. In other words, if workers have decided rightly (jointly with the executives) for all the managerial decisions they will have positive returns, through shares.

We have figured out a scenario like this to *liable* involve employees, that is to give them the chance to deeply contribute for the firm development and to enjoy of its profits, but it cannot be profitable if they do not decide for the real firm benefit.

Moreover, there is plenty of countries where workers own shares of the firm; if we start thinking about this, it already happens for the top managers across the

companies, they are even paid with shares packages and their size depends on the achieved results; in fact if the targets have been reached the top level executives can cash in the bonus.

We think to implement the same process for all the workers, the higher is the degree into the company the higher the responsibility will be (and so the decisional power weight); we aim at a system where all the workers play their own key role in managing the firm, the outcome is to empower all the employees (whatever her level is) and to allow them to cope with important decisions. If we want to briefly recap this thought with a statement we could say: workers decide for the managerial plans (with different degrees), they *partially* run the firm, they get back the economic benefits (mainly with shares). The same topic can be so illustrated:



With this cycle we wanted to show you clearly that not all the whole liability is up to the employees, just a part (lower than the executives), but with this involvement they can realize how positive strategies can be implemented to grant

profits (than given out via shares).

They can receive back economic returns if the strategies for which they voted for (or against) have been useful or not to achieve these outcomes; the higher is the internal degree of the worker the higher her role into these decisions will be.

According to Noe (1993), the workers efficacy and their environment perception is grounded on perceived benefits and the possibility for needs development; in other words, the scholar claims that to have "customized" employees is necessary to feel them satisfied with their job, if a worker knows to be allowed to achieve certain positions or some economic benefits she will be more willing to actively participate to the firm life.

We could interpret this thought with a sociological point of view, in particular we quote Granovetter, he is used to saying that nowadays the workers are asked to identify themselves with the firm activities, that is to play an active role into the process; this idea enabled to pass from a production system in which there was no room for the employees (they were just seen as simple input) to a system where they are positively seen, they are supposed to increase the firm status.

This is something similar to our insight expressed until the previous page, we were standing up for a workers' involvement within which they have to give a remarkable support for the company strategies.

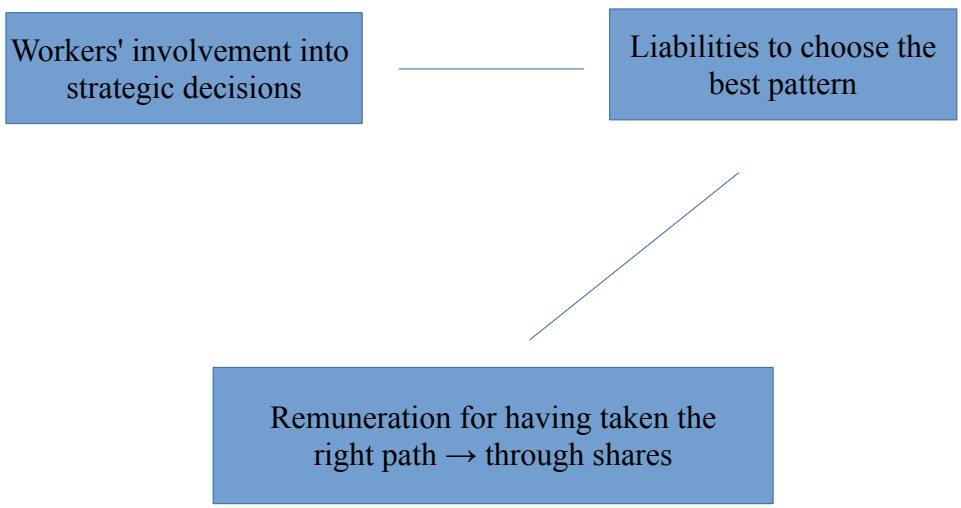
We act in two ways simultaneously, on one side they have to be taken into account (by the executives) since they work for that firm; on the other side, this major involvement is not given by the chance, it has to do with liabilities, by being empowered to decide they have to deliberate pure and sane decisions.

By coming back at Noe, there is even another way, workers might be more productive if they are conscious of their chances to make career, or if they do develop their needs: let us suppose the involvement to consists in shaping the working hours, if she knows that her working day can perfectly embed with her private needs, she will be more efficient since she is able to combine both activities.

We have to acknowledge the Noe's statement, in our simulation we have just fixed on the employees' involvement into economic projects, the scholar looks at this item with a different perspective: we could involve a worker in terms of loyalty,

there would be many ways to do so, as proposed by Noe it is relevant even the perception of the working environment, the more the employee feels better with her job the more she will be efficient.

By ending the reference to Noe, let us just add that the final outcome is the same, if the worker is more involved (this time in terms of job perception) she will be more productive and the representing unions will stand up for innovative plans. There are many ways to involve workers into the company daily life, we have opted for the more economic one, instead of focusing on working conditions we have preferred to give more impact to the monetary benefits and liabilities in the decision process:



A similar idea have been studied by Conte (1988), he provided one of the first econometric analysis upon the impact of worker participation (into decision-making processes) over the productive efficiency. First of all, he outlines a critical point of view, the employees' involvement guarantees the potential for conflicting influences over the firm performance; this means that the scholar adapts even a controversial use of the power (derived from the involvement), the workers can use it to control and in case to stop the management decisions.

The results of the analysis underline a positive link between the workers' participation and their efficiency, it has been proved that if the employees are more involved into the decision-making process there will be an increase in their productivity.

A second part of that studied observed the impact of workers' ownership over their efficiency, that relationship was positive too: if workers own company shares, their degree of productivity gets higher.

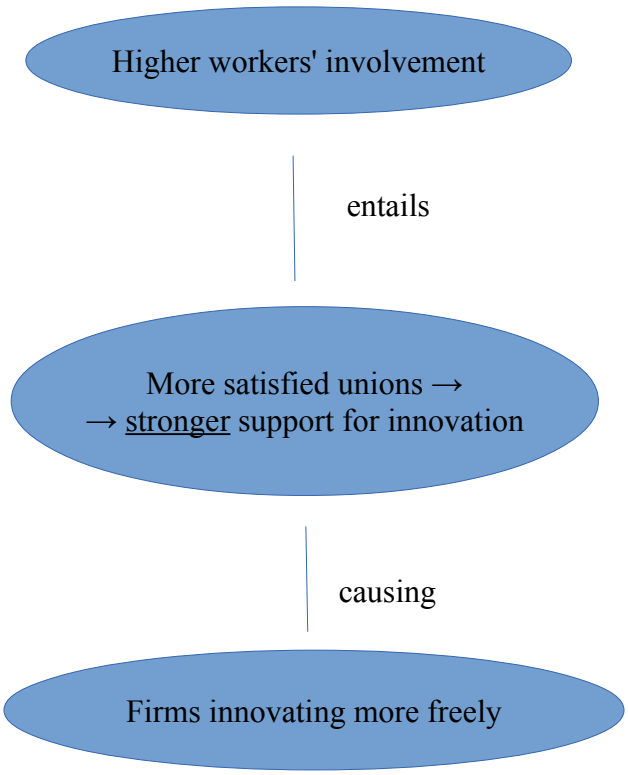
All these statements on the workers' involvement, that can take various forms, are the preface to understand how the unions might enhance their support for innovation, so to be more productive. We have thought that it could occur mainly with more satisfied employees, obtained with more involvement for them (once more, into decisional processes).

3.4 Section 4

Is there more innovation if unions are more flexible?

In this part we try to understand if there could be a sort of causal relationship between flexibility degree of unions and innovation plans, set up by firms.
First of all, let us tell you that we impose a constraint to grant such a link among market agents: in our simulation model all companies are allowed to increase their level of innovation if and only if there is unions support. It is needed to clear the previous sentence, with innovative projects we refer to the profits slices directed towards the updating of the production lines (and consequently of products) by the managerial sector jointly with the employees (according to their involvement); that amount invested to make the productive processes more efficient does depend on the generated profits and upon the trade unions consensus.
In this project we have just stayed on the unions support, we strongly claim the idea according to which the higher is the unions flexibility the higher the innovation plans will be. By going deeper, we firmly think this bridge between unions and companies to be based on the contracts: the unions favour is represented through signed deals, if they agree the innovation can take place with less hurdles.
Moreover, in our model we have bind the support level (of unions) for investments on the previous page feature, that is the involvement degree, in fact the higher the workers' participation is the higher the unions flexibility will be; we have preferred to build up such a causal effects chain to constrain agents actions each others.
Consequently, unions flexibility goes to affect at its turn the level of innovation plans acted by the firms, these can invest freely their profits to update their establishments if there is no pressure from unions. Let us be clearer over this last point: there is no ceiling for the innovation increase, we just assume that more support triggers more investments, these will be even larger if the unions

consensus is greater; by saying it differently, we reason in terms of fluctuations of these two parameters, the higher the one is the higher the other will be. A brief scheme graphically reproduces it:



The chart above gives you a quite clear vision of the idea behind, if one of the agent changes behaviour then all the next variables will be affected, there is a desired purpose to liable get into the market functioning all the economic actors.

According to Galasso (2013) investments have to be seen as the *engine for the economic growth*, in turbulent times and with markets slowdown there should be a common consciousness of the general duty to make change the negative current events. In this overall sign of responsibility the author points out the liability of the unions too, since they stand for the workers' rights they are empowered of a sizeable part of the whole economic bargain.

Galasso reminds ourselves one of the most popular examples of conflicts between trade unions and firms: Margaret Thatcher, she is remembered for her deeply active dialogues with unions associations. Mainly, her economical politics were directed towards technological innovations to improve the English economy, these updates fought with the drop of workers (because of the factories modernization, where the human labour force started slumping).

The debate has its roots in this opposite vision of the companies development, firms want to be more competitive (to do so they need to invest continuously) and unions prefer less innovation to do not decrease the amount of hired workers.

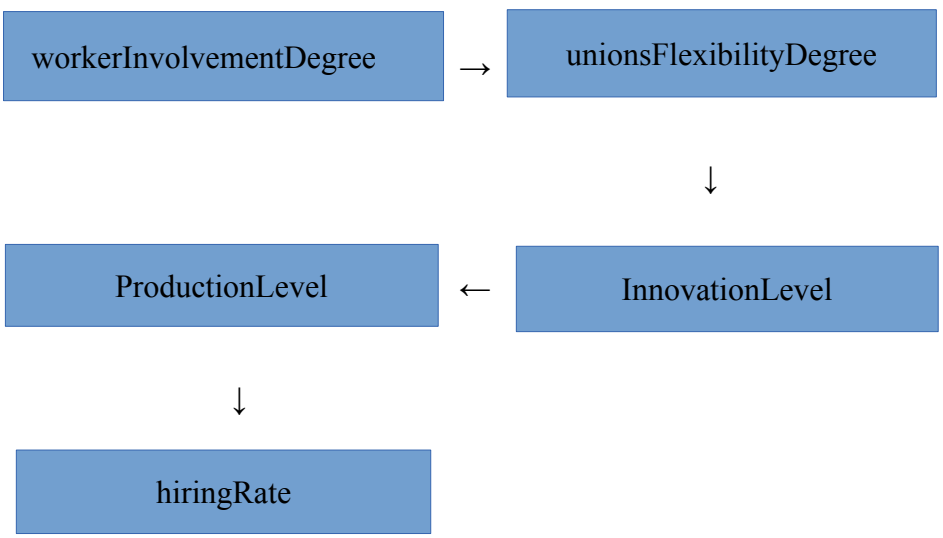
Galasso keeps on by reporting a glimmer of the Italian economic situation: on one side (the major part of) these workers associations do not want to be replaced by machineries, on the other side the unions chiefs accuse firms management to avoid innovative changes. Essentially, the Galasso's point of view focuses on a greater awareness of unions, he claims for them a more active role in improving the current critical situation.

For what concerns our simulation model, we do not want to take part for one or the other perspective (neither with unions ideas nor for the firm aims), we have quoted Galasso's thought since it perfectly embeds into our causal relationship. The key point of the scholar's theory is the influence of unions principles over the innovation updates, Galasso stresses the idea according to which there should be a more active union for granting better market conditions: likewise, we have imposed a higher innovation (made by firms) if and only if there is more support of unions.

4 NetLogo model

4.1 Logic

The simulation model starts with a labour market in which both unions and firms follow their own behaviour, just by looking into their strategies; both agents react as a consequence of the decisions taken by the counterpart, instinctively and not due to it (as we will get later). To depict schematically such a chain let us put in this way:



That relationship stands for our starting point, this means: let us start from a random level of workers' involvement degree, this affects the flexibility level of the unions towards new investment plans set up by the firm. Consequently, a more flexible firm will allow for more innovation, thus higher production and in the end it makes increase the hiring rate (followed by a drop in the unemployment rate).
This mechanical setting is where we set out the imperfect functioning of the relationship between firms and unions, we are aware that a low level of workers' involvement (or at least so judged by the trade union) would block all the next

steps, we would get low unions flexibility implying no new innovations, no increased production and no new hired workers.

By being conscious of this chain reactions we will shape this simulation to endow it with commands guaranteeing fairer behaviours.

This last concept has to be deepened, let us say in other words: we are going to insert new commands (via learning processes) thanks to which both agents act by taking into deep consideration the aftermath coming from its own choice.

We provide a couple of examples to make it clearer: the trade unions won't be any more focused on their purposes, they do not just take choices to maximize their utility function (in our model representing the workers' involvement), but, moreover, they look at the possible firm reaction of their decisions.

On the other side, a firm takes consciousness that if it does not involve its employees (because from a labour point of view it is not profitable, for instance) the union can be close at denying its support for innovation plans.

Through a learning process we are going to shore up the initial framework, we have begun with a series of actions performed by the agents within which they were just acting as a precise consequence of a previous event, it was quite similar to a robotic sequence.

After having introduced *the learning process commands* we aim at getting a system of reactions where both agents (firms and unions, workers are either agents but they do not embed in this complicated mechanism) take action by having in mind the possible aftermaths, positive or negative. They do know that if they reason just for their convenience the other agent could penalize them.

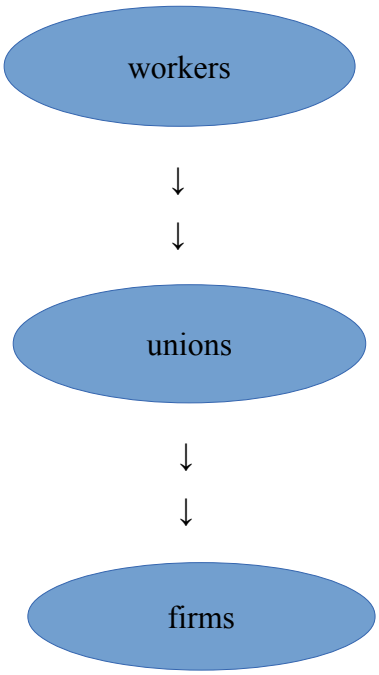
4.2 Codes

The codes section starts with a series of *globals*; a global is a key strategic word, used at the beginning of a simulation program, to make it functioning it must be written before any command and definition. With a global we can put into the model new variables, that can be executed by all the agents and it can be applied anywhere in the model.
In our case we have labelled as globals: innovation level, hiring rate, unions flexibility degree, worker involvement degree and production level. We have a plenty of globals for two reasons:

1. our globals are variables that can be executed in several parts of the simulation, it might happen that they are recalled more than once;
2. two of them are performed by both agents, firms and unions, we refer to worker involvement and unions flexibility degrees; they are jointly used and they are used several times during the execution process.

Immediately after the globals we have written down the *breeds*.
As it has occurred for the globals, even the breeds can be used at the beginning of the codes section, otherwise it does not work (and the program cannot be run at all). It must be before any definition function, as we have said for the globals.
Inside a breed we find two names, the first one spots the name of the agent-set associated with the breed itself, the second one gives us the name of a single member of that agent-set.
In our model there are three main breeds, represented by unions, workers and firms. What has to be noted is the core of our scheme, we have opted for a simple labour market setting; inside it we fix our mind on the relationships network linking these three agents. We could have got into many other actors of the real

labour market like public offices, regulator authorities or category associations.
The way of reasoning that we had in mind when we wrote this code can be quite sufficiently captured by this scheme:



Brief explanation of these links: workers are represented by unions, unions interact with firms to make workers' rights actually respected, firms ask for more (or less) employees according to the relationship outcomes they had with the unions.
As it can be seen in this view, firms, unions and workers are strictly tied up among themselves and for such a reason we have thought no more agents would be necessary to explain the functioning of our labour market.
We have added up other two breeds that are more specific than the previous ones: improvements and worsening. What they do mean will be explained further, simply because it fits better into the explanation of the commands in which they

are used.

The first command we face is "*to setup*".

It starts with "clear-all" (we could have written a shorter "ca", the meaning is the same), this enables us to reset all the global variables to zero every time this command is run, through the button "setup".

Inside the general command setup we have included the set-up for all the agents, in this way when the button setup is pressed all the agents are set up as well. These setups that I have spoken of are: setup-workers, setup-unions, setup-firms.

Within the setup we have included another important initial step, it shows us the starting level of the interested variables and in particular they are: unions flexibility degree, innovation level, hiring rate and production level. These values have an own lower bound, it is reported in the interface with an output area, within it we can find as minimum levels:

- unions flexiblity degree is 2: it means that exists from the beginning a minimum union support to the firm; this tells us that there is a basic level of innovation, production and hiring by default;
- innovation level is 1: this is an immediate aftermath of what said in the previous list point; since a minimum level of trade unions flexibility is guaranteed there is a (low) innovation amount from the beginning;
- production level is 2: if no innovation plans are set up the company production enhances as well, it could soar more from that level if and only if it was triggered by a higher innovation level;
- hiring rate is 2: this a chain effect of the previous points, as innovation takes place, consequently, the hiring rate is positive too. More precisely, even if there is no increase of innovation from the initial level of 1, we suppose to have a positive hiring rate, constant to 2. That is meaningful, we are interested in seeing if added innovation at the beginning level of 1 produces positive effect on the hiring rate

(it does not affect us negatively if we begin with a positive level of 2, since we just look at the increase of it, due to innovation changes).

We have decided to tackle with a context in which a minimum level of flourishing for all the agents was granted; it means workers, unions and firms could survive even if there was no innovation projects. The overall economy would thrive as well, but it would occur in a no competitive environment. Once we get into the model the possibility for all the agents to be more efficient let us seewhat might happen. This is exactly the core of our analysis: to observe if these agents can agree upon new changes and to converge towards a more profitable state for everybody. After having introduced the innovation changes we notice what the agents behaviours are and we split their reaction in two possible paths:

1. if both firms and unions react positively to innovation plans, all these above listed values go upwards from the initial levels, meaning that they boost an economy expansion;
2. if these two agents stick on their own positions without taking into account the other's reaction, those beginning levels puts the whole economy into a depressive spiral.

The “to setup” ends up with *reset-ticks*, it gives us the chance (once the “to go” button is pressed) to observe these values to start from their own levels and not from zero; it entails we can keep valid the remarks of above, the beginning differs for all the variables, successively, they vary according to certain commands:

As clearly observable into the graph, innovation, production, hiring and flexibility do not start from zero, but above it.

The second command that we have handled with is “to report”, with this we have been able of reporting the initial values of the interested variables into the output (of the interface). It has been labelled as *initialLevel* to make it understandable as much as we could. To go into details we can say that it is so internally composed: as first name we put the name of the analysed variable and as second its associated value, it has been done with “output-type” and “output-print”. These commands print the value (it corresponds to our initial levels, already defined at the setup end) in the interface output area.

The setting ends up with the building of the three agents.

A tricky way of setting them up is via a slider, to be clearer let us put in the following way: the general command “to-setup *agent-set*” is widely used to identify different classes of agents; in each set-up we will determine the basic features of the agents (like size, colour and position).

We want you to look deeper into the slider (observable in the interface), since via this tool we can modify the number of these three agents to notice whether what we prove with a few agents will hold even with a lot of them. In other words this

instrument would grant us to check if our simulation is consistent, both with many interacting agents and with a few of them.

We have generated three similar commands "to setup-*agentset*"; which they include as agentset workers, firms and unions. In all of these three cases we have begun with the shape creation, we have done it through the basic command "set-default-shape", in this way we can define a default initial shape for all the agents of that agent-set. In our cases we have labelled each class with a similar comparison with the reality, that means: workers have acquired the shape of people, firms are spotted with a sort of plants (whose NetLogo name is exactly firm, we have modified its initial setting through the Turtle Shape Editor), unions are represented by a flag (we have opted for this image just to convey the intermediary function of the trade unions between workers and firms).

The number of agents can be increased or decreased, as said above, through the interface sliders; to make it possible we have written it down in the code to create *agents* with the slider called HowMany*Agents*.

All the agents are created randomly, in fact we "ask *the agents*" to setxy (x and y stand for their coordinates) totally by chance (in the codes we wrote *random-pxcor* and *random-pycor*).

So far we have deeply described the basic setting of our simulation model, all of them are run when we press the button setup in the interface (a part from the definition of the globals and the breeds).

From this point onwards we will be analysing the dynamic evolution of the model. After having clearly built up the framework of the simulation it gets more challenging to notice in which direction all the agents (through their descriptive variables) move, in terms of behaviour and variables fluctuations (we hint at the chart values).

With dynamics we refer to the reactions of one agent as response to the movement of another agent. We try to work out how agents take action as track of precise behaviours. This would entail that a firm will opt for a precise innovation strategy according to unions decision.

This concept seems to be quite powerful and even current, since, we aim at achieving a chain reactions (mainly of unions and firms, we set aside in this frame

the workers' choices) within which both parts have to take decisions in a constrained setting. We stress this point because the relevant outcome that we would like to get is a natural cause/effect relationship, inside it both firms and unions will behave according to their own purposes but they do not forget what the other's goals are.

The first mover in our simulation is the firm, even if we could claim for it a sort of passive first move, since we ask the *firms* to involve workers but they perform this request randomly.

We make this insight clear immediately: firms have to opt for a random level of workers' involvement degree between 0 and 10. The value generated is bounded between those values but the firm has not the power of taking one precise number. The coming out level has been so defined (without a criteria) because we are not interested into seeing what number the firm would choose, rather, we notice how the next variables that we are going to explain ahead would react to different levels of the workerInvolvementDegree. We have the faculty of setting up whenever we want a new simulation (through the setup button) and so we might have a different (always randomly generated) workers' involvement degree, starting from which we are going to analyse the diverse behaviours of the other variables.

The range of flow for the workerInvolvementDegree variable has been chosen between 0 and 10, we did not include negative values simply because it would not make any sense (for the firm) to negatively involve its own employees, even logically it is devoid of sense. From the NetLogo point of view the mechanism allowing us to randomly set the degree is *random-float*: this function reports a floating number included between the two numbers written just after it, this testifies why we digit 0 and 10, in such a way we are excluding any negative numbers.

Conceptually a 0 degree of involvement implies an exclusion of the workers from the company decisions, instead, a 10 degree means that the employees can voice their ideas as well as the executives ones. We do not just look at these extremes, there are other middle values able of generating different patterns.

“To involve” is the command through which the workers' involvement degree is

executed by the firms.

The next one concerns the union's reaction to the firms decision (upon the involvement). This command has been named “to standUpFor” because of its way of conveying us what is the union's will of supporting innovation. Unions are asked here to set a level of flexibility (if it is negative it turns into rigidity), this is decided according to the previous passage. Unions will be willing of giving out a strong support to new innovations (proposed by the firms) if and only if they judge acceptable the degree of workers' participation.

The adjective acceptable is measured through a slider, it controls what can be the minimum level of involvement seen as right by the unions. The slider extremes are 0 and 10, where 0 as minimum would represent a disinterested union, since it would enable the firm even to not involve workers, instead a 10-level would stand for an exigent union, to increase its flexibility it asks for an extremely high degree of involvement.

There is a negative flexibility too, in the cases in which firms do not include into the managerial decisions its employees (this means a workers' involvement degree of 0) unions react by dropping their flexibility; in such a context it gets rigidity and it assumes a value of -3.

By coming back at the positive side of the union's flexibility we have split in two possible scenarios. First of all we need to remind ourselves that we have an initial level of unions' flexibility equal to 2, it plays the role of a divisor: unions' flexibility enhances from the starting value (of 1 step) if workers' involvement degree is greater than the minimum required by the union.

The increase is just of 1 unit and it has been called “aStepForward”, it is added to the current level of unions' flexibility. This rise is possible only if the employees' participation is sufficient for the union, the latter will be more flexible since the represented workers are fairly treated by the company.

The second scenario, that we have depicted, deals with a slump into the flexibility level, it takes place when firms involve workers less than what thought to be sufficient by the union; consequently unions show to be less willing of agreeing on innovation plans and they plunge negatively their current flexibility of 1 unit, it brings the name “aStepBack”.

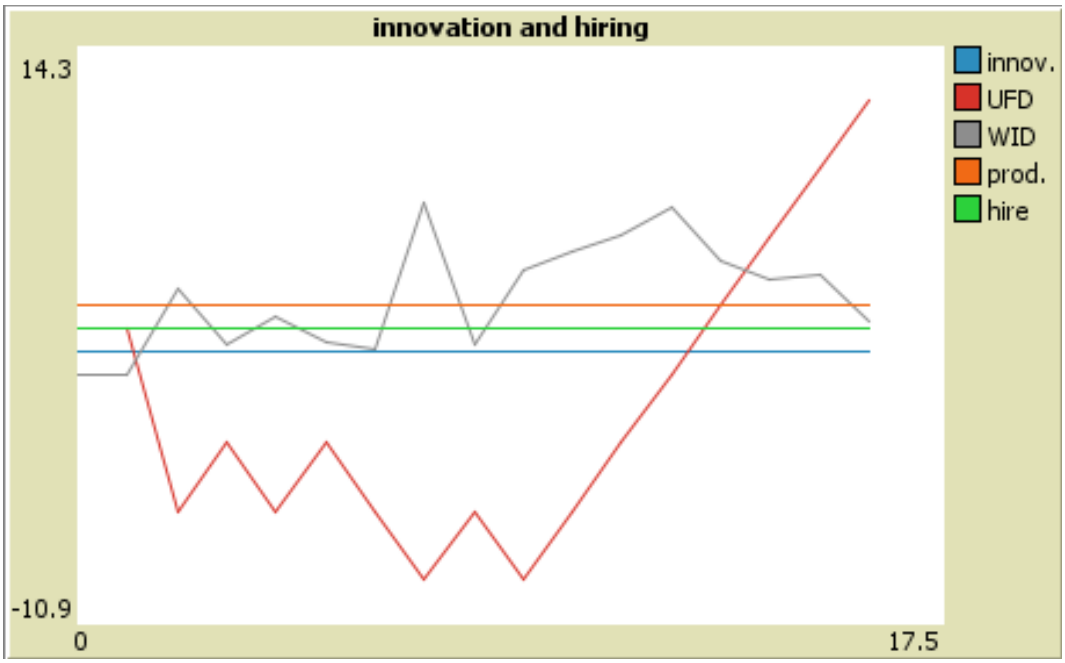
Both “aStepForward” and “aStepBack” are agents, respectively, of the breeds *improvements* and *worsening*, with the former we refer to all positive steps ahead of all the variables (whenever a variable gets bigger than the previous period), with the latter we hint at all the steps back in negative terms (whenever the variable gets smaller than the previous period).

In the case of the command “to StandUpFor” both “aStepForward” and “aStepBack” make soar/slump the union's flexibility degree of 1 unit.

After having defined these two first commands, “to involve” and “to standUpFor”, we are able to show you up the logic stated in the previous page, let us say this with other words: the level of workers' involvement (randomly) decided by the firm deeply affects the union's choice of flexibility, it comes out immediately after having observed the participation degree.

More precisely, unions will set a flexibility degree as a linear aftermath of the involvement; the flexibility will get higher than 2 (initial level) if and only if trade unions judge sufficient the participation level chosen by the firms.

We can be clearer by plotting a chart:



The grey line tracks down the workerInvolvementDegree variable (WID), the red one stands for the unionsFlexibilityDegree (UFD).

The slider in the interface, representing the minimum flexibility required by the union, is fixed at a level of 2, meaning that unions do not ask for a great level of involvement.

Once more remark is needed to make the graph understandable: the UFD value at time t will be a consequence of the WID value at time t-1; this means that unions take action (in terms of flexibility level) with a 1-period delay.

The green line (showing the hiring rate, here kept constant) helps us to see where is 2, since we have put the slider of the minimum required exactly at 2; 2 will be a threshold spotting the two possible paces: upward if flexibility gets larger, downward if smaller.

Let us provide you an example: if the WID drops below the green line (=2) at time t+1, in the next period t+2 UFD will be downward sloping. It happens so because a slump into the WID below the required level by the union is followed by a reduction into the flexibility guaranteed to the firm for new innovation plans.

From a conceptual point of view it is strongly relevant: unions want the firm to get into the company decisions the represented workers more, if this condition is not fulfilled they disagree to bolster innovation projects.

On the other side, if WID stays above the (required) level of 2 for more than one period the UFD can increase for several times until reaching the positive sign (as in the chart of the previous page), where this goes beyond the initial UFD of 2 and this would imply an increasing flexibility, successively leading to innovation progresses.

In the case shown in the graph WID has started (randomly) from 0 and UFD from 2 (as pointed out in the output area of the interface).

Furthermore, we can notice one more feature: from time t=9 until t=17 WID has stayed above the level of 2, it has enabled the UFD to increase continuously, to get over the initial value of 2 and it reached a peak of 14,3.

Let us move forward, the next command concerns again the firm behaviour.

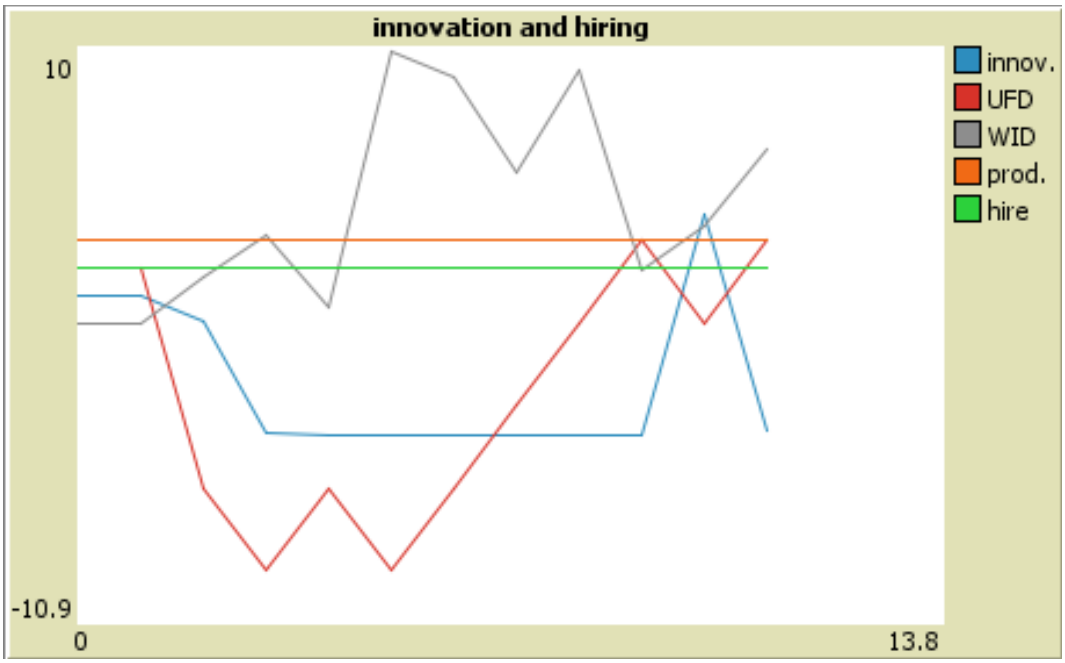
That is “to innovate”; as written in the output area of the interface there is always a minimum level of innovation performed by the firm (it is equal to 1). We have

assumed so simply because we are interested in noticing if different levels of union's flexibility might cause an increase (or a decrease) above (or below) this starting value; this means we are looking for the impact of other variables over the current level of innovation that can be higher than zero as well.
For the innovation we have set as feature the sin of this variable: in the chart we will be seeing the sin of the innovation, this trick allows us to contain too high values of this variable.
Even in this command, as we have applied for the previous one, the innovation level can undertake two patterns:

1. if the union's flexibility exceeds its starting level of 2 (meaning that unions are increasing their support to innovation) the firm invests more into innovation projects because of the deals signed with the unions; some more words are needed, when we speak about union's flexibility we refer to more innovation agreements signed and consented by the unions, their power does count over the implementation of new plans for innovating;
2. if the union's flexibility drops below the level of 2 we attend to a decrease of the innovation, mainly due to less flexibility to agree upon new investments.

The steps upward and downward are of 0.5 and they are given into NetLogo commands by two agents, respectively called “upDates” and “aBitOfFailure”, belonging to the general breeds *improvements* and *worsening*. Let us take the positive case: if union's flexibility degree goes above 2, innovation can enhance and its increase of 0.5 with respect to the level of the previous time.

Let us go analysing a chart:



In the graph above we have added innovation compared to the previous chart, we have maintained UFD and WID as before (the blue line stands for the innovation levels).

Firstly let us focus on the links between innovation and unions' flexibility: until the moment in which UFD stays below its starting level of 2 the innovation does not increase and it stabilizes at a negative value; when UFD breaks up the level of 2 (because WID is above the minimum required for several periods) even the innovation starts growing and it increases over the initial point of 2. The enhanced value of innovation, let us suppose that it takes place at time t+1, follows the positive increase of UFD that occurred at the previous time t.

Since we are tackling with three variables now, let us adopt a broader view including their movements all together:

- if at time t WID goes over the minimum required level by the unions at time t+1 UFD starts increasing;

- if at time t+2 UFD has reached a level higher than its starting level of 2 innovation acquires 0.5 unit more;
- by adding up all these positive slices, at time t+3 innovation can have exceeded its initial level of 1, meaning that there is more innovation into the firms projects.

This list above allows us to state that all of them are tied up, negative WID (or too low levels) would trigger negative UFD and no room for innovation.
Let us go beyond, the next step involves production.
We begin with a positive level of firm production even in absence of innovation increases, it comes from our basic features: (as written in the output area) we have starting levels for all the analysed variables, in this case since innovation is by default equal to 1 it guarantees a positive production of 3.
Once more we are willing of stating that in spite of these (initial) positive values we are more interested in highlighting the causal effects among variables, in this particular context we will try to shape as much as we can the inference of innovation over production.
As performed for the other variables so far described we are going to work out the same way of reasoning for this link, for such an aim let us split in two paths:

1. positive scenario: if innovation goes up its initial level of 1, production will increase of 2 units. The meaning behind this causal relationship claims that a small increase of innovation of 0.5 units sparks more productivity for firms, it occurs mainly because of a gained capacity of being more efficient and competitive through new innovative platforms. In fact the first outstanding outcome of innovation is reflected into more productive production systems. Our production increase of 2 units passes throughout this soared productivity, to be clearer as possible as we can let us say with

these words: an innovation increase is followed by a more proportional increase of production, the latter enhances more than the former because of its gain from productivity benefits;

2. negative scenario: if innovation drops down its initial level of 1 it takes place a decrease for the production level; this would entail a reasoning like: if firms do not set up innovation plans to keep up with the always more competitive markets, they have not the chance to improve their production lines and (in the short run) they would suffer a decline in production, due to less productive and competitive processes and products.

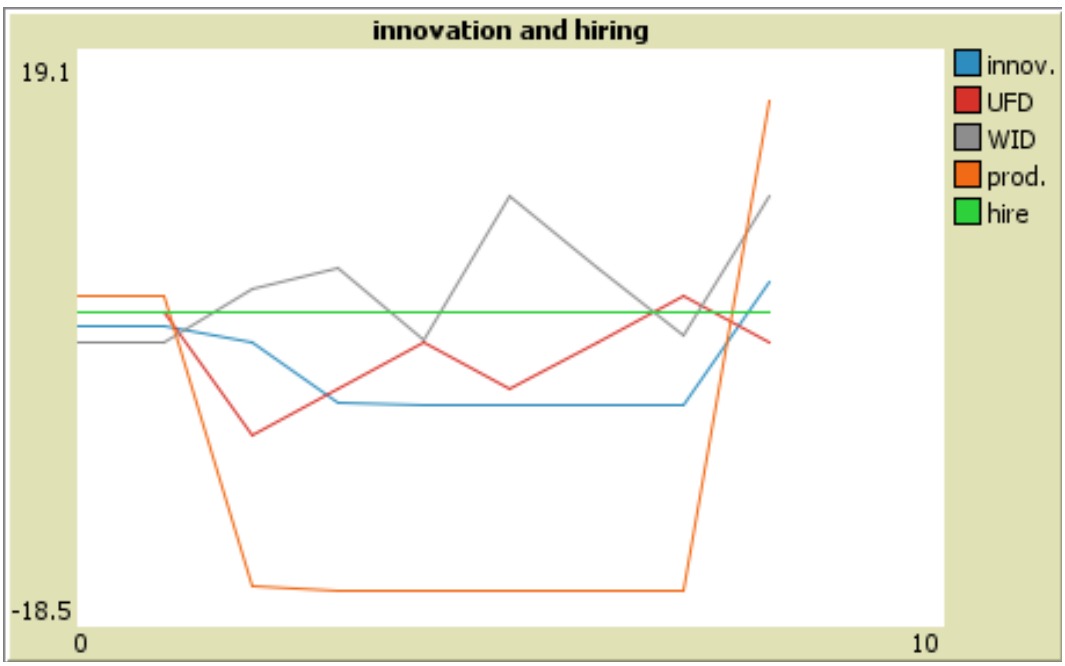
For what concerns the NetLogo procedures we have applied the same logic adopted for the previous commands: “IncreaseOfProduction” and “DropOfProduction” are the two agents measuring the steps above and below the starting level of production, they are agents of the general breeds *improvements* and *worsening* and they are worth of 2 units.

Our analysis has focused so far over four main commands, which are “to involve”, “to standUpFor”, “to innovate” and “to produce”. It gets necessary to join their own paces altogether and to spot what their chain reactions are, in particular we are going to depict a positive framework: firms choose randomly a degree of workers' involvement equal to 4 (by keeping in mind that we set the minimum required level of participation by unions at 2), it satisfies the wish of the trade unions since they notice a more involved worker inside the company executive decisions; it makes increase unions' flexibility, they are happier with the previous choice made by the firm and in so being they sign in new innovation plans launched by the firm management. Innovation updates are allowed and it breaks up the default value, thanks to more collaborative unions firms have the consent to set up productive changes. The very first observable result lies into the productivity; in fact even little increases of innovation (we hint at updated production processes, rather than the product ones) trigger a more productive production line, this latter can exploit a more efficient way of producing what

built up so far, it would imply less efforts (mainly in terms of costs) to produce the same goods and it brings the name of productivity.

For those reasons production will enjoy of an increase greater than the one of innovation, the main productivity result ends up with a rise of production more than double with respect to the one of innovation (0.5 units for innovation and 2 for production).

This thought is represented in graph above too:



The chart of the previous page depicts a quite complete scenario of the way in which our variables interact among themselves: all of them start fluctuating negatively, until WID stays above its minimum required (by the unions) for several periods, it enables the UFD to rise and to reach a peak higher than its starting level. This last event causes positive effects in the next periods for increases in innovation and production. All these steps occur just as a fulfilment of the conditions for each variable.

The next parameter to inspect is “to hiring-rate”.

With this command we can truly assess the benefit of innovation, let us say with a

brief statement: more innovative processes guarantee more productivity, then followed by more production, but above all the gained productivity (whose origin is inside the innovation) grants the workers to be more productive. In other words, after innovating, a worker can produce more than before, meaning for more efficiency.

Within this command we have defined how firms hire new workers as consequence of the previous actions, that means as result of innovation and production levels.

By saying in a few words: if production goes up, the firm will be able to hire new workers, or we could say that it is forced at doing so, since the new required products (by the consumers, for the higher quality coming from the innovation plans) have to be built up by more employees.

Before going to comment the related codes, we would like to specify what the core of this command is: the fluctuations of "to hiring-rate" is compulsory to the increases and decreases of all the commands described so far. It stands for the last aftermath of an effects chain, if innovation is enabled to enhance (because of more flexible unions) than production will go up as well and the hiring rate too.

Since there is an excess of products demand over the current firm supply, the company has to decide for hiring new workers to close that gap.

In our simulation we have imposed a constraint, the increase in the hiring-rate will be lower than the one of production, that implies production will soar more than proportionally with respect to the hired workers.

Let us pass to analyse the codes. First of all, we have defined the marginal worker as agent "oneMoreWorker" of the agent-set "improvements". Within this breed we have included all the positive steps ahead of the model, in this case "oneMoreWorker" is a single agent of that; we have set it equal to 1 (this comes from our assumption of hiring 1 worker per time).

The condition for the hiring-rate to increase is left to the production level, if it is above its original value of 3, the hiring-rate will go up as well.

To be more precise, if the production gets bigger of 2 units, there will be just 1 worker more: if the production requirements is met, the hiring-rate will increase of just 1 unit.

This feature stands for our wish *of conveying the more productivity* of the workers thanks to innovation, in fact if firms were freely enabled to continuously innovate their production lines (and so products too) we would have workers every time more productive; it would take place because of technological changes, they would guarantee the workers to produce more in the same time.

In our model we have supplied an example of that: (if innovation goes up) production passes from 3 units to 5 (since the increase is of 2 units, as already commented) and the hiring-rate soars from 2 units to 3. In the first period we would have each worker producing 1,5 units of product, after the innovation increase she will have increased it to 1,67.

This basic idea highlights the key concept of our simulation, an economy can afford to decrease the unemployment rate (by hiring new workers) if and only if there is more innovation leading then to more production, all of this has to start from more flexible unions and opener firms (towards workers' involvement).

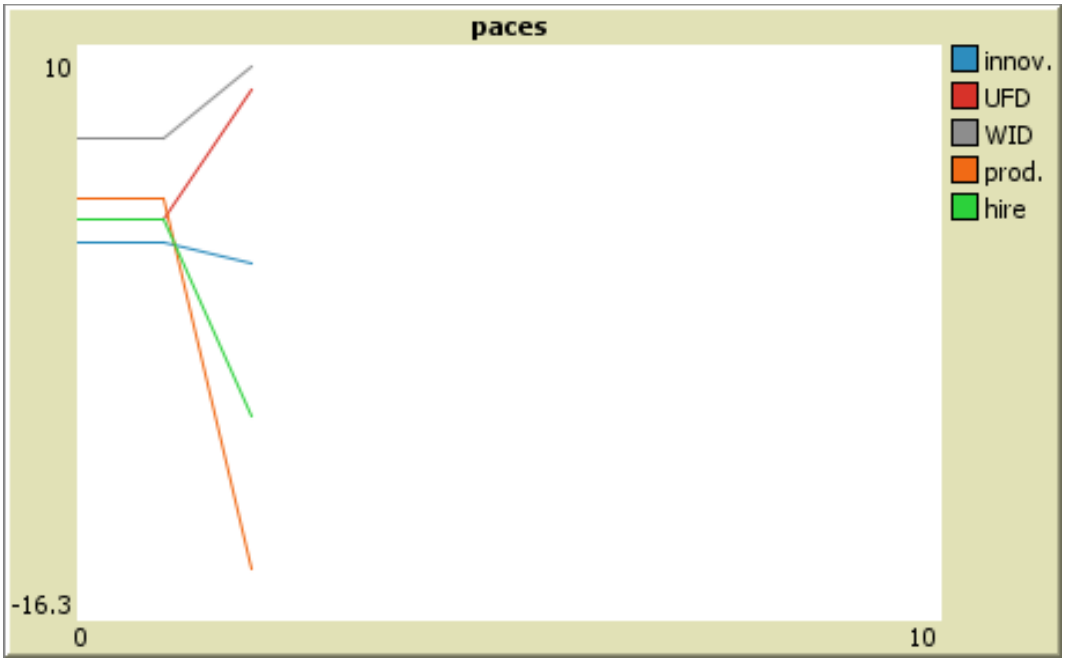
The same flow could occur conversely, we have defined “anUnemployed” one agent of the general breed “worsening”, the latter includes all the negative steps of the model, in this scenario it spots one less worker. Even here, the hiring-rate decreases of 1 worker per time.

As we said for the positive side, if production goes below its initial level of 3 (entailing that there has been drop in the goods demand, so the firm has too many workers currently employed) the hiring-rate will slump of 1 unit.

This action takes place as aftermath of all the previous effects, whose last step is the production level, if lower than where we have begun, the hiring-rate will have to tumble.

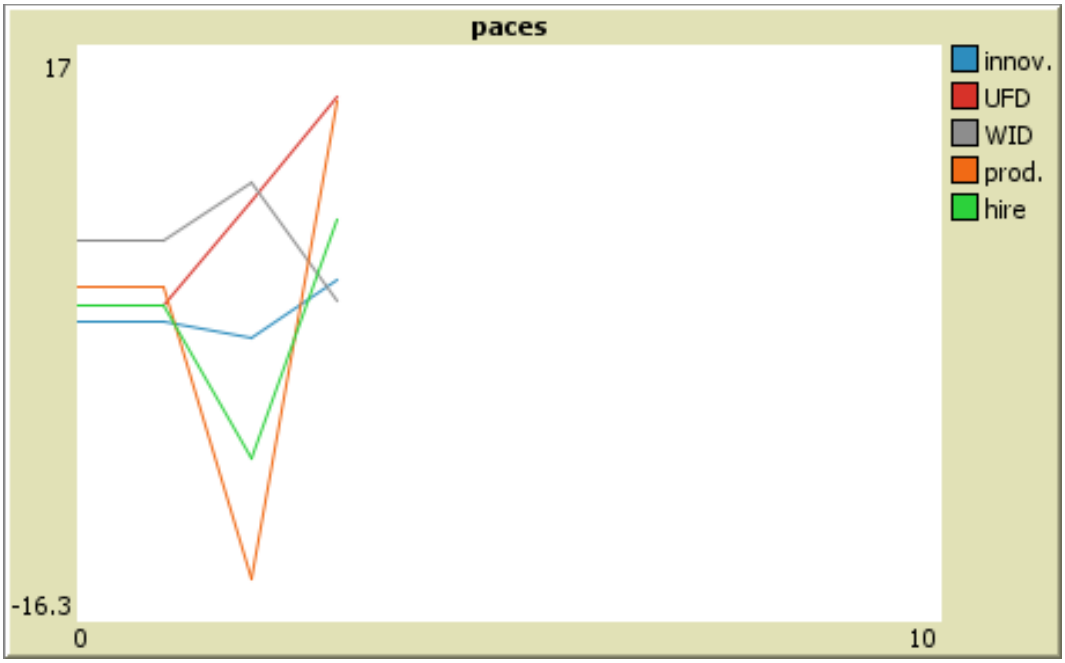
So far we have specified the key role of all the effects chain, whose first step laid in the workers' involvement degree and the last is the hiring-rate: workers' involvement degree, unions' flexibility, innovation, production and hiring are the commands regulating the whole functioning for the labour market in our simulation model.

Before passing beyond, let us recap their common flows with a complete chart:



In this first period we start with a randomly chosen workers' involvement degree of 5,7 (in the chart it is labelled with WID, it is the grey line), since the minimum involvement required by the union to support innovation is fixed by the slider at 5,0, the unions flexibility increases from its starting level (it is called UFD, the red line); innovation, production and hire slump because they do not have already incorporated the positive increase of unions flexibility, since it has occurred just at this time and in our model all the parameters movements are functions of the others just until the previous period of time.

In fact to notice the positive steps of innovation, production and hiring we have to press the button “to go” once more to observe what happens the next period:



In this second time, innovation goes up because of the positive increase of unions flexibility of the previous time, UFD went above its original level of 2, this was the condition for the innovation to get bigger. This latter passed over the starting value equal to 1 and so it allowed for production to go up as well, at its turn followed by a greater hiring rate (this went up because of a production level bigger than the basic value of 3). In this second period it is quite clear one assumption stated in the pages before: the production level increases more than proportionally to the hiring-rate, in fact the orange line (production) goes up far beyond than the green one (hire).

We have settled a command for putting manually the initial seed, it can be done with “to setSeed”, there is the correspondent button in the interface, in which we can digit the original seed, it can be taken randomly too; “random-seed” sets the seed of the number generator.

The next command is useful for clearer charts, it allows us to have more defined graphs. It is called “to exportMyPlotAndInterface”, with this we export the plot “innovation and hiring” showing all the movements of all the variables according to their command codes. We will use these exported plots within other software

(like R) to clear up the full image.

In order to export the interested charts we have created a button in the interface, whenever we press it, the graph is automatically exported into the indicated destination (it is a ".png" file).

Previously we have commented the use of "to hiring-rate", that was the hiring procedure within the whole chain of the parameters, it was the evolution of the way in which firms do hire workers after having settled the innovation and production levels.

After defining that we have thought to insert even a command telling us what are the basic conditions to hire, while the "to hiring-rate" represented the evolution, the command "to hire" sets the requirements to be hired.

To fully depict a hiring setting we have defined "aWorker" a single agent of the agent-set "workers" (that rallies all the model workers), satisfying the conditions for which she can enter in the firm.

These two conditions are: 1. the worker must be "in-radius" of 10 around the company, in NetLogo commands "in-radius" sets out the circumference within which the condition works; 2. the worker must be blue, it implies that she is not already hired somewhere else, in other words she must be unemployed.

If those requirements are fulfilled an arrow will graphically appear between the two agents, starting from the firm until the worker; furthermore, the worker gets green, the changed colour helps us to distinguish between being employed and unemployed.

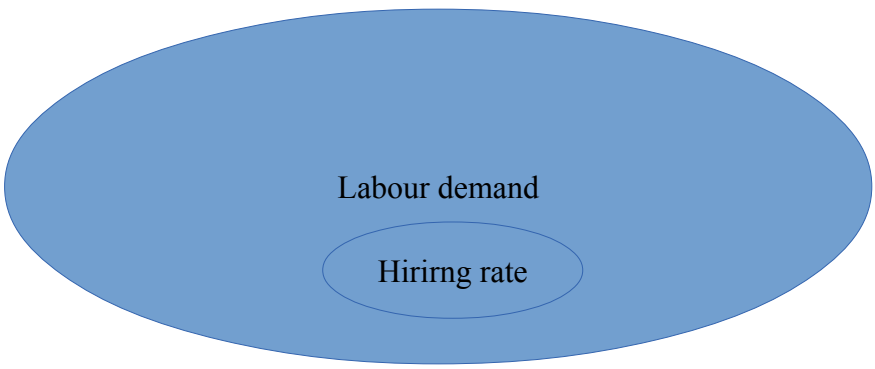
That was the process through which workers are employed, that stands for the basic features to be hired into the firm, if you are in that ray and you are not still working for other companies you will be hired. We can call these steps the normal state of the worker to be "hireable", but it is not sufficient, in fact those requirements are the basic conditions (a sort of entry level), then the hiring procedure will occur just as consequence of the chain effects; the worker (satisfying those aspects) will be employed if and only if there is more production, at least more than its starting level.

On the other side, all firms can fire workers, as they need more workers they also need to reduce them.

We have done this by referring once again to the “links procedure”: we have called “anArrow” all links starting in the firms and ending up into the workers, all these links disappear (and so the relationship of work too) when a precise condition is met by the labour force. The latter is quite relevant to understand what we think about the firing, the employees are laid off if they are more than what currently needed by the company.

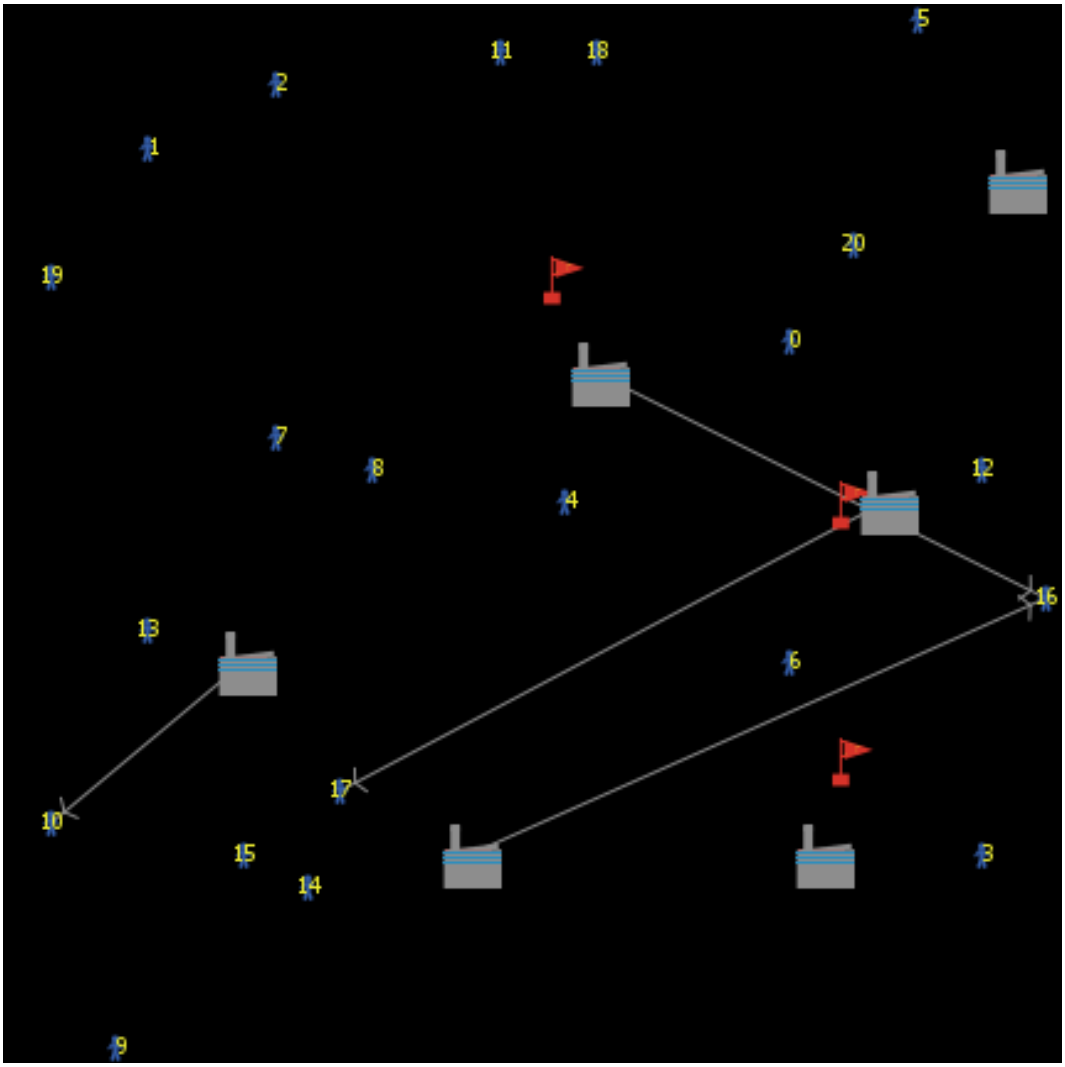
In order to comply with this condition we have created in the interface a slider, whose role is to show what the labour demand is, that means how many workers are demanded by the firm. It perfectly works as ceiling for the maximum number of people that can be hired, in fact if the hiring rate goes beyond that boundary the excess of workers are fired.

We can explain better with a graphical representation:



The bigger cycle represents the labour demand, that is how many workers are needed to fully exploit the production process; while, the smaller one stands for the hiring rate, so how many workers are employed by the firm according to the chain effects that we hypothesize in this labour market. Until the smaller cycle (equal to the hiring rate) keeps being inside the greater one (equal to the labour demand, that is the amount of workers required by the company in the market) there will be a continuous enter of workers inside the firm, for sure if both hiring

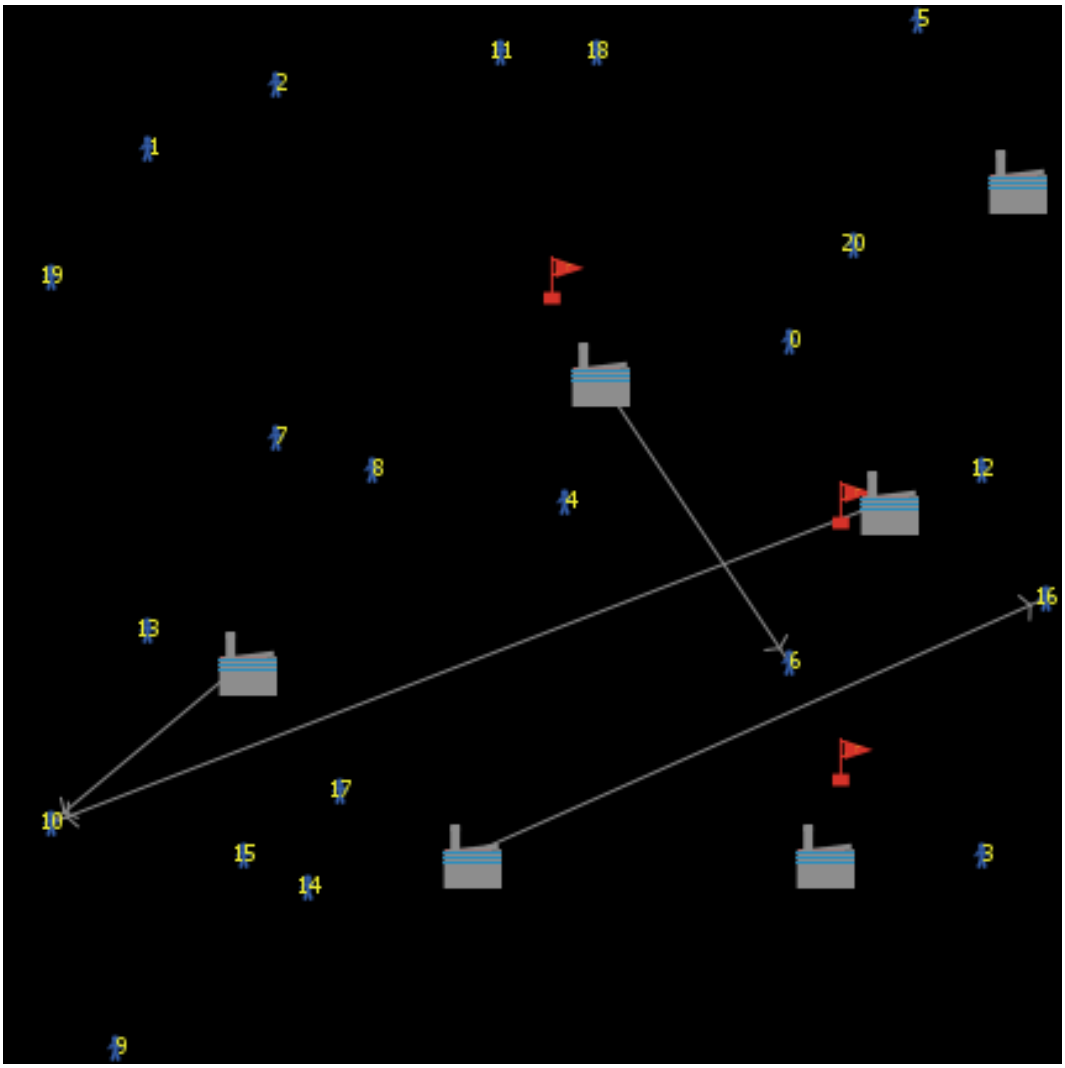
commands are met (as we have deeply stated in the previous page).
But if the labour demand equals the hiring rate, there will be no more new employees, since the current ones have already reached the number wanted by the firm itself.
If it so the link between firm and worker will blow up (it stands for the working relationship between them) and no more employees will be accepted within the firm.
We have spotted the same for the workers' side: we have defined “aLink” a link connecting firm and worker, if there are no more links between the inspected worker and all firms the colour of her will turn to be blue. This last setting is essentially useful for two main reasons, first because it is graphically clear to split between who is hired and who is not, second because of the finished working relationship (it helps us to turn out a stopped relationship of job for that worker).
The next command has been inserted to guarantee the system to be close to the reality, in fact by observing the movements of the links between firms and workers we have been noticing that it could happen to have the same person employed at the same time in two or more firms.
Once we have been aware of that we have opted for more clearness in the system, it is highly unlikely that in the real world a person works for several companies in the same period of time.
We are speaking of the command “to optFor”: we ask workers to choose, it means to stay on just one firm; we have defined two links with the name “anArrow1” and “anArrow2” the links ending up in the workers (in fact end2 is myself, that is the worker since we ask the workers to apply this command). The condition says that if “anArrow1” is different from zero, it means that it exists and so there is already a relationship of that worker with a firm, the second link “anArrow2” must disappear, it implies that the second relationship with a second firm must finish.
We can give you the insight with a couple of charts:



In that graph we can notice that the worker 16 is hired by two companies at the same time, it is so because of two links ending into this worker.

According to our command “to optFor” it is not possible, she is obliged to choose, that is to work just in one firm.

Let us see what happens the next time with a second chart:



In the second period the employee 16 works just in one firm, she has finished the relationship of work with the second firm, since she was compelled to be hired only in one company.

Furthermore, let us suppose that worker 16 was employed in three firms at the same time, according to our command “to optFor” she would be forced at choosing and so the next periods would set out the following scenarios:

- at time t=1, she is in three firms;
- at time t=2, she stays only on two;
- at time t=3, she will finally work only in one firm.

This list entails that the "choosing process" takes place gradually over time, in fact the excessive links disappear just once per time, so if there are many firms for one worker the choosing path will might take many periods before seeing the employee working in one firm.

The last command of NetLogo codes regards the trade union behaviour, it has to do with their flexibility degree.

We have named it "to learn-Union" because it concerns a sort of learning process for unions, it widens until the innovation level derived from unions flexibility.

"Be-more-flexible" is an agent of the general breed "improvements", in fact it points out one unit more of flexibility for unions. This more unit is added to the current flexibility degree (the command is "unionsFlexibilityDegree"), by increasing it positively. To see realized such a positive event a condition has to be filled by the union itself: the hiring rate must be lower than a critical level, that we have called "alarmingHiring" and regulated through an interface slider, whose values rebound between -10 and 10 with an increment of 1 unit per time.

Its meaning tells us the basic concept for the command: the alarming hiring rate is a level of hiring rate judged by the unions as critical, that means too low; if the number of workers (represented by the hiring-rate) is less than this threshold the union starts worrying, because it thinks that there are too less hired people.

When such a situation takes place, that is the "hiring-rate" is less than the "alarmingHiring" the union enhances its flexibility degree of a bit, that means of the unit-agent called "be-more-flexible".

Let us explain this command just in words: the union increases its flexibility to innovation plans when it gets aware of the low level of employment rate, if there are a few workers employed in the firm the union acknowledges that it would be necessary to support more innovative projects to grant the firm to produce more and so to hire more.

The more the alarming hiring is low (close to its lower bound -10) the more the union bears unemployment, it means that the unions does not intervene to increase support until there is a very high level of unemployment rate; for sure in the reality it would be quite rare a situation like this, since normally trade unions do not want to have negative unemployment at all.

5 LEARNING

In this last section of our simulation we are going to look beyond; once we have set up the settings of the model, consisting of several parameters linked each other, we try to learn from what we have built up.

Since this section brings the name “learning”, we want the model to change for learning how it behaves; inside our simulation model we have included many variables, whose movements flow is tied up with all the other ones, if the root changes then all the others will change as well.

In this part we are going to test our setting, we are deeply interested in analysing it, with the purpose of learning from that. All the parameters are allowed to fluctuate, their values rebound between two extremes, this makes increase the chances of having many possible scenarios, but “What is the best one?”.

Via a learning process of the model we hope to understand how the whole model works, and above all if it enables us to achieve our aim, standing for a greater hiring rate (this is our variable of interest, its level will be just the ending aftermath of all the other parameters).

We have decided to add up another “learning process”, thanks to which the union will learn from its own behaviour: here we will not be the learner of the process rather the union plays this role.

To be more precise let us use other words: as noticeable in the NetLogo simulation, the union will get more conscious of its behaviour by observing what are the effects of its attitude towards the innovation. The probability of having a more flexible trade union gets bigger with an-always decreasing hiring rate. The union itself is aware that if it denies support for innovation plans, there will not be the latter ones, consequently production will fall and the hiring rate too. To avoid such a downward sloping scenario the union will be more willing of signing contracts for innovative projects. In the end, the trade union can understand that by being too rigid the final outcome will be negative (above all) for its own

workers.

Our learning section will be split in two subsections, in the former we will tackle with the learning process of the whole model by adopting the genetic algorithms to know more about the results given us by the simulation; in the latter we will just focus on the learning process of one specific agent: the union.

5.1 Subsection 1: *Theory*

This slice of the learning process will be joint by many insights of Miller (1998), he gives us a broad view of the simulation models put in a more flexible perspective. First of all he reminds ourselves how much relevant is getting the use of these simulations in diverse fields, from policy to management; in particular he claims that they are used because of their easy way of being modelled to look into complex systems, most of the time featured by several parameters. The smart point of Miller's view consists in giving the primary role to these same parameters to understand the functioning of the simulation models.

Essentially Miller does not deny that too many variables are complex to manage, but he appreciates even the other side of the coin: thanks to these variables we can become more aware of the model itself, let us add that through all the combinations of their flow we can reach clearer vision of the simulation.

In the Miller's work it is explained how a model structure (and its robustness) is valid by using non linear algorithms, these help us to solve the implications of our model, with them we can know more of how it works.

We are going to adopt the active non linear test (ANTs), quoted from Miller's paper, with these we can easily test the weaknesses of our model structure, where it lacks of consistency and to improve it.

As said above we are going to use the active non linear tests, which are a useful tool to precisely define a class of algorithms, at their turn used to deeply analyse

the model.

According to Miller the main task of the ANTs is quite simple, they rely on the use of a non linear algorithm to look for a set of acceptable (and allowable) fluctuations of the model by aiming at maximizing the variation between the original framework and the obtained one (after the perturbations, fluctuations are so labelled by Miller).

Miller turns us out a general way of assessing the validity and the robustness of the simulation model: by varying the objective function (it represents our aim, what we are looking for analysing) for this optimization path we can check the model in many ways. The analysis will depend on what the actual choice is, that means what the variable of interest is, that is the goal of us as observers.

Miller tells us that ANTs are widely used even to investigate further many models together, composed by several parameters under precise assumptions; this is something similar to what we are going to do as well. From our point of view we are going to work with the ANTs because they enable us to compare many scenarios coming from our model and then to select the best one.

With ANTs, in particular we are going to use the genetic algorithms, we will be empowered of getting the best from our simulation: thanks to the adoption of BehaviorSearch we are going to analyse the way of functioning of our model and by using the genetic algorithms we are going to get the optimal value (of the variable of interest, the hiring rate in our case).

Miller keeps on by outlining a primary role for the non linear search algorithms, they give us the chance of undertaking a more direct search path, whose benefit is to look for groups of parameters that truly affect the whole model mechanism.

Let us just embed this statement to our frame: the use of the active non linear tests (at their turn defining the algorithms, that we adopt) is powerful to spot the weaknesses of the model, these can be upgraded by knowing more of the model itself. By getting more comfortable with the model structure we might understand of how it behaves, where it lacks and where it leads us.

According to Miller, we share his thought altogether, through the ANTs we will not be reaching a precise estimate of the likelihood of the model scenarios, rather it provides us meaningful insights of the extremes of the model. This has to be

firmly understood: the genetic algorithms guarantee us to get the boundaries of the simulation, by computing all the acceptable calculations we will receive back the bounds of the model.

Above all, these sort of search mechanisms have to be perceived as a mean to unveil potential weak points of the model, to correct them if they do not comply with our final variable of interest. Once we have noticed what the outcomes of the model are, we can opt for reviewing the main assumptions to achieve more satisfying results.

This is the most valuable greatness that we have to acknowledge to the genetic algorithms, they detect where the model could be improved just by reporting the effects, then is up to the modeller to act to change what is wrong according to him.

In his paper Miller has used the active non linear tests to find out new sets of variables, such that the main conclusions of the simulation over the future mechanism of population growth path will be in contrast with the original setting given to the model.

Let us spend a couple of words more about the ANTs to better convey you why we are going to exploit them. Firstly, by continuing referring to Miller's paper, to set up active non linear tests we use non linear optimization algorithms to look for fluctuations of the model. We have as aim to maximize an objective function to stress the model. The objective function is what we are interested in getting, so what the model purpose is, and we try to get it by stressing the model. To stress the model stands just for to test it, to notice how it reacts to different scenarios, how it behaves if we change the parameters values.

Miller focuses on two types of optimization algorithms adaptable for the ANTs, even if there is a variety that could be used: the hill-climbing algorithms and the genetic algorithms. In our simulation we are going to use the genetic ones (GA), after having decided it we have to opt for the interested parameters to analyse and test them.

With the help of Miller's research we can set out a generic algorithm form:

1. Let $A_h(p)$ gives the implications of the simulation model for certain hypothesis labelled with *h* under assumptions *p*. $A_h(p)$ is the objective function, that means our goal: "What triggers the hiring rate?". The hypothesis *h* gathers all the relationships among variables that we have assumed to tackle with, in particular we focus on the relation union-flexibility/hiring-rate; the assumptions *p* rallies the parameters of the model, it means the basis over which we have built up the simulation. It is relevant to define the original assumptions of the model that we had at the beginning, let us spot them with *p′*. To embed this definitions into our model we say that the $A_h(p)$ stands for our goal, a greater hiring rate due to a series of chain effects (more involvement for workers, more union flexibility, more innovation and more production), we aim at understanding what sparks positive effects over the hiring rate. The hypothesis *h* of our model can be so resumed: more flexibility of unions will trigger more hired workers (even if we will be including here all the chain effects starting from the worker's involvement degree until the hiring rate), so we think to a more collaborative union to enhance the number of employees; we did not choose this hypothesis randomly, it is strongly tied up with the learning of the union (faced in the subsection 2). We want the trade union to become more aware of its key role into the labour market and this is the reason for which we have constrained it into the hypothesis of the genetic algorithm. The assumptions *p* are all the effects pointed out in section 1: at given levels, more worker's involvement degree causes more union flexibility, if union is more willing of supporting innovation plans the firm is free of innovating its production lines (and then products), this leads to an increased production and it soars the hiring rate too. The difference between *p* and *p′* is that the former is composed by the

parameters values that we get with the algorithm for the maximized objective function, the latter includes the initial parameters values form which we have begun;

2. We define the enabled fluctuations of the assumptions with Δp, this gap has inside all the perturbations of the assumptions, from the initial values up to the final ones. This can be fitted into our contest: the Δp picks up all the parameters values rebounding between two extremes; all the observed variables flow between two limit values, the actual one can be modified with the *slider* in the NetLogo interface; that is, the boundaries of our Δp are written in the *edit* of the NetLogo sliders;

3. Miller advices us to spot our objective function with: $\Pi (A_h(p), A_h(p'))$; an objective function is the final aim of our simulation, what we expect from the model. For us it is the a hiring rate positively affected by a more flexible union;

4. to reach that purpose we have to use an algorithm, it gives us the chance of maximizing the objective function of point 3 under the constraint that $p \in \Delta p$, we do not take into account assumptions out of the defined set.

Once we have shaped the maximization problem, the next step is to choose the proper algorithm, the one that fits into the interested variables search. First of all, it has to be known that there is a plenty of optimization algorithms, all of them can be embedded into for the ANTs.

According to Miller, algorithms can be said to be good if they are able to search over non linear objective functions while they do compare discontinuities in a huge search space. These discontinuities might arise for reasons belonging either to the intrinsic nature of the model parameters or to the kind of allowed perturbations.

The core of the search process acted by the algorithm is to give us out a series of

fluctuations of the functioning of the model; in many cases we could bump into too many flows of the simulation such that it would be impossible to deal with all of them; that is the reason for which it gets primary to better select the amount of model iterations, in this way the algorithm can just manage a few runs of the model. As said at the beginning of this first subsection Miller takes into account two diverse algorithms: hill-climbing algorithms and genetic algorithms (GAs).
Let us spend a couple of words more for both of them even if we will be just working with the genetic ones:

- *hill-climbing*: this algorithm starts working by choosing a random solution inside the search space; for an iteration of the algorithm a new solution is randomly chosen from the neighborhood of the first solution. If the new solution is found in a higher value of the (initial) objective function, it becomes the best solution (called by Miller "status quo"); otherwise the best solution remains the previous one. This same process of assessing what is the status quo of the model keeps going on for a fixed number of iterations, once they end up, the algorithm comes up with the status quo as the solution for the objective function;
- *GA*: these algorithms are rather performed for complex optimization problems. In the genetic algorithms a set of possible solutions is initially created randomly. Each solution inside that population is tested whether is suitable for the problem, and it is labelled with a measure of *fitness*.

Consequently, the genetic algorithm builds up a new population of solutions, within this we will find out an outstanding property of these algorithms: they reproduce both old solutions (according to their fitness degree) and new ones (by creating these new solutions through "genetic operators"). These genetic operators have the task of giving us new solutions for the optimization problem by recombining the solutions; normally there are two types of them:

crossover, they link again pieces of existing solutions in a way such that they do preserve those parts of solutions that are positively performing; mutation, it makes randomly small the alterations in a solution and prevents the system from being entangled in local optima.

After having fulfilled with their role, the GAs give us a new created population, with new solutions inside; from now one we will be dealing with new generation of algorithms and we will be called again at testing the model (but now with this new class of GAs).

At this point of the explanation it embeds perfectly to speak of the space within which we will be operating, that means to define where the genetic algorithms comply with their task, we refer to the *search space*.

The GA looks deep into a space for finding out enabled perturbations, it has some precise limits inside which it is charged of gathering all the allowed fluctuations of the model itself; in other words we could say that the algorithm that we use is a powerful tool whose utility consists in detecting all the possible variations of the initial model within a willingly defined framework (whose boundaries are the limits of the so defined search space).

Let us deepen such an item further: we use into our search process the genetic algorithms since they provide us a research path at end of which we will be more conscious of the way of functioning of the simulation, this is mainly due to the analysis and the evaluation of the scenarios coming from the variations of the model (and they do arise by varying the parameters values in an allowed range); but this is not all, we have to constrain the model, that stands for binding it to big too broad to be properly investigated, for this aim we are asked to bound it by depicting a search space, inside it we will perform our search process.

Furthermore, as specified by Miller in his paper the choice of this space truly affects the outcome, this means that by opting for a specific space we are just interested in determining some precise aspects of the simulation; in fact by setting

limits for the space means to focus on certain model variables and at the same time to rule out other ones.

According to Miller a useful way to set out a search space is to draw it around the initial parameters values, the scholar advices us to define the space in the neighborhood of the original parameters because it allows us to clearly compare the fluctuations with the starting point.

After having spoken of the space within which we analyse the simulation we talk about the function to maximize, it means the objective function that we want to maximize for having a clearer vision of the model functioning.

We apply this optimization process inside the active non linear tests, we define the function (as specified in the previous page where we said how to set up the maximization problem) to look into, we aim at optimizing it, into the search space, to get back sufficient results. These results have to be sufficient in explaining how the model works, we want to be equipped with insights of the model that tell us how the simulation model itself behaves.

Once we have converged to a satisfying search space we will define a maximization problem in this way: $A_h(p)$ is the objective function, it gives us the insights that we want to receive, it originates from hypothesis h by using the assumptions p and with Δp allowed perturbations.

Miller claims the key role of the genetic algorithms, the objective function (that we use) spurs the active non linear tests to detect perturbations deviating from the original path of the model; Miller keeps on saying that ANTs are extremely useful to look into specific areas of the model, they do find out precise areas of which we want to know more, this means we can just focus on a single aspect of the model that we are not sure altogether. With the ANTs we can decide to analyse just one precise behaviour of the simulation by circumventing it, in this way we can improve one single mechanism of the same model. In fact, as underlined by Miller is to restrict as much as we can the search space such that just a few perturbations are allowed to take place and so we can achieve more satisfying explanations of the model functioning; with these words Miller reminds ourselves that the mean benefit of the active non linear tests is to neglect all the non desired fluctuations, just to fix our search analysis on one (or more) interesting behaviour

(s), this allows to get back consistent outcomes.

To be clearer Miller defines a cost function in this perspective, Φ (p, p'), where it is an increasing cost function of the number of included perturbations, the more fluctuations we include into our tests the more it costs for us in terms of consistent results; more perturbations will lead us to a less satisfying explanation of the phenomena. With cost we refer to the distance between the initial assumptions p' and the final ones we reach p, the larger is this size the more it will cost for us and the less consistent outcomes we will obtain.

Miller ends up his paper by emphasizing the outstanding role of the active non linear tests, in saying that they are the most useful tool used for reaching a complete analysis of our simulations; ANTs are recognized to be remarkable because they allow us to test what occurs into our models, we can get more aware of their way of functioning. Once we think to be done with the simulation settings we can begin with its exploration, to go deep inside means to acquire a higher degree of its knowledge. By adopting other words we could state that after having outlined the frame of the model we still have to start, that means the most relevant phase of making simulation just starts taking place with its flow analysis.

Secondly, Miller reminds ourselves a strengthen of the ANTs, they guarantee us to find out possible weaknesses of the model itself, this does entail that if we have built up our model over fragile basis, with the genetic algorithms we spot them and consequently we can improve it. The next aim is to construct a model better shaped, after having learnt from it, to define a more complex system.

Miller concludes by saying that with active non linear tests we can detect best and worst scenarios of our simulation, to develop insights of how to enhance it globally by modifying the parameters values.

The same topic has been studied by Stonedahl (2011), he analysed the useful task with which genetic algorithms comply with the exploration of the parameters spaces in simulation models; essentially he looks into the adoption of this class of algorithms to understand and consequently to further explore the several behaviours generated by the simulation.

To say differently, with his research Stonedahl wants to end up with a precise role for the GAs, how they could help us to define the model functioning. The same

issue has been tackled by Miller, both authors refer to the common function of the GAs as investigating algorithms, they try to embed these genetic algorithms as a link with the Agent based models. In fact, as reminded ourselves by the scholars the ABMs are a powerful simulation technique through which we can represent interactions amongst agents following some precisely defined rules.

This is exactly the point that we would like to handle with, since with our simulation models we are able to depict an ideal scenario (as we did in our case), in such an imaginary landscape we aim at getting a benchmark-representation where all the agents reproduce a required behaviour (by interacting among them). But that is not sufficient, it could be seen as bounded: with NetLogo we construct quite complex ABMs, but without knowing how the model behaves, in fact in NetLogo models we find just an overall structure; if we want to study deeply the roots of the model we have to go to BehaviorSearch.

Here we have the turning point (and it is the core of the Stonedahl's analysis too), after having got the expected results from the model we want to be more comfortable with the *possible evolutions* of the same and above all we would like to know why we got those results; as claimed by Stonedahl, the agent based models are getting popular rapidly, but to be used as they should be they are not complete if they are not joint by a deeper investigation with the genetic algorithms.

One of the immediate advantage of using this class of algorithms to analyse the model is the following: since the majority of the models are built up over many variables it would be too costly (in terms of time especially) to reproduce and to look into all the possible scenarios generated by all their combinations, and we would not come up with any consistent outcome; the genetic algorithms (as we have already said by speaking of Miller's paper) have the peculiarity of offering us a metaheuristic search mechanism, that consists in a combination of optimization problems at the end of which we will receive back the optimal solution.

Stonedahl tells us something more about the evolution of this type of algorithms, even called evolution-inspired algorithms, this term is a useful indicator of their role: the genetic algorithms implement two kinds of evolution (in the analysis of the model) for programming and for setting strategies. This is the key point of the

GAs, they have an intrinsic nature leading us to undertake an evolutionary path, that will enable us to program further the model and, if necessary, to set up new strategies.

We think one passage of the Stonedahl's paper to be extremely valuable, where he underlines that the mean contribution due to the genetic algorithms is their capability of detecting the **DNA of the model**, from this their feature it finds the origin their name, genetic.

The GAs are the application of principles of biological evolution into the computer science, aiming at a problem solving technique; in fact they are a search procedure used to explore the simulation behaviours.

We have decided to quote the Stonedahl's paper because the purpose is then applied it into our perspective, the scholar wants to find out a reply for the following question: " Do GAs give us an actual search technique to look into the parameter spaces of the ABMs?". We are interested in knowing how much powerful its answer is, then to apply it into our simulation project; we could say that the Stonedahl's research is a sort of needed comprehension of the effective power of the genetic algorithms.

For sure, without any doubt, Stonedahl answers positively to the above question, he claims a fully searching role for the GAs in the investigative analysis of the simulation behaviours; however he tells us that it would be too narrowed to just supply us a positive reply, without saying the reasons behind it, for this extent he splits the original questions in sub-questions that are meaningful for better depicting the genetic algorithms role:

- how can the genetic algorithms be used to provide us complete answers to our questions over the model structure? That means, is there a proficient way to use them to better perform?
- What kind of results do the GAs find in the search process? Or, how could we interpret their discoveries? (To be fitted into our goal expectations);

- Are the genetic algorithms more efficient than other similar techniques? Or, with respect to other algorithms? (such as the hill-climbing, mentioned by Miller);
- Where is their efficiency directed towards? That is, where do they give us clear results of their action? And, could they be improved with the aim of giving us clearer replies?

A section of the Stonedahl's paper is dedicated to the search space, we have spent some words to describe it while we were commenting the Miller's statements; let us add up other features of the search space to go beyond, that means to convey you what we refer to when we mention it.

First of all, we have to begin by saying that with search methods we mean the many ways of exploring the parameter space; there is a plenty of possibilities for investigating the parameters of the simulation, we might use dozens of them, but not all can be embedded everywhere. To prove this, once more we rely on Stonedahl's words, he reminds ourselves that "to search" is a synonymous of "to optimize", according us this comparison is truly meaningful; because with an optimization problem we draw an objective function that we want to maximize (with respect certain conditions and under some hypothesis), and exactly this function will stand for the model behaviours that we are interested in studying.

In other words we can say that the search space outlines the framework within which there is contained the objective function (= purpose of the analysis) that we are going to maximize. Some scholars have defined the search space as a box, whose limits are the boundaries of the investigative process.

The paper of Stonedahl is grounded on the links between *NetLogo features* and *BehaviorSearch benefits*, where with NetLogo we define the simulation model and with BehaviorSearch we investigate its fluctuations.

Stonedahl tells us that one of the key features of the ABMs is the use of randomness, this can be an advantage for the modeller, since every time that we run the model we get diverse outcomes that could be useful for analysing the

model itself, by adopting several perspectives.

In NetLogo, by default, every time we start running the model, we end up with different results (of the parameters values), this takes place because of the diverse initial *seeds* for the random number generator.

Stonedahl says that, given the randomness of the model runs, a common approach is to see each model generated as a signal with some amount of noise, to run that model for a fixed number of times and finally to take the mean of the results; this means that we are aware of the multitude of outcomes created by the model, to skip possible misunderstanding results we have to take the mean value. To comment this passage Stonedahl proposes two related issues:

> 1. if we are looking for the search space of a specific objective function, it is far better to distribute trials based on how much promising the area of parameter space is. For instance, if we realize that after 20 trials the fitness of an individual is lower than the fitness of other individuals in the population (within the same region of the search space) we should have no doubts that to run other 10 times the model to improve the statistical significance (of the observed individual) makes no sense. With this example Stonedahl claimed that while we are running the model we have to be ready to detect if we are searching the right parameters, otherwise if they have any statistical consistency it might make sense to stop it and to look for other potentially interesting parameters;
> 2. if we have noise in the output of an agent based model we have to carefully interpret it, since it could be a measure of the predictability or robustness of the parameters.

Let us refer just once more to Stonedahl's paper for what concerns the chromosomal representations due to the GAs role.

We know that agent based models can contain a huge range of parameters types, for this reason as we have said in the pages before by using genetic algorithms we can easily handle with all of them, because of the GAs capability of being flexible enough to tackle with all of these many representations.

So far there is nothing of new, in fact to go further in explaining the remarkable task of the genetic algorithms we are asked at saying why they are so needed: we have to begin by knowing that ABM are featured by many parameters types, in each model we will be constructing we will have a quite sufficient complex setting that will give us a variety of results. We exactly start from this mass of outcomes, where the genetic algorithms focus their work on the appropriate choices of the chromosomal representations.

According to us this underlines the key role of the genetic algorithms, they combine the many types of results as human chromosomes; through these combinations a new generation of outcomes is generated and the optimum can be so spotted.

To this purpose we have firstly asked ourselves if optimization problem has been properly posed. It is a necessary step, since if the condition above is negative, the efficiency of the genetic algorithms in exploring the model behaviours will fall down. During the same phase, another question could emerge, that is if the genetic algorithms are the best technique to use, and in this case Stonedahl helps us in saying yes, in fact the most complete technical analysis can be just filled by the GAs. Even if Stonedahl points us out that it is not possible to clearly spot one algorithm as the most efficient in each kind of search mechanism, in fact their fitness varies according to the model we are studying; he specifies that it might be that to deeply explore some *precise agent based models* it is preferable to use one precise type of them, the genetic one.

With *precise ABMs* we refer to those cases where we are constrained at working with a huge number of fluctuations, this is actually our simulation: since we have built up our model over many parameters (we list here the 5 most important: workers' involvement degree, unions flexibility degree, innovation level,

production and hiring rate), their summed fluctuations lead us to several scenarios, that is exactly what Stonedahl was referring to.

5.2 Subsection 2: *Applications*

This section is dedicated to practical experiments of BehaviorSearch. After having described the theoretical use of genetic algorithms, by quoting some scholars' point of views, we start elaborating these useful means for learning processes.
We have built up a simple model to convey you as clear as we can the general idea behind the utility of the GA into the ABMs; the second case instead will stand for the link with our own NetLogo model (described in this thesis).

5.2.1 First example

Settings
Let us begin with a simpler simulation model, created with NetLogo and analysed with BehaviorSearch. The main reason for which we start from this case comes out from our goal of allowing you to surely get rid of all the doubts upon GAs efficiency.
The frame of the model is as follows:

> *We look into a market composed by two categories of agents: buyers and sellers. They interact among each others by exchanging commodities. An exchange takes place if and only if the buyer's price is at least equal to the seller's price, if it is not*

so there will not be any exchange into the market. As referee agent we have the buyers, they will purchase a good just if a seller is close to them (and as we have stated above because of prices level). To be more precise we have labelled both categories prices with "reservation prices".

Consequently we focus just on one seller (Seller 0), her price will be named "Smartprice". The reason for which we look at one precise agent comes from the overall aim of the analysis: we are interested in noticing how 1 agent behaves into the whole community in which she operates.
This last idea has to be explained further: in NetLogo we have put together all the codes, both of the single agent (Seller 0) and of the two categories (buyers and sellers); instead, in BehaviorSearch we are going to switch them off, we are going to set up a behaviour-analysis of the single agent (with a few parameters, that means how she reacts if there are just some of the model variables) and a behaviour-analysis of the single agent inserted into the whole model (where there are all the NetLogo parameters). In the first case ("the incomplete one") we are going to observe how the Seller 0 will offer her own reservation price (Smartprice); in the second one ("the full case") we are going to look at both the price of buyers/sellers categories and the Seller 0' s price. A common element between the two searches is the stress upon the Fitness, meaning the maximized objective function, that in our case is the mean of exchanges; we will be interesting in assessing if it enhances in one of the two cases.
The emphasis will be on the single seller, it represents even one of the aims of this research, it can be resumed into a question:

" Does the single agent modify her behaviour choices when plugged into the whole model, with all the agents moving in? That is, does she improve (it means "to decrease") her offer price?"

Let us spend a couple of words more over that, the stress is grounded on this basic idea: when the single agent operates into the overall system (with all the other agents), she learns from them and she will end up with a lower reservation price than what actually she would offer by acting alone (this concept will be better explained ahead, when we speak of the BehaviorSearch model).
That means the Seller 0 if taken as the only parameter of the investigation she would give us a price quite high, far from the price at which exchanges take place into the market; moreover, the fitness of the search will be lower than the one of the global model (by observing all the NetLogo parameters).

NetLogo codes

First of all we have defined two classes of breeds: buyers and sellers, respectively representing two agent-sets, within which are gathered both single agents, sellers and buyers. All the turtles of the model own a reservation price, differently settled for both kinds, buyers' price is settled lower than the sellers' one.
Moreover, for what concerns the initial functions of the simulation we have inserted just one global, standing for the exchanges amongst the agents, in particular we are going to focus on the *mean of exchanges*.
With the setup we have created 30 buyers and 30 sellers, randomly located; this choice is not obvious, we have opted so because it guarantees us to always have randomly-arisen agents, otherwise if they were fixed we could have some agents that would not exchange at all (since generated far from all the others and not allowed to change position). To fully understand it let us add up that all the buyers are going to set up exchanges with the sellers if and only if two conditions are simultaneously fulfilled:

1. a Seller is in a maximum radius of 5;
2. if the reservation price of buyers is greater or equal to the sellers' one.

If those conditions are met the number of all the exchanges will increase of 1 unit. This passage is quite crucial, let us spend some words more, more specifically: the buyers' reservation price augmented of the product between a random number (given by the increase of the price itself in a range floating between 0% and 30%) and the price itself must be at least equal to the sellers' reservation price (dropped of a percentage between 0 and 30 times the reservation price itself). If that inequality is respected the number of exchanges will get higher.

The conditions listed above operate into the NetLogo model through a command imposed to the buyers, in particular: if a seller is in radius of 5 and their price is at least as the sellers' one the exchanges will be more.

As we have stated in advance into the preface of this section, we observe, a part from all the buyers and sellers, even a single agent: Seller 0, whose price is labelled as Smartprice. All the agents move randomly, by turning around themselves of 360º and they go ahead of 1 step per time.

To end up the codes section let us say what you are going to find into the interface:

- through the “setup” button the model starts; with the “go” button the model is run *forever*;
- there is a monitor, checking for the mean of the exchanges, how it evolves over time, is goes up or down, due to the price meetings between the two categories of agents;
- we have created three sliders: two of them represent the maximum (100) and the minimum (0) of the buyers' and sellers' prices (considered as whole groups); the third slider allows to shift the Smartprice of the Seller 0, even this is bounded between 0 and 100. All of them have an increment of 1 unit per time.

BehaviorSearch

This is the most engaging part of the research, since after having settled the model parameters in NetLogo we are going to analyse its behaviour.

To tell you why this step is so relevant, let us turn the previous sentence into our perspective: in NetLogo we have created two classes of agents interacting among themselves if two conditions are met, otherwise no relationships occur, in particular we have spotted one precise agent of one agent set. With BehaviorSearch we want to know how that single agent moves into the whole system, and this is done in two directions: a) how the agent moves if she is the only turtle inspected; b) how she changes her behaviour if observed into the overall model (with all the other parameters). Furthermore, the second most relevant observation will be on the Fitness function, we want to note if the mean of exchanges is greater when Seller 0 operates alone or if when she is in the overall community of agents.

We have exactly performed so, the first trial that we have made concerns the behaviour analysis of one single agent (Seller 0), we have named it **individualGA**, standing for the adoption of genetic algorithms with one individual.

Let us resume here the settings:

- parameters specification: Smartprice, the reservation price of Seller 0, between 0 and 100 with an increase of 1 unit;
- measure (to be observed): mean of the exchanges;
- search method: we use genetic algorithms with standard binary chromosomes;
- we want to maximize the fitness function (equal to the objective function) and all the measures will be collected at the final step;
- we begin with a randomly created initial seed every time, this allows us to start always from different points and so it is more likely to get diverse outcomes;

- we perform three searches, since one single could not give us back the best parameter, instead, more searches may improve confidence.

By executing the search process we get three different results:

- Search 1: Smartprice = 15.0
- Search 2: Smartprice = 12.0
- Search 3: Smartprice = 10.0

In all three cases the Fitness has been of 7.22 (in the last search was just a bit higher = 7,24); the reservation price of Seller 0 has dropped each time until reaching 10.0, this means that this seller has revised her offer price downward by enabling for more exchanges, as testified by the last run fitness. In fact, our focus is stressed on the fitness, we take here the mean of all three searches to compare it with the next run case.
To better understand these results let us introduce the second BehaviorSearch that we have made: **individualCollectiveGA**, that means we observe all the parameters of NetLogo simulation, here the Seller 0 acts with all the other model agents. The BehaviorSearch features are the same of before with the exception of the parameter specification: buyers' reservation price, sellers' reservation price and the Smartprice of Seller 0 (that was the only one of the first run). Let us remind ourselves that we use genetic algorithms and the aim measure of the search process is again the mean of exchanges taking place between sellers and buyers.
We recap the results in the table below

	Search 1	**Search 2**	**Search 3**
Buyers' price	95	60	65

Sellers' price	82	58	54
Smartprice	62	33	48
Fitness	***27.48***	27.26	27.35

After all these searches we can easily notice that the best results belong to Search 1, since in that case we have the highest Fitness, that means we get the highest outcome of the maximization problem. We have to admit that both sellers' price and the Smartprice are much lower in Searches 2 and 3, but what allows us to have the highest Fitness in Search 1 is the buyers' price (approximately 30% more than in the other two searches).

Two more considerations are needed, as comparisons with the single-agent BehaviorSearch (**individualGA**): in that case the Smartprice was lower than what we have here but the truly interesting variable is the Fitness of the function itself, in fact there we had just 7, instead here our objective function has a Fitness greater than 27 and this means we have more exchanges made between two groups of agents than the case in which we were focusing just on one agent. Moreover, by comparing the price of Seller 0 with the one of her agents class (sellers), we can observe that Seller 0 offers always a lower price, meaning that she performers better than the class average.

5.2.2 Second example

Settings

In this second application we refer to the analysis of the so far discussed NetLogo model: labour – market simulation. In order to have a complete vision of the model let us dedicate a few lines to state the main conceptual lines.

The model system is composed by three categories of agents: workers, trade

unions and firms, by interacting among themselves the same agents can improve their value parameters.

Let us deepen their roles separately: workers, they can be hired or fired by the firms, the more workers are hired the higher the hiring-rate will be; unions, they are the intermediaries between workers and firms, according to their flexibility (towards innovation plans) the firms will be able to increase/decrease innovation and production (consequently hiring); firms, they can hire/fire workers, by the initial level of workers' involvement degree can be derived all the other parameters ending up with hiring-rate, its role is crucial.

To translate these statements in words we could say that we observe a system where workers are hired by firms **if** unions sign innovation projects **if** firms properly involve workers' into managerial decisions; we have constrained all their actions among them, they are bind at acting in precise way if they want to be better off, that is to improve their current state.

Furthermore, we might say that there are just two *active agent-sets*, unions and firms, workers can be said to be passive since their status (employed or unemployed) is just a consequence of what is decided by firms and unions actions. Whenever unions move, they have two possible paths: either allow for more innovation or neglect it and stay on a rigid behaviour; a union more willing for innovation will enable the firm actually to innovate more and in so doing to enhance production level, the final outcome will be a greater hiring rate (that stands for the unions' aim too).

But, on the other side there is the firms' constraint: unions will agree on innovative plans if and only if workers are actively involved into managerial decisions; it would be possible to set up an overall improvement of all the model parameters leading to more innovation, more production and more hired workers (with respect to the initial settings) if and only if employees participate into company decisions.

NetLogo codes

We have been looking at NetLogo codes in the pages before, in spite of this we are going to recap the key codes, useful to better understand the BehaviorSearch analysis.

We begin with initial levels of the following parameters: unions flexibility degree is 2, innovation level is 1, production level is 3, hiring rate is 2; the first move, as we have said in the previous section is up to the workers' involvement degree, decided by the firm. In our model this parameter is chosen randomly by NetLogo [random-float 10], meaning that the software generates a random value between 0 and 10; the purpose of doing so is that we are not interested in leading the firm to behave in a certain way (i.e. to not involve workers at all or doing that fully), rather we prefer noticing how a precise behaviour of the firm (in involving workers) can affect the next parameters of the model. In other words, we could start from both high and low levels of employees' involvement, but our goal is to analyse how much this involvement (positive or negative) make change the next variable, such a unions flexibility.

Moreover, we do not start from zero – levels of these parameters, since we suppose a minimum of variables to exist as well, then from this framework we analyse how the whole system can improve, or perform worse too.

Through the command 'to involve' the firms (randomly) involve their own employees into management decisions, they can be taken into account with a value flowing between 0 and 10: 0 means that workers are out of all the decisions; 10 stands for a workers' weight equal to executives' one.

As aftermath, after noticing the involvement degree, unions opt for a flexibility degree, that will be negative (even called rigidity, towards investments) if workers are not involved at all (workers' involvement degree is set to 0); the flexibility will be positive and greater than the starting level of 2 if the involvement is greater than a threshold: 'minimum involvement'.

This last parameter is regulated through a slider in the interface, whose values rebound between 1 and 10; if workers' involvement degree chosen by the firm (once again randomly) is greater than the minimum involvement the unions flexibility will get higher, otherwise it will drop from the current level. It is

interesting to notice the meaning of such a relationship: the level of involvement decided by the firm has to be higher than 'how much is required by the union to be sufficient' to involve workers. This means that the higher the 'minimum involvement' is the more difficult will be for the firm involvement decision to fulfil with this and consequently to allow for more unions flexibility.

The outcome of this relationship will determinate the unions flexibility move, if the firm involvement decisions is higher than the minimum required by the unions, the unions flexibility will be of 1 step greater than the previous level.

A higher union flexibility will trigger more innovation, if the former is higher than the initial level of 2, innovation will soar as well; this is a pure consequence of the deals signed by the unions: the more deals are signed (for innovation) by the union, the more the firm will be enabled of setting up innovation plans. All firms are bind at innovating if and only if unions agree on innovation plans, if they do not then innovation will plunge.

The third step regards the production, whose level will enhance from the initial value of 3 if innovation is greater than its own starting level (of 1). Let us be clear in this point: if innovation is higher than 1, production will increase of 2 units, this means that more innovation sparks more productivity (that is, with the same inputs we can produce more output) and the associated increase of production will be more than proportional because of the gained productivity (we could look at this as the capability of being more efficient, that is a consequence of new innovative ways of producing).

More production will lead the firm to hire new workers, since in order to be able to meet the excess of products demand the firm needs more workers to produce this extra – demand: the structure here is similar as above, if the production is higher than the level from which we have started (= 3), a new worker will be hired, since more production has to be performed by new employees, the ones that are already in are not sufficient to produce everything. A negative scenario is possible too, if the production slumps below 3 there are too many employees into the firm, some of them will be laid off.

What we have described so far is the chain path of the observed variables, if one of them changes the next ones will be affected too; in particular the key role is

played by the workers' involvement degree up to the firm, its level will influence all the other ones.

The core of the whole simulation is the hiring-rate, we want to get back a specific way in which firms hire/fire in response to the external signals, those ones given by the other agents, like trade unions. For this aim, let us point you out the hiring process; we refer to the command 'to hire': we have defined 'aWorker' an agent of the agent-set 'workers' that grounds within a 10-radius circumference of the firm, with colour blue. These two conditions to be hired mean: 1) a firm willing to hire relies just on the workers close to itself; 2) the worker has to be blue, that means the worker is not already hired in other firms and she is so unemployed. For all the workers complying with these two requirements the firm will spot the job – relationship with a link, the workers' colour will turn into green (that is hired, it turns out the positivity of the obtained job).

As the firm hires, it can fire too; that takes place when the 'hiring rate' is greater than the 'labour demand', if it is so the link between firm and worker will disappear and the worker will become again blue (unemployed). The condition that we have imposed to wipe out the job – relationship stands for an excessive hiring rate with respect to the actual labour demand of the firm itself, by saying this in other words we can state that the needed number of workers by the firm (labour demand) is lower than the hired workers (hiring rate).

Let us be clearer over this last item:

- hiring rate: it represents the number of workers hired by the firm as (last) consequence of the effects chain described so far (by starting from workers' involvement degree until the production level); its value comes out as the levels of the previous parameters. As a paradox, it could enhance with no limits;
- labour demand: its value can be modified through a slider in the interface; it is an **upper bound** for the potentially always increasing value of the hiring-rate. For the firm it is possible to hire until it reaches the maximum needed by the firm, called by us 'labour demand'.

We put a second condition for the workers, if they are simultaneously hired by more than one firm they are forced at staying just in 1 of them: 'anArrow1' and 'anArrow2' are two links representing two job – relationships of two firms with the same workers, if it is so 'anArrow2' will die; this means that just the first link (of firm 1) will persist with that worker. We have decided to insert this condition since it makes sense for an employee to work just in 1 firm in one period.
Last step concerns the unions flexibility, we impose conditions for improving the same: if the actual hiring rate is lower than the 'alarmingHiring' the unions will get conscious that it has to be more flexible, since the unemployment is achieving levels too high. The 'alarmingHiring' can be regulated with an interface slider and its meaning might be explained in this way: it is the level of people hired by the firm and seen as worrying by the union, they think that the actual number of workers hired is too low (they would like to have more people employed) and to avoid it plunging further they increase their flexibility, of 1 unit.
The more the union bears, entailing not afraid of having unemployed workers, the more the 'alarmingHiring' will be lower, that means they start worrying (and so increasing flexibility) when there are just a few people currently employed.

BehaviorSearch

How to use it?

Before analysing the results of BehaviorSearch let us tell you how it is organised the software itself and above all how it is tied up with NetLogo simulation; we can split it in 5 internal structures:

- parameter specification: here we have directly imported the NetLogo parameters that are object of investigation, that means it gives the boundaries of the model to analyse (footnote: the first operation to do is to load the related NetLogo model of which you want to get more conscious through the button “Browse for model...”). In the relative window you will see all the loaded

parameters from the model interface, in fact BehaviorSearch will withdraw all what it will find out in the NetLogo interface. In our case it has taken all the sliders (regulating the number of agents, such firms, workers and unions; the parameters values to observe, like innovation level, production and others; the initial seed and the critical values sliders, such minimum involvement and labour demand). For all of them there will be specified the range of values in this way [*minvalue increment maxvalue*]. This first section is useful to tell BehaviorSearch what parameters you want to take into account for the analysis, it is possible to focus just on some of NetLogo interface variables, by wiping out others not relevant;

- second section: in this we have to tell BehaviorSearch what are the main rules of our investigation, it means it works as a bridge with NetLogo. We have specified how we put commands in NetLogo: the model is set up with the "setup" button, it goes ahead with the "go" button; the measure in which we are interested is the "hiring Rate", it is the aim of the whole analysis, it stands for the key parameter to be looked at; the overall system in NetLogo works if ticks is > 0 and it stops if ticks > 0, this notation spots the spatial time of the model, we study that when the first tick is executed and after 60 ticks we do not notice more other flows. In fact the step limit is of 60 ticks, as we have underlined in the NetLogo codes description we have supposed to work into the middle-term, equal to 5 years (corresponding to 60 months, that are 60 ticks, having defined 1 tick as 1 month);
- search method configuration: as we have said in the commented part of the learning section we use the Standard Genetic Algorithms as tool of investigation. Moreover, in this third part there are specified other elements of the searching process, measuring diverse rates, they are: a) mutation rate, giving the likelihood of mutation in each model agent, we have kept the default standard value of BehaviorSearch equal to 0,03; b) population size, it represents the number of individuals in any generation, set to 50; c) crossover rate, it is the probability with which we need two parents create an agent, otherwise it is asexually, it is 0,7; d) population model, it is for us "generational", meaning that the overall population is replaced totally and not just a random part of it, when the model is run again; e)

tournament size, it measures how many agents decide when an agent has to reproduce, it is settled at 3. We have opted for taking "on" the option "use fitness caching", since it rules out a model if it has already observed, that means if BehaviorSearch bumps into a set of parameters with the same values of a previous investigation, it neglects the second run; the benefit of taking this option regards the time, we do not waste it in doing something of already seen. Last remark of this section concerns the choice of Standard Binary Chromosome, as search encoding representation, in which every parameter is converted into a string of binary digits, and these sequences are linked together into one large bit array; after this operation, mutation and crossover rate will occur on a per-bit basis;

- objective (or fitness) function: we have specified that our goal is to maximize the object, the "hiring rate" for us, that means to get the higher value of it. All the measures of the parameter will be collected at the end of runs; the model will be run 3 times, since just one search cannot be sufficient to give us back the optimal value; we combine all the replicates with the mean. Last option regards the possibility of running the model once more (after the normal three) to look for possible better values, it means higher hiring rate. After all these options we are almost ready to press the button "Run BehaviorSearch";
- before seeing the results of the searches there is just one more window in which we have to decide for: 1) the path in which to save the results; 2) how many times to run the model, we have said the best thing to do is to run it more than once since one search might not find the best parameters, more searches improve confidence; 3) we decide the ID numbering into the output files; 4) we can change the initial random seed, it would be better to modify it every time we perform a new search; 5) we opt for the number of threads, depending on the PC used by the user; 6) we do not take into account the option "brief output", it would eliminate the two extreme values, both positive one and negative one.

After having defined the settings we can comment the obtained results, we have computed three searches (to improve consistency):

first of all, let us say that after having performed three searches the BehaviorSearch software will finally concentrate upon the best of them, in our case it is the first search, in fact the most useful aspect of working out more than one search is to have a range of fitness results among which you look at the best one. In Search 1 we have ended up with a fitness of 14.10, meaning a hiring rate far greater than the initial level of 2, this means we were able of increasing the rate of people employed in a precise scenario.

We report in the next page the BehaviorSearch chart showing the path of all 3 searches, where the red line represents the best one (Search 1):

To fulfil with BehaviorSearch essence we have to say what the model settings are, in other words with BehaviorSearch we have obtained the best measure of the hiring rate (that is our variable of interest), but we want to know how the simulation model behaves to grant us such a so positive parameter. For this purpose let us interpret the other variables and what their optimal values are.

As we have already claimed in the NetLogo codes explanation the root of the model goes around the workers' involvement degree, whose optimal value in BehaviorSearch is 9.0, it means workers have to be highly involved into company decisions. Unions will be willing of increasing their support for innovation plans up to 7.0 (we had a starting value of 2 in the interface output of NetLogo) since the optimal level of minimum involvement given by BehaviorSearch is of 6.0; this tells us that the involvement decided by firms is greater than the minimum required by unions, this makes arise unions flexibility.

The optimal of unions flexibility is much higher than its beginning value of 2, this allows innovation to enhance its level, whose best is settled by BehaviorSearch at 5.5, this conveys us the idea that innovations will be more than where we have started from (there we had an innovation of 1).

Production will soar too, the best level given us after three runs is of 12.0; we have begun from a 3 – level; but mainly thanks to innovation increase, production has reached a 4 times amount.

In the end we have got all these positive increases on the hiring rate, in fact BehaviorSearch has come up with an optimal rate of 14.10; this means 6 times than the origin, that was of 2.

After having reported the figures of the searches, let us comment them on words, since it is deeply relevant to understand what is the idea behind BehaviorSearch: with its searches we have had the chance of analysing how our simulation model behaves, that means how its parameters evolve during all the runs; this software has run the model three times, during which we have ended up with different results, we have obtained three diverse final levels for all the observed parameters. The main task of BehaviorSearch is to look for and then to show what are the best values (for certain parameters) after having looked into the model itself; in our case we have done that three times to compare many possible landscapes and then

to choose the best one.

This is in fact our goal, to notice what are the model settings that are fitted to spot the optimal value of the fitness function, the hiring-rate. As we were saying by referring to Miller's paper, we want to maximize an objective function (even called fitness, measuring the hiring-rate) under certain parameters, these are all the others of the simulation (like the workers' involvement degree). With BehaviorSearch we have obtained the optimal levels of all these other model variables that set the framework to give us the best measure of the hiring-rate.

All these best values have been reported in the previous page, but let us stress the hidden meaning: we have got just positive values, all of them lay above their starting ones (in NetLogo can be read both in the interface output and in the sliders); this positive chain ends up with a huge hiring-rate, that is 6 times than the original level, it means that BehaviorSearch (after three searches, let us remind yourselves once more) has found out a positive path for all these tied up variables, where each of them (since positive) enhances the next one, until the hiring rate.

In this ideal framework, BehaviorSearch has already pointed out the best level for the agents number: 9 firms, 51 workers and 5 unions, all have increased and in particular focus on the number of workers (a higher hiring-rate is followed by more employed workers).

To complete the remarks we could add that it is verified our initial assumption, that says a higher level of unions flexibility will trigger a greater hiring-rate, it is so according to BehaviorSearch results: a 7.0 unions flexibility sparks a 14.10 hiring-rate; this takes place through the effects chain involving all the other model parameters (innovation and production), above all we have to turn out the importance of a large workers involvement degree, in fact unions are willing of being more flexible because of a higher involvement degree for their subscribed workers (whose level is greater than the minimum involvement, that is the threshold accepted by the union to make bigger the support).

In the end, we want to stress the basic concept of BehaviorSearch analysis in our perspective: once we have decided the objective function (the hiring-rate) we are deeply interested in knowing how to achieve the maximum of that and under what assumptions. With BehaviorSearch we have obtained the optimal for the hiring-

rate and it has given us even what the best levels for all the other parameters are, in our simulation model it is extremely relevant to notice even them, since all the variables values are linked each other, if one changes the others will be affected.
In other words with BehaviorSearch, after having underlined the final aim (that is the fitness), we want to note how the model behaves globally, that is in terms of all the parameters included into the system, in our case: a higher hiring-rate can be reached only if unions flexibility degree is more than its initial level and it occurs whenever the workers' involvement is more than zero, in the BehaviorSearch runs we have seen fulfilled these assumptions with values much higher than the minimum required (equal to the starting levels, this condition belongs to NetLogo codes).

5.2.3 Third example

Settings

In this third example we have deepened the second one, that means we have looked more at the behaviour of one specific agent within the general framework.
We have been analysing one precise agent, that is one Union: our aim in this direction is to notice how it behaves with respect to all the other agents of the same kind (it means all the other unions).
We have supposed to investigate that union in two scenarios, let us depict them with two questions as follows:

- how could our union behave when all the others are rigid and therefore no innovations are set up by firms? There will be a more or less flexible union?

- Conversely, how does it act if there is an overall flexibility, sparking innovation? Will it be flexible too?

By using BehaviorSearch we will try to answer both of these questions; once more, our purpose is to understand what is the pace of one single union with respect to all the other agents of the model.

NetLogo codes

For what concerns NetLogo we have kept as in the previous example the same structure, a part for one more feature.

In order to look into one union behaviour we have specifically defined its own characteristics in NetLogo, let us recap them in two parts:

a) *Interface*: we have plugged in just the slider measuring the flexibility of the single union, we have labelled it as "aTradeUnionFlexibility", it flows between 0 and 10 with an increment of 1;

b) *codes*: we have drawn them within the command 'to standUpFor' since the flexibility of the single union is a sort of *subset* of the flexibility of all the unions (seen as agent-set); we have named that inspected union "aTradeUnion", whose flexibility might take all values below and above zero (except for zero); its flexibility level has been set equal to the one of all the unions plus a random number between 0 and 1. Our choice of doing in this way comes from the assumption of the nature of the contracts, we claim that with a relationship "1 Union – 1 firm", the union is more flexible because it can bargain over all the deal aspects. We are interested in testing how this more flexibility is managed in the overall context, when there are all the other unions dealing with the firms, at the same time.

BehaviorSearch

The BehaviorSearch analysis has to be split in two parts; in the first one we have focused on the behaviour of “aTradeUnion” with all other unions rigid and consequently firms dropping innovation (in this searches we have ended up with a small hiring-rate, lower than the initial level).

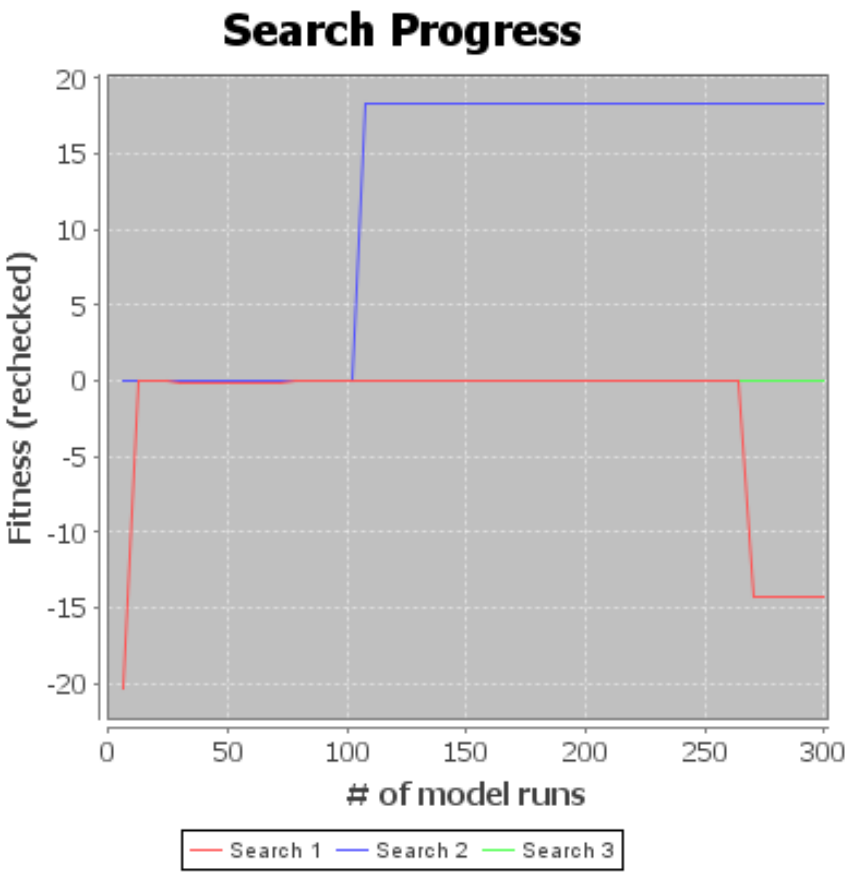
In the second section we have looked at the opposite landscape, in fact we have observed how “aTradeUnion” moved when all the other unions were enhancing their flexibility (more than the original level, as written in the output of the NetLogo interface) and firms could so afford to soar innovation; the final outcome was a greater hiring-rate.

Let us resume these results with a list:

1. first scenario: we have computed three searches, as we did in the previous example, to avoid having inconsistent results; as always, BehaviorSearch gives us back (after having run all the three searches) just the best of them, for this reason we have concentrated only on that. With a workers' involvement degree of 2 (far lower than the minimum required by unions, settled at 9) there is an overall drop in unions flexibility to -4. Since all unions (except for 1, “aTradeUnion”) have slumped their support for innovation plans, the firms have to plunge it as consequence, it reaches a negative level of 3,5. The final parameter to observe is a decreased hiring-rate, it achieved a level of -13.9 (in Search 3, green line), going down from the initial value of 7. In this settings the flexibility of “aTradeUnion” went down from the original level of 6, going to 4, but it still positive and higher than the one of all the other unions.

   Let us show you the data with a chart as follows:

2. second scenario: even here we have relied on three searches, the best of which gave us: a workers' involvement degree of 10 caused an increase in unions flexibility of 3,0 (since they were requiring a minimum involvement equal to 5). This gained flexibility triggered a step forward for innovation too, in fact firms set up innovative projects for a level of 9.0, it has sparked an increase in the hiring-rate until to 18,3 (in Search 2, the best of three, it is the blue line). In the end, the flexibility of our analysed union went up to 10.0, more than three times with respect to all the other unions. The graph below gives you the insight:



Remarks: we can compare both sections of results to understand how the single union moves when it is inserted in the whole model, one of the main conclusion can be observed into that inspected agent, it over performs by comparing it with all the other unions. In both cases we have had the "aTradeUnion" agent following the pace of all the other unions, when the common trend was negative it went down as well (even if it kept a positive level, but lower than the starting point); when all the unions were supporting for more innovations, it has increased its flexibility too, in this case it made more than three times with respect to the average. A second remark, instead, has to do with the effects chain of all the agents, taken altogether: when the involvement degree was below than the required level for unions, by causing less flexibility and lower innovation, the final outcome was always a smaller hiring-rate. That means, the common pace for all the agents is the same of the second example, what has changed here is just the

behaviour of one single agent, compared with all the rest.

Let us fix on the positive side, since our goal is to get a high hiring-rate let us see the main features when we have obtained a value of 4,0: we could got a doubled level of hiring-rate thanks to positive chain parameters, it means a sufficient high involvement degree for workers allowed for more unions flexibility, whose aftermath whose more innovation and more employed people. In this frame, the single agent “aTradeUnion” behaved according to our commands, given in the NetLogo codes, where we have asked it to set a level of flexibility equal to the unions average plus a random variable (between 0 and 1); what has to be noticed here is the result of BehaviorSearch, it gave us the best value of the single union (in terms of flexibility) to reach the level of hiring-rate equal to 4. This means, to achieve a labour market in which firms hire double than the initially, all unions have to be more flexible, but the single inspected agent has to be much more flexible, in fact it will set it more than three times compared to all the others.

In other words, we have given to the “aTradeUnion” those features willingly, that means we have already decided for its specific behaviour, we thought that one union has more flexibility because of the reasons stated in the NetLogo explanation; by being aware of this, we were interested just in observing what is the optimal behaviour of the single union within the overall framework, even if always higher than all the others (but *how much?*), it comes from our own initial assumption.

6 Lateral thinking

After having shown you the main results of BehaviorSearch analysis let us spend some more words on the key elements of this software, as you should have easily noticed we have been able of looking at the ABM structure in a different way, in fact we have been studying its way of behaving.

In a sort of way we could say that we have chosen to look into our simulation model with an original perspective, we claim to have referred to a different way of thinking: there are some links with the *lateral thinking*, by exploiting the GAs.

According to Wikipedia definition, the lateral thinking is a way of solving problems, it is done by adopting many different perspectives, all of them converging to the final solution; this path diverges from the direct way, which implies to directly tackle the issue and to find out a unique solution.

The pioneer in this direction is Edward De Bono, who taught in many universities throughout the world (such as Cambridge, Oxford and Harvard); in his theories he claims the possibility of handling rational problems with an alternative method: if we try to solve a problem with a rational way of thinking we might get good but limited outcomes, instead with the lateral thinking we can end up with innovative and creative results (Wikipedia).

De Bono spots two ways of thinking: vertically, as we do normally to solve all problems, and laterally, by using this alternative approach.

De Bono is used to detecting the deepest gap between this two methods with a brief statement: the vertical thinker knows exactly what she is looking for, she has in mind where to go; instead, the lateral thinker is looking for something but she does not want to know what, until she finds it. This means to be opened to all possible paths, without neglecting anything.

We have decided to quote De Bono's contribute over the lateral thinking with respect to our project since there are some slight comparisons: the use of BehaviorSearch is a broader view to tackle with the simulation model, if we had used just an ABM *to explain the unions-firms interaction* it would have meant to

try to look at a phenomenon only relying upon the NetLogo settings. Instead, we have opted for a larger view of the topic, through BehaviorSearch we have tried to understand something more of that economic relationship (involving unions and firms); that was possible thanks to the GAs role. In other words we wanted to go beyond the ABM simulation, we were aiming at a deeper explanation of the observed interaction and we did it with BehaviorSearch.

We could say to have worked out a lateral thinking perspective, since while we were running the BehaviorSearch we were not looking for a specific framework of the model (as it would be set up by the vertical thinkers); but, we were awaiting for something without wiping out any possible results. After having obtained those model behaviors we could interpret them on the basis of what got, this is the link between BehaviorSearch and the lateral thinking, the former allows to investigate models (deriving from an ABM simulation in our case) by searching what the best interpretation is, without ruling out any possibilities until the final result is provided, just in that moment it is enabled to judge the overall simulation.

7 Model key points in results versus recent events

This section copes with the most recent events in which we can find some tracks of our items, we have built up a simulation model aiming at an ideal scenario for both agents categories, unfortunately the reality shows us different aspects. In spite of this, we are going to report here some evidences of links between the agents based model and the current state of the economy.

With the simulation model we aimed at a market functioning within which both sides of the economy (unions and firms) act towards a common goal, there is no excuse in our framework for them to blame the counterpart, we have empowered both with half of the whole liability: if one does not move for the common purpose there is no chance to get a higher hiring-rate. In fact the hiring-rate summarizes the aim for both unions and firms: if there are more employed workers means that there has been a production rise and at the same time we have passed through more involved workers.

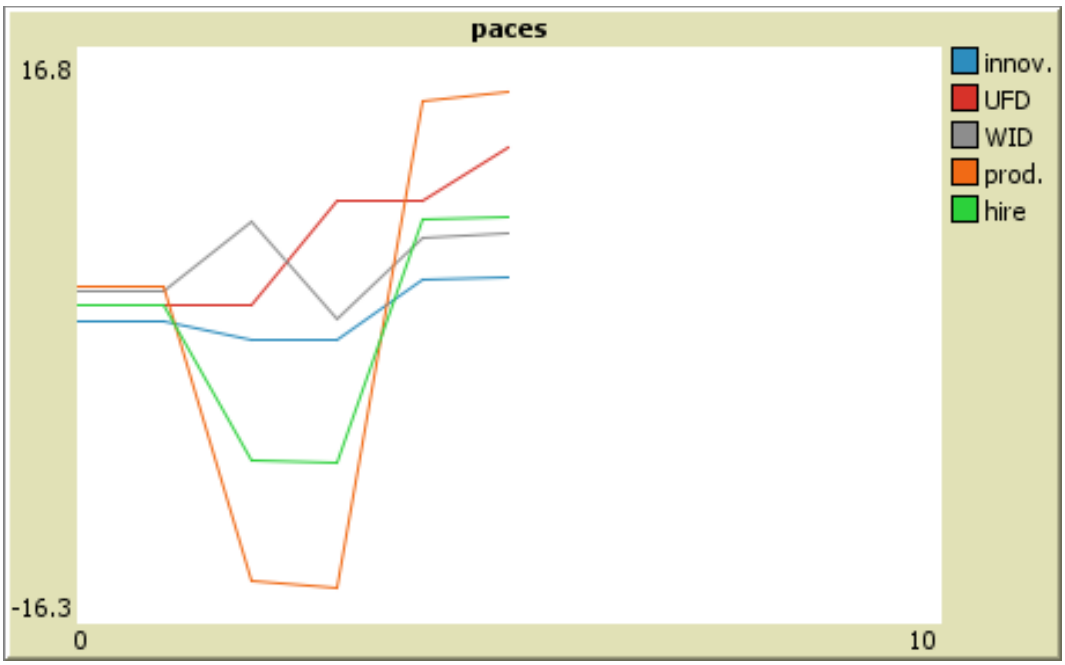
We would label our model as a fair one, we have depicted a setting in which there has been traced the path to reach a better off system, both agents would be endowed with richer parameters, but in order to achieve that state it is necessary to precisely behave. In the model an internal constrain arises: we can notice how to reach a better society, where all agents would enjoy of more results, the only bind is to act not just for themselves, rather for the whole community.

By starting from this thought we have ended up with clear outcomes (mainly thanks to BehaviorSearch): we can think of a labour market with more hired workers, entailing more innovation and more production, if and only if unions and firms take action responsibly, if they decide how to move by looking at the other's preferences we will get a better society (in terms of employment rate).

With this agents based model we have provided you with the mean features that a labour market should own in order to improve, whose key basis are the common efforts, all the involved agents cannot afford to act just to achieve their own

purposes, if it were so no real development would really occur.

This contemporary movement of the parameters can be observed with this chart:



It is quite clear from the image the common path for unions and firms variables: while the workers' involvement degree starts increasing (grey line) the unions flexibility goes up as well (red line), the latter causes a rise for innovation, production and hiring. The above chart testifies how the agents actions flows are interdependent each other, if one gets positive the other will become too.

So far we have spoken of our model, it is even relevant to compare it with the reality, another step of this section analysis consists in spotting similarities and gaps with the real labour market.

Our simulation have been created around many variables, all of them allowed us to make interact unions and firms; we are going to spot similarities with today labour market features just for a few parameters, we have decided to deepen only the ones that are widely tackled, nowadays, these are:

- workers' involvement degree: we will be looking for comparisons with current firms, in other words we are going to search how companies involve their employees, what kind of incentives they use to do so and how it can be related with our work;
- unions flexibility degree: the goal here is to understand how unions support innovations, whether they are flexible or not towards new ways of producing, we will quote some sources that inspect the unions role in today economic situation (*liabilities and duties*);
- innovation: this parameter is just up to the company decisions, how it decides for more or less innovation and, above all, if it is useful or useless to be more competitive.

We are going to deal with links between the above listed simulation parameters and their related values in current market.

Let us begin with the first one: workers' involvement degree.

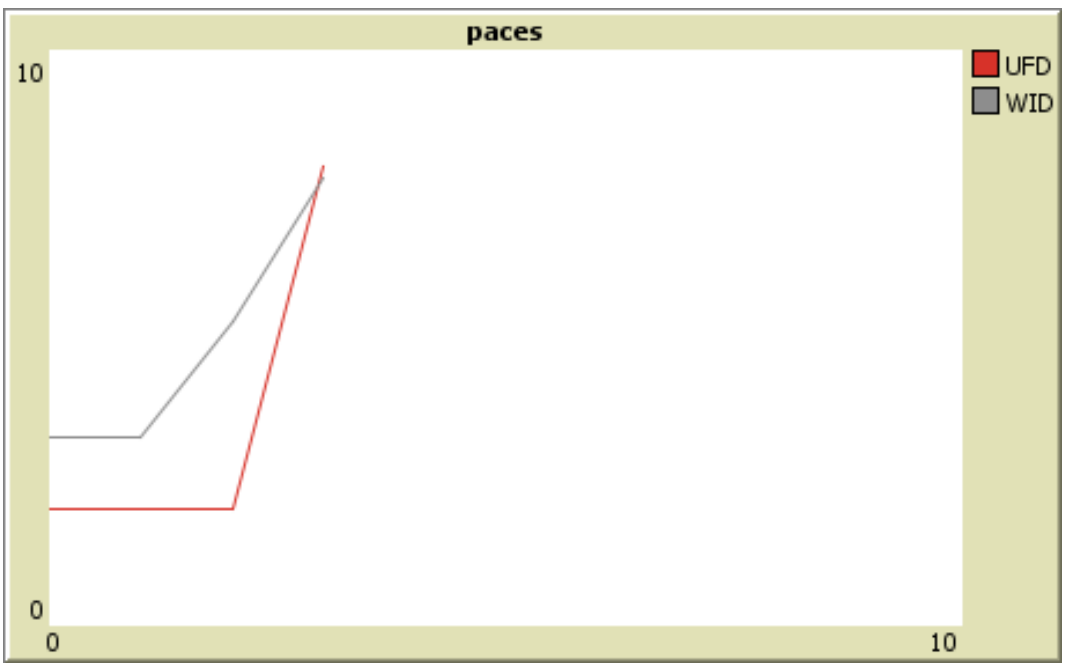
By saying degree of involvement we hint at the liability given by the firm to its own employees; in the simulation model we had defined this command as the level with which the firm management makes participate the workers to the decision-making process and its positive value (above an original threshold) triggered more unions flexibility.

In the simulation model we have begun with an idea: if firms involve more their employees the related unions will appreciate it and consequently they will support more firms plans; by saying it differently we have liably constrained firms, if they wanted to be more supported for innovative projects they had to be opener towards their workers.

Even in this passage we have reasoned in terms of responsibility, through our Netlogo codes we have emphasized this insight: we have elaborated a commands sequence where the firm can achieve a higher degree of innovation just if it fulfils

with the unions requests. To end this thought: the first passage of the model guarantees positive results only with *mutual collaboration*.

If we had to speak just of NetLogo structure we should underline the randomness of the workers' involvement degree variable, we have defined it with no precise value, we did not want to give it a defined level, it is taken randomly by NetLogo. We are much more interested in how its initial level goes affecting the next variables, it can be easier to understand it with a graph:



By starting with a positive workers' involvement degree (WID), increasing over time, it is evident that if WID goes up at time t=1, unions flexibility degree rises too, but it does at time t=2. With the chart above we have tried to convey you the proportional dependency of unions level of flexibility on the employees' participation, if the former has been chosen high by firm executives, there will be the latter value positive too.

In this section we are even interested in knowing if today firms involve their

workers, if it is so how they are taken into account and what is the impact into the economic scenario (that means, if there are positive or negative results of doing so). According to the website About.com, the best way to involve workers is through their influence in the decisional process, it is something similar to what we have stated in our model, but here they go ahead: it is relevant to give decisional power to the employees since they get aware of their chance to improve their jobs, that is, by deciding jointly with the management the workers have the possibility to deliberate over decisions directly affecting their jobs.

In the website it is stressed the *participating liability*, in fact workers can take part to the overall contribute to improve the company settings and to play a role for the firm success. People willing to give their contribute are asked to create the so called "green-team", whose matrix is the motivational spirit leading to the most innovative degree for the firm; in other words, the About.com web site spots a special team (internally to the firm) composed by employees working for a continuous improvement of the company itself.

About.com underlines the same feature we had point out: the involvement degree of employees is for a firm mainly done by giving them power to decide, because of this gained responsibility they will identify more with their firm role. If we had to turn out the common point between this source and our basic ideas we would answer the liability in taking the best choices for the company development.

We are not saying that is the best way to profitable involve workers, rather we can report a different pattern to do so: through salaries increase.

According to your point of view we can detect many ways to involve individuals, so far we have stood up for a direct involvement into the managerial processes, now we tackle with a diverse method: by enhancing workers' revenues.

To support this last view we quote a quite recent press release of FIM (Italian association of metalworkers), in this statement it is communicated to all people enrolled in this workers' confederation the achievements of the union, representing their colleagues in Germany by IG Metall.

In a few sentences there is the core of the unions point of view (regarding the workers' involvement): IG Metall tells its workers one of the last goal reached with the German companies, it is an increase if 3,6% of the monthly salary and

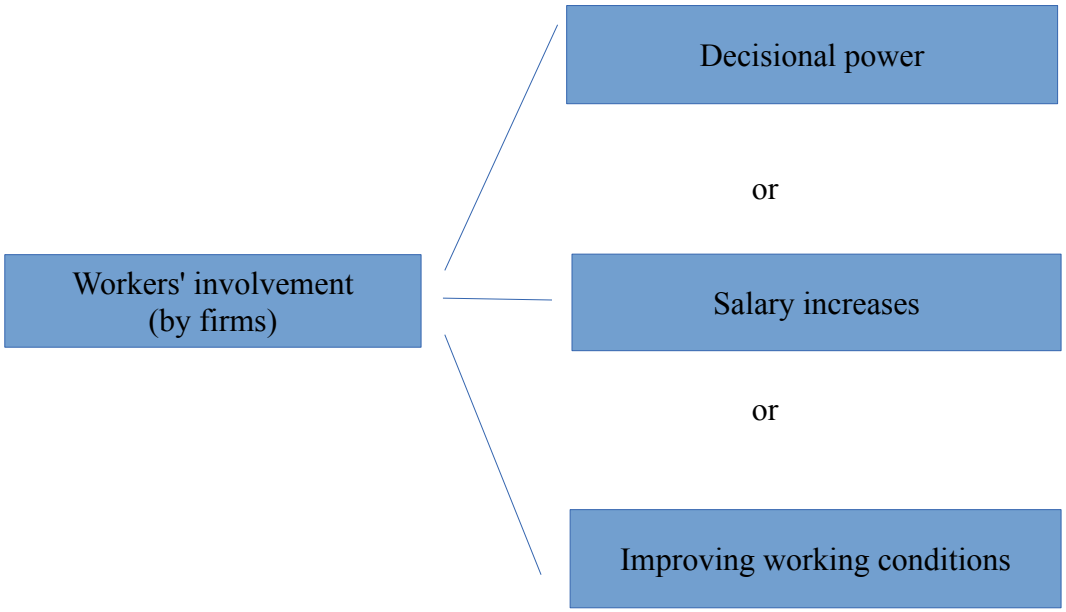
the same contractual conditions for the temporary workers too.

We have found this perspective relevant, especially to set out the different meaning of “workers' involvement” for the agents participating to the market; we have decided to refer (and to rely on) to several ideas of this item in this section to convey you our opinion of relativity: once more (we want to be extremely clear over our thought concerning the employees' participation) we have opted for a direct power of all workers into the decision-making process, but it is not the only one in today firms, in fact many of them prefer acting other involvement types on the basis of their relationships with trade unions. These latter aim at achieving a diverse status of workers' participation, they think to be much more relevant to increase people's salaries or to ensure their working conditions rather than making them more powerful.

There is an extreme example of the unions point of view, it has been deeply described by LaStampa (16/03/2013), in which it has been reported the original salaries-decisional process acted by a German consulting firm: Vollmer & Scheffczyk. This is a mix of both involvement kinds: workers *decide* (1st involvement) their *salary* (2nd involvement). In this company the revenue amount is decided by the employee, she can decide how much she deserves for her contribute to the firm overall improvement. Firstly, it is needed to say that they are ethically bind, in fact once you are hired you have free access to balance sheet data, employees salaries included. We have said ethically since everybody knows how much you gain and, above all, if you deserve such an amount of money by comparing it with your efforts for developing the company itself.

A second step is original too, once you have been assumed you have to speak about your desired revenue with three employees (already working there), by doing so you should evaluate properly how much you are worth, you are going to be constrained to propose a salary very close to what you actually deserve. Furthermore, the idea is contained into the *mutual control*: if you are charged of high responsibility you will feel to be obliged at giving your best to not justify your salary level with your colleagues.

If we had to resume the involvement kinds of today firms we could draw a scheme like follows:



Let us pass now to the second current topic: unions flexibility.

With unions flexibility we refer to the behaviour of trade unions towards innovation projects, let us be clearer: in our simulation model firms were allowed to set up innovative plans if and only if they had unions support, otherwise they had to drop it; flexibility (or rigidity) is the key element for agreements between firm and union, if the latter disagrees with certain plans the innovative change will not take place any more.

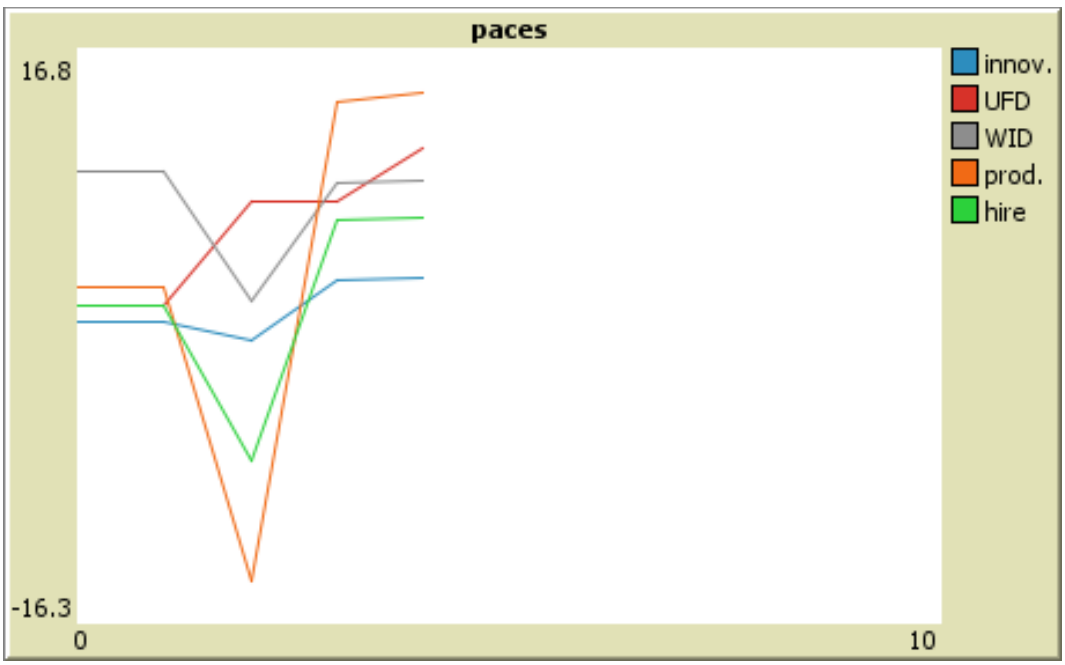
As we have stated in the previous sections we have decided to charge unions of this liability to directly involve all agents for the final outcome: an increasing hiring-rate.

As for the other commands (especially the firm ones), the behaviour of unions cannot be given by chance, it has to be embedded in the overall mechanism; according to our NetLogo codes, they act responsibly, their movements are fitted in the global effects chain.

One of the main results of BehaviourSearch was exactly of the unions side, they could have played an auxiliary role to achieve more hiring if they had behaved by

looking at both their own aims and the firms ones: that is, we had more hiring partly because of more flexible trade unions.

Let us show you how unions can be seen as positive intermediaries, that means by reacting (in terms of flexibility) positively to more involvement of their represented workers:



The middle role for unions is given in our graph by the red line, it is observable that it goes up if the previous period of time the workers' involvement degree variable went up; consequently, if at time t=2 unions flexibility gets bigger, at time t=3 we will have a rising innovation, in fact the light blue line goes up the next time.

Once more with this chart we have pointed you out the causal effects of all the parameters of the model, they move together accordingly to all the others; we have bind our agents to fluctuate altogether.

In this description we are even interested in the current behaviour of unions (how

they respond to new innovation plans proposed by firms) and to compare it with our model features.

First of all, let us tell you that nowadays you might find flexible firms for more unions flexibility, this is to prevent disagreement of trade unions, in fact a lot of international companies are adopting more flexible working hours for their employees, to allow them to fit it with their private life. This is done to meet easier unions requests, such as more favourable working conditions, and as consequence unions will stand up for firm plans more willingly.

We would even insert this firm action in the previous category: involvement, in fact by shaping the working conditions can be seen as a way to "customize" the employees.

By coming back at unions side, there has always been a wide debate over the unions position towards employment rate and innovation, according to the Economist (28/11/2002) unions throughout Europe have always been reluctant for innovation projects, since the introduction of new machineries would have slumped the human labour force.

Historically there were a lot of bargains and strong debates between employers and unions to update the factories, this is the mean reason for which we have given so much emphasis to the sign of contracts between them: to reach a deal between firms and unions means to converge towards a common aim, where both agents groups work for achieving the same purpose, that is a higher hiring-rate, by doing so we know it may seem quite unrealistic but both are equally liable.

According to this article there has been a remarkable drop in trade unions membership, until a few years ago unions were wide associations in which the majority of workers saw their rights respected, nowadays we assist to a tumble in their enrolment.

There is no hint for an answer, we could interpret this with two views:

1. workers are no more satisfied of union representation, they feel to be no more protected by their actions; it is even likely that workers do not

recognize themselves any more in the ideals stated by unions leaders;

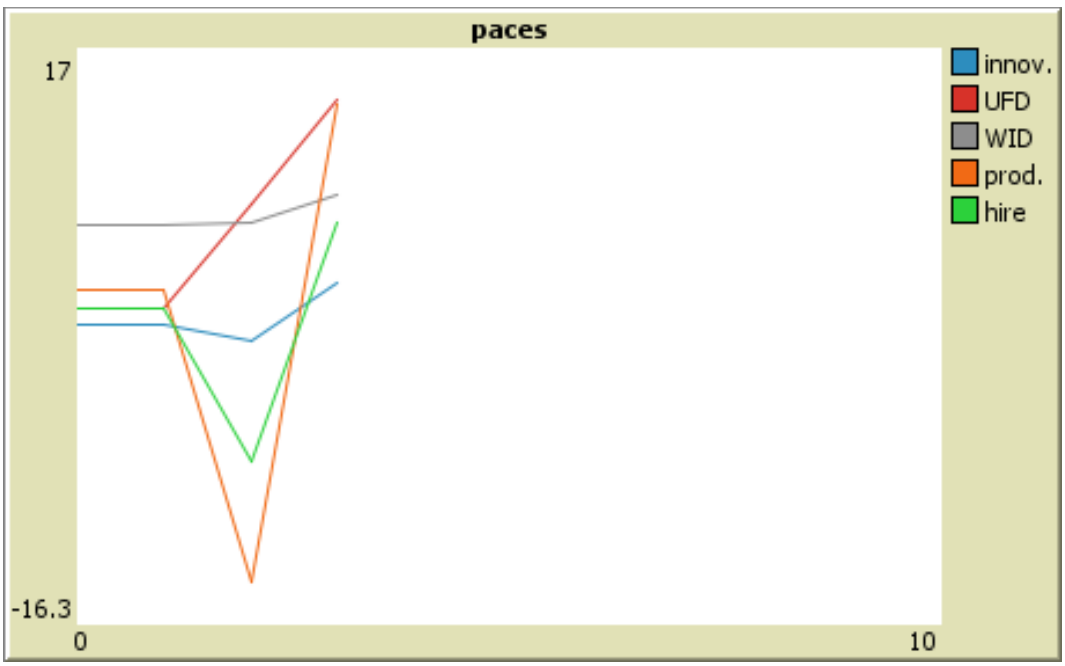
2. the blame might be of firms, their closure towards dialogue with unions might have discouraged workers to not be part of these associations.

Once more, we have spotted a double liability for firms and unions at the same time, it is neither clear nor easy to detect a blamer, both can be responsible for less membership in unions and for a continuously higher unemployment rate.
We can end up this second analysis by saying that there are two groups of agents shaping the unions flexibility: unions, they know the importance of innovation support for firms plans; firms, their behaviour affects the unions reaction and consequently it has impact on the hiring-rate (the same concept is observable in the NetLogo codes, where the union flexibility degree was the cause for innovation level and then for hiring, but at its turn the union flexibility was sparked by the workers' involvement degree decided by firms). We might conclude by underlining that the unions flexibility, *both in codes and in the reality*, is due to their own behaviour and to firms actions too.

Let us go analysing the last feature: innovation.
By saying innovation we talk about the investments made by firms to keep up with more innovative processes and products, we think innovation to be doubly observable in firms: firstly it is needed to update the production line, in order to guarantee a more modern productive process to create, secondly, new products to satisfy the customers demands.
Innovation is the core of our analysis, it is the middle check of the whole system functioning, by referring to the NetLogo codes from innovation onwards we will have increasing parameters if and only if the previous variables have risen too. We could say that from innovation, by passing to more production and finally with more hiring, there is a natural sequence, they will always cause each other

positively, in fact it is far more troubling to induce positive effects among: workers' participation, unions flexibility and innovation itself (this is the 1st chain part). The reason is that in the 1st chain part we involve both unions and firms simultaneously, their actions meet together, while in the second part we are going to refer just for firms actions.

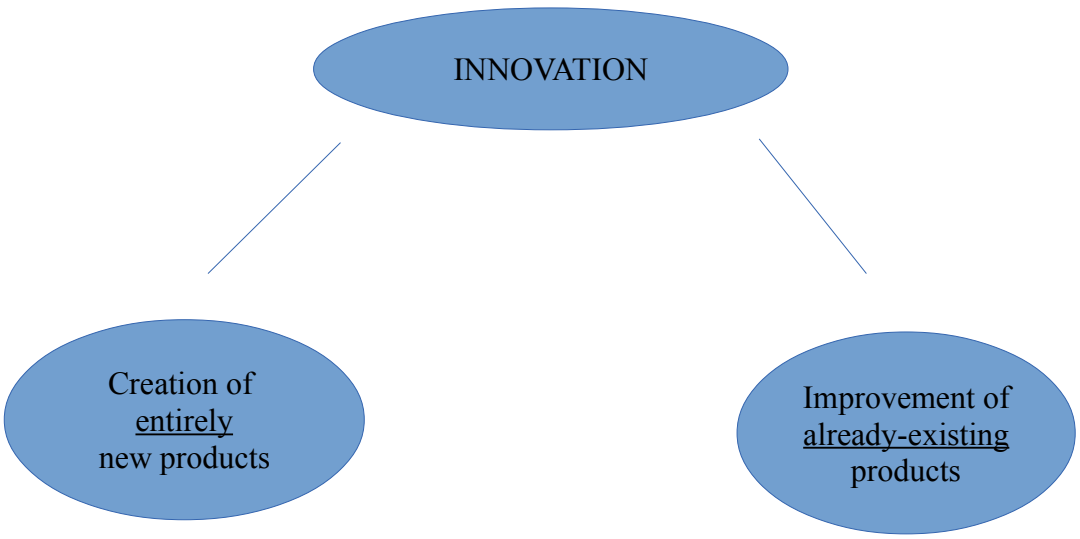
To be clearer let us give you the same basic insight with a graph:



Innovation (the light blue line) goes up because of more flexible unions, the positive rise is immediately reflected over the production (orange) and hiring (green); since all these three decisions are uniquely taken by the firm they occur together with no difference of time.

Innovation is that mean through which companies can delete crisis, by getting more modern the firm essence (that is by betting on new products) there is the key to get out from the crisis status, even Albert Einstein was used to saying that the best innovations have been made to exit from the current weak situation.

Let us tell you that our idea of innovation is composed by two ways of actually innovating the products:



That is the key distinction, we prefer speaking of *pure innovation* just if something of new has been created and in fact in our simulation model we hint exactly at this: innovation is seen as firm investment for new kinds of products, we do not look at simple improvements.

Our point of view finds similarities with today firms strategies: in the Harvard Business Review (2009) innovation is defined as a messy process, difficult to measure and to manage. It keeps on by highlighting that the majority of people is used to detecting innovation with extended periods of growth, during which salaries go up and unemployment rate goes down.

The most relevant contribute of the Harvard Business Review (called HBR too) for our analysis is that, even according to this journal, innovation is a sort of vaccine to avoid market slumps and the key element for enhancing growth; HBR gives us the example of General Motors, there is the idea to which the American car maker today would have been the largest producer if it had invested as Honda and Toyota. With this example it is clear the idea of new innovations, in fact both

Honda and Toyota are the car makers that have most launched new products (and they continue doing so); with that opinion, HBR wanted to say that by creating continuously new goods there are much more chances to beat the rivals.

A similar concept has been developed by Cainelli (2003), he claims that technological change and innovations are seen as the economic drivers for growth in all the developed countries, they are the mean setting for the competitive process, with them there are the basis for a development of the economic structure.

After having described and compared our model with the modern papers, let us say that from the beginning we have built up a model step by step, it is made of several parameters embedded into each other, we can try to predict the next variable value according to the value of the observed one.

We did not perform such a structure with no relevant meaning, we wanted to replicate, *both through codes and with reality links*, a system where there can be a better level for all the parameters, where all agents can take advantage only if all the economic actors have acted with a double vision: for themselves and for all the rest. In the end, we can state that with NetLogo codes structure and BehaviorSearch results we have been able of proving these insights: we have tested that it is possible to achieve a labour market where more people work, but it is implementable just if all the unions and firms parameters are altruistic enough.

8 Appendix: *NetLogo codes*

```
;; breeds of agents, as labour market economic actors
breed [unions union]
breed [firms firm]
breed [workers worker]

;; breeds of steps, for variables fluctuations
breed [improvements]
breed [worsening]

to setup
  clear-all
  setup-workers
  setup-firms
  setup-unions

;; we start from no-zero levels of these variables exactly to observe if they vary, both positively and negatively
;; within different contexts, if their interaction makes their values increase or decrease

 set unionsFlexibilityDegree initialLevel "unionsFlexibilityDegree" 2
;; a minimum of flexibility is supposed to exist, to guarantee a minimum of innovation and production
  set innovationLevel        initialLevel "innovationLevel"        1
;; from 1 to 10, 10 means all profits are invested (after the costs), percentage of profits to investments

  set productionLevel        initialLevel "productionLevel"        3
```

```
;; firms produce a few, even with no innovation increase (from a basic-level of 1)
  set hiringRate              initialLevel "hiringRate"            2
;; even with no innovation a minimum of hiring is guaranteed, but costant to 2

 reset-ticks
  end

to-report initialLevel [varName value]

  output-type varName output-type " " output-print value
  report value

end

to setup-workers

  set-default-shape workers "person"
  create-workers HowManyWorkers

  ask workers
     [set size 0.8
       set color blue
        setxy random-pxcor random-pycor
         set label who set label-color yellow]

end

to setup-firms

  set-default-shape firms "firm"
  create-firms HowManyFirms
      ask firms
```

```
      [set size 2
        set color grey
         setxy random-pxcor random-pycor
        ]
end

to setup-unions

  set-default-shape unions "flag"
  create-unions HowManyUnions

  ask unions
    [set size 1.5
      set color red
       setxy random-pxcor random-pycor]

   end

to go

tick
if (ticks >= 60) [stop]
;; it allows us to analyse a definite limit of time,
;; where 1 tick stands for 1 month, the whole time period is of 5 years = mid-run
innovate
standUpFor
involve
produce
hiring-rate
hire
fire
optFor
```

```
learn-Union

end

to innovate
;; starting from a minimum of innovationLevel = 1

 set innovationLevel sin(innovationLevel)
;; it allows to put a ceiling to innovationLevel variations, in the plot, by reporting the sine

;; if unions flexibility is greater than the starting level (= 2) it means that unions are getting more flexible
;; if UFD is > 2 then innovation will increase of 1 (= 0.5 upDate)

 ask firms
   [let upDates one-of improvements
          if upDates != 0 [set upDates 0.5]
            if (unionsFlexibilityDegree > 2)
              [set innovationLevel
                  innovationLevel + upDates]]

              ask firms
                [let aBitOfFailure one-of worsening
                  if aBitOfFailure != 0 [set aBitOfFailure -0.5]
                    if (unionsFLexibilityDegree < 2)
                     [set innovationLevel
                         innovationLevel + aBitOfFailure]]

;; if UFD drops below than the initial level of 2 then innovation will decrease as well
;; innovation will slump because unions do not sign contracts for setting up
```

```
innovation plans

end


to standUpFor

;; unions flexibility depending on workers' involvement
;; if WID is > 0 it entails that workers start to be involved
;; and unions begin to increase their flexibility (with respect to the initial of 2)
;; let us split in 2 cases: if WID < 0 we have negative unions flexibility (meaning
rigidity = no support for innovation plans)
;; instead with WID > 0 we have an increase of unions flexibility of 1 step (=
aStepForward)

;; if there is no involvement the flexibility drops below zero, meaning rigidity
   ask unions
          [ if (workerInvolvementDegree = 0)
            [set unionsFLexibilityDegree -3]]

;; if the involvement is positive we get a unions flexibility increasing of 1 step
ahead
          ask unions
              [ let aStepForward one-of improvements
                if aStepForward != 0 [set aStepForward 1]
                  if (workerInvolvementDegree > minimumInvolvement)
                      [set unionsFlexibilityDegree
                          unionsFLexibilityDegree + aStepForward]]

;; minimumInvolvement (given by a slider) is the minimum level of flexibility
required by the union
;; seen as acceptable, if the WID (decided by the firm) exceeds this minimum the
```

```
union enhances its flexibility
;; otherwise, if it is lower than the minimum, the union drops its flexibility


                ask unions
                  [ let aStepBack one-of worsening
                    if aStepBack != 0 [set aStepBack -1]
                     if (workerInvolvementDegree < minimumInvolvement)
                       [set unionsFlexibilityDegree
                           unionsFLexibilityDegree + aStepBack]]

                  let aTradeUnion one-of unions
                    if aTradeUnionFlexibility != 0
                      [set aTradeUnionFlexibility
                          unionsFlexibilityDegree + random-float 1 ]

  end

to involve

;; the level of involvement is set randomly, from 0 to 10,
;; a level of zero means workers are out of the firm decisions
;; a level of 10 means their vote is worth as the one of the executives,
;;between 0 and 10 there are intermediate levels

  ask firms
        [ set workerInvolvementDegree random-float 10 ]

 ;; the involvement degree is at least zero. not less since it would not make sense
to have a negative involvement
end
to produce
```

```
;; the starting point is 3, even if there is no innovation increase the firms of the system will produce an amount of 3
;; the increase of production is more than proportional with respect to the innovation increase, it passes through a gained productivity
;; an increase of 0.5 in innovation is followed by an increase of 2 in production,
;; since more innovation sparks more productivity (technology), allowing to (more-than) double production
;; technology gained with innovation guarantees us to get a much higher production (0.5 vs 2)

 set productionLevel sin(productionLevel)
;; it enables us to put (and to observe) a ceiling to production value


;; the increase of production is more than 1-unit because boosted by the higher productivity,

  ask firms
     [ let IncreaseOfProduction one-of improvements
       if IncreaseOfProduction != 0 [set IncreaseOfProduction 2]
         if (innovationLevel > 1)
         [set productionLevel
             productionLevel + IncreaseOfProduction]]

;; if innovation plunges from its starting level of 1, production goes down as well

    ask firms
       [ let DropOfProduction one-of worsening
         if DropOfProduction != 0 [set DropOfProduction -2]
          if (innovationLevel < 1)
            [set productionLevel
```

```
                productionLevel + DropOfProduction]]

 end


to hiring-rate

;; the hiring rate of the firms goes up if there is more production,
;; this means an excess of products demand by the customers over the firm supply,
covered by hiring more workers

  set hiringRate sin(hiringRate)
;; we put an upper bound to the hiring rate fluctuations



;; a production increase of 2 is filled by 1 worker,
;; not 2, since with more innovation it is supposed to have more technological
productivity

    ask firms
     [ let oneMoreWorker one-of improvements
       if oneMoreWorker != 0 [set oneMoreWorker 1]
         if (productionLevel > 3)
           [set hiringRate
               hiringRate + oneMoreWorker]]

;; at the starting levels 2 (hired) workers produce 3 units, that means 1.5 unit per
employee
;; with a 1-unit innovation increase (and consequently of productivity and
production)
;; we have 3 workers producing 5 units, this entails 1.67 per employee
;; more innovation, more productivity and more production make increase the
```

single-worker-capability of production (1.5 → 1.67)

```
    ask firms
      [ let anUnemployed one-of worsening
        if anUnemployed != 0 [set anUnemployed -1]
          if (productionLevel < 3)
            [set hiringRate
                hiringRate + anUnemployed]]
```

;; a decreasing production (below the initial 3) causes a downward shift in the hiring rate,
;; some currently-employees will be fired, because of less demand

end

to **setSeed**

```
  random-seed mySeed
```
;; mySeed links with the input in the interface

end

to **exportMyPlotAndInterface**

;; this command guarantees us to export our plots and to plunge them in other contexts

```
   export-plot "innovation and hiring" word timer "Plot.txt"
   export-interface word timer "instantaneousInterface.png"
```

end
to **hire**

```
;; we have defined aWorker as an agent of the agentset 'workers'


  ask firms
     [let aWorker one-of workers in-radius 10 with [color = blue]
       if aWorker != nobody [create-link-to aWorker
                                 ask aWorker [set color green]]]

;; firms hire workers in-radius 10, they are tied up with an arrow (as link)
;; if a worker is hired her colour turns to be green (just to graphically-spot that
she has been hired)
;; there is just one condition to be hired: to lay into a 10-radius circumference
around a firm

end


to fire
;; this command is given through a missing link,
;; if workers lose the job the link disappears

;; if the number of hired workers is > than the firm labour demand we ask
'anArrow' to die
;; the hiring rate is observable in the interface monitor, while the labour demand
is regulated with a slider
;; the labour demand gives us the number of required workers by the firm
   ask firms
     [let anArrow one-of links with [end1 = myself]
       if (hiringRate > labourDemand)
          and anArrow != nobody [ask anArrow [die]]]

;; when a worker is fired it turns to be blue
```

```
;; it occurs when there is no more a link, with the firm

     ask workers
      [let aLink one-of links with [end2 = myself]
        if aLink = nobody [ask workers [set color blue]]]

;; the link with the firm has disappeared before, as a consequence of the above
condition (low labour demand)
;; here we refer to the lack of a link to allow workers to be blue (meaning
unemployed)
end

to optFor

;; with this command we avoid having a worker employed in TWO (or more) firms
at the same time
;; if it happens in 1-period one of the firms will fire her
;; if a worker is emploed in 3 firms, she will be fired in the 2nd period by one firm
and in the 3rd period by the 3rd firm,
;; finally she will be working just in 1 firm

 ask workers
    [let anArrow1 one-of links with [end2 = myself]
      let anArrow2 one-of links with [end2 = myself]
       if anArrow1 != nobody [ask anArrow2 [die] ]]

;; anArrow1 ties up a firm with a worker [end2]
;; if there is already a link between 1 firm and a worker, a 2nd link will be wiped
out

end
to learn-Union
```

```
;; with this command we introduce a learing process for unions
;; the more the hiring rate drops the more the union will increase its flexibility

  ask unions
        [ let be-more-flexible one-of improvements
           if be-more-flexible != 0 [set be-more-flexible 1]
                if (hiringRate < alarmingHiring)
                    [set unionsFlexibilityDegree
                        unionsFlexibilityDegree + be-more-flexible]]

;; the alarmingHiring defines the level of unemployed judged as worrying by unions,
;; the lower it is (i.e. -9) the less they worry for unemployment rate -> they bear a negative employment rate
;; instead, if they worry for a -2 level it means that when that level is reached they understand
;; it is necessary to bolster innovation and so they start increasing their support

end
```

9 Conclusions

This thesis finds out its core around which it has been set up into the troubled relationship between the two major agents of the labour market, they are unions and firms. For sure in this field we could have included other economic actors, but they would not have had a primary role, since we think to split the whole bargaining power between unions and firms (we did not give relevance to the State role and for other category associations).

The starting point has been the complicated agreement involving unions and firms, we have begun from the weaknesses of their links, we have been noticing how their different points of view did not grant any solution for the common problem, that is the hiring rate. We clearly acknowledge that there could be even other aims for both firms and unions, but we are firmly aware that all the rest passes through this parameter, that is common to both.

Once we have stated and entangled the problem we have started outlining our own setting; we have realized that by keeping on behaving in that way both unions and firms would not exit out from the current critical economic situation. By saying it with simpler words: we have started with a clear purpose, that means to spot some solutions to decrease the unemployment rate, that is to allow firms to hire more, this has been our goal, we wanted to understand how to improve the current labour market to enable the hiring-rate to flourish. By keeping in mind that aim we have hypothesised the solution to be the *disagreement* between the most relevant agents: firms and unions. We have supposed that their market strategies are not compatible each other, they were acting just to achieve their own objectives without thinking about the other; since the labour market is mainly made by their relations and deals *we have supposed that by improving the way in which they interact we could get better outcomes, in terms of unemployment rate and hiring-rate.*

Once we have had clear in mind the aim to reach, that is how unions and firms

should act to achieve a higher hiring-rate, we have defined the optimal settings to guarantee the labour market a better way of working. To do so we have used NetLogo, thanks to this software we have been able to create our framework; we have set up a structure such that it points out an effects chain, the latter includes a series of commands (for both agents) executed by firms and unions in sequence.

With the use of NetLogo we have had the chance to put in practice our basic idea of labour market relationship: there can exist just one way to improve the economic relationships, it takes place through a more liable behaviour for both agents, they cannot act only for their aims. By adopting NetLogo we could translate this insight in codes, where all their actions are consequence of the other agent's action.

While in NetLogo we have shaped our idea of unions – firms relationship, where both agents move *because of* other agent's behaviour and *in function of* its aims without forgetting of the aftermaths on the other agent's next action, in BehaviorSearch we have tested the consistency of this setting.

With this second software we have checked out if the labour market framework, that we assumed (in NetLogo) to improve the market itself, does work or does not. We have figured out several scenarios, the main obtained results have highlighted a similar concept to our initial hypothesis, BehaviorSearch gave us the noticed parameters levels to maximize a measure, that is the hiring-rate for us.

By having certain variables, whose way of working has been taken from NetLogo, we wanted to get the best possible value for the hiring-rate; by exploiting the genetic algorithms BehaviorSearch looked for the optimal levels of our NetLogo commands (belonging to both firms and unions) by having in mind to maximize the hiring-rate. We have computed many searches to test the consistency of our results, on average we have found our insights to be verified. BehaviorSearch has shown us that to maximize the hiring-rate the best path was to undertake a common behaviour for unions and firms: if both agents act together by not just focusing on their own purposes, the final hiring-rate is higher compared with situations in which firms and unions observe only their strategies. In terms of commands values: we have got higher hiring-rate when firms involve more their workers in decision making processes and unions are more flexible towards

innovation projects, these are the two main behaviour changes for these agents to solve the problem and to have a lower unemployment rate.
Let us add that with BehaviorSearch we have used the so called *learning process*, that is to understand how a simulation model works and behaves; all the passages adopted in this thesis have been compulsory for the final outcomes, to give them their importance let us recap the main steps of the project as follows:

1. problem definition: we have noticed how the labour market works, what the key agents are and how we could make it work better;
2. new structure: with NetLogo we have had the possibility to set up an alternative labour market model, within which it arises our idea of liability, we have spotted into a more responsible action for both firms and unions the solution to the current unemployment rate. All the NetLogo codes clearly show you how agents (in our idea of economic relationship) take action, they move consequently to the other agent's action;
3. consistency of results: BehaviorSearch gave us back the feasibility of our assumptions, we have obtained outcomes that replicate our thought; we have proved that our ideal relationships between unions and firms are (one of) the key solutions to the labour market mechanism.

The above listed points stand for the thesis structure, we have spotted the problem, then we have proposed our alternative way of seeing the labour market and in the end we have tested the consistency of this model. We have ended up with a right simulation model, where it is possible to improve the unemployment rate (represented into our agent based model by its contrary, the hiring-rate) only with more *liable participation* for the main economic actors, unions and firms.

Let us say this is not the only possible pattern, in fact there could be other ways to develop the labour market, we leave this idea to future studies over the same topic. For instance we could imagine a different landscape, where there exists a deeper focus over the marginal effects of these actions: by supposing that our results are the initial ground, we could look into the percentage effects of unions and firms movements: “What is the percentage impact over innovation level of a 1% more flexible union?”. A work like this would improve further our analysis, since we have been studying the units change.

Another scenario subject of further investigations might be a different way of involving workers, as stated in the previous pages of this section there can be many ways to make participate the employees: with other studies we may see that by differently involving workers (that is with salary increases) unions are more willing to support innovation, so the impact of unions flexibility would be larger over new innovative projects.

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